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Marginal q and Firms' Capital Investments: Evidence from Time Series Data of Japanese Manufacturing Industries*

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Abstract

In this paper, we verify the predictability of marginal q on firms' capital investments. We compare Granger's causality of four manufacturing industries with the LA-VAR model and Vector Error Correction Model(VECM). We obtain the empirical results that the null hypothesis of no Granger's causality from marginal q to investments is accepted for the chemical industry and iron-steel industry, and it is rejected for the transportation equipment industry. For the product machinery industry, null hypothesis is rejected with the LA-VAR model, but accepted with VECM; it is not robust result. These results indicate that the chemical and iron-steel industry, with higher uncertainty and irreversibility, could not adjust their capital investments in response to the fluctuation of Tobin's q, while the transportation equipment industry could do so. Following the analytical implications by earlier theoretical studies, it is considered that uncertainty and irreversibility restrain their capital investments, or firms with uncertainty and disposal cost do not invest in equipment because of lower Tobin's q than the threshold value. Thus, the role of uncertainty and irreversibility is important for predicting capital investments by Tobin's q.

Keywords: marginal q; Granger's causality; irreversibility; uncertainty

JEL Classification Numbers: C32, E22

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1 Introduction

Tobin's q, which came to light after Tobin's publication(1969), is regarded as a major factor in the decision-making of firms' capital investments. Tobin's q summerlized in several textbooks on macroeconomics[1]. Tobin's q is calculated by "firms' value evaluated in the stock market" divided by "repossession value of firms' stock," and this is called "average q." This theory shows that the firm should increases its investments when q is larger than 1, and decrease them when q is smaller than 1.

In contrast, we can obtain Tobin's q from the Lagurange multiplier when we solve the profit maximization problem of a firm with infinite horizons considering the adjustment cost. When this multiplier is larger than 1, the firm performs investments. The Lagurange multiplier implies a shadow price: the variation width of the objective function of the present discount value of the firm, with the increase of accumulation of capital stock. Thus, this multiplier is called "marginal q."

Hayashi(1982) shows that average q and marginal q are equivalent assuming that production and cost are homogeniously linear and that the price of production goods and capital stock is equal. Following Hayashi(1982), several studies have verified firms' profit and investment behaviors considering average and marginal q.

However, firms cannot adjust their capital investments and accumulation of stock immediately even if Tobin's q fluctuates; firms adjust them after a few periods. In other words, we can predict the firms' future investments by observing the fluctuation of q. In order to analyze the trend of macroeconomics, it is important to forecast the investment behaviors of firms or industries observing their qs.

Obviously, firm's capital investments are influenced by other factors: for example, irreversibility and uncertainty. When a firm's equipments has long periods of duarability, or when the marginal cost of investments is high, the firm faces high irreversibility. According the theoretical work by Caballero(1991), such a firm with high irreversibility tends to reduce its investment by uncertainty considering certain conditions. And the study by

[1]For example, please see Mankiw(2009), Romer(2005) and Obstfeld and Rogoff(1996).

Dixit and Pindyck(1994) shows that threshold values of Tobin's q will rise as uncertainty increases. When Tobin's q does not reach the threshold value, the firm does not carry out investments, considering disposal cost; therefore, uncertainty restrains the firms from performing the investment further by the "option to wait."

Thus, the firms' capital investments, especially in the material industries with large-sized equipments, might respond slowly when their Tobin's q increases. The empirical study by Ogawa and Suzuki(2000) shows that the materials industry in Japan significantly restrains the investments in response to the rise of uncertainty of demand, and this evidence is consistent with the theoretical implications of previous studies such as Caballero(1991). The empirical analysis performed by Honda and Suzuki(2000) shows that, in the sense of Dixit and Pindyck(1994), the threshold value of q for electric machiney is higher than others in Japan, employing a logistic curve.

Previous studies on capital investments and Tobin's q utilize firms' or industries' micro data, which is a cross-section or panel with short periods. In contrast, only a few studies perform time series analysis focusing on investment and Tobin's q theory. Matsubayashi(1995) shows that uncertainty restrains firms from carrying out investments in both Japan and the US, and that uncertainty tends to be caused by instability of financial markets and by supply shock in Japan. Matsubayashi(2011) performs time series analysis with the structural VAR model, and states that depreciation of the Japanese Yen has positive effects on expected profitability, Tobin's q, and investments in the machinery sector. The empirical study by Hori and Ando(2002) also utilizes Japanese time series data of sales, which is regarded as the proxy of Tobin's q, investments, call rate and liquidity asset. In this study, they perform empirical analysis with the Lag-Augmented VAR (LA-VAR) model developed by Toda and Yamamoto(1995) in order to verify the effects of liquidity asset on investments and sales. This study shows that liquidity assets are Granger caused by sales, investments by liquidity asset and sales by investments; this evidence shows that the fluctuation of liquidity asset is caused by imperfect capital asset market and that the transmission mechanism of monetary policy does not work sufficiently.

Hori and Ando(2002) and Matsubayashi(1995) are important studies in which time series analyses of capital investments are performed, however, these studies employ aggregate data. Matsubayashi(2011) utilizes time series data of several sectors in Japan, however, this study focuses on the effects of exchange rate on capital investments and Tobin's q, and does not discuss the differences in the effects or predictability of Tobin's q on firms'investments in detail[2]. As Ogawa and Suzuki(2000) and other studies have indicated, the response of investment to Tobin's q and other factors, irreversibility and uncertainty, differs by industries. Figure1 and 2 show the plots of investment-capital ratio (IK) and marginal q (MQ) of several manufacturing industries. The average values of IK and MQ are shown in Table 1. They indicate that trends of investments and marginal q differ by industries. The chemical and iron-steel (the material industries) industries tend to have lower IK than production machinery and transportation equipments including motorvehicles (the machinery industries). In contrast, chemical and production machinery industries have higher MQ and that of iron-steel industries are patricularly low.

Then, in this paper, we verify the predictability and influence of Tobin's q on capital investments of the Japanese manufacturing industry using the LA-VAR model and the Vector Error Correction Model (VECM). We employ the VECM when cointegration is detected. In the LA-VAR model, we do not have to consider the existence of a cointegration vector between included variables. But we have to re-examine Granger's causality considering cointegration because linear combination may consist of included variables in the long run theoretically. Here, we utilize Japanese time series data of four industries: chemical, iron-steel, (material industries), production machinery and transportation equipments including motorvehicles (machinery industries), and compare them, considering the implications of Ogawa and Suzuki(2000).

Section 2 presents the data description and empirical analyses. Ssection 3 is the discussion, and in section 4, we draw out our conclusions.

[2]According to Matsubayashi(2011), impulse response functions from marginal q to investments are significantly positive in manufacturing and wholesale.

2 Empirical Analysis

2.1 Data

In this paper, we utilize the data of four manufacturing industries: chemical, iron-steel, production machinery and transportation equipment[3].Some previous studies employ data of manufacturing industries, and this study also does the same. We estimate the 4-variable LA-VAR model that consists of marginal $q(Mq_t)$, investments over capital in the last period(I_t/K_{t-1}), real effective exchange rate$(REER_t)$ and long-term interest rate(LR_t)[4]. Here, we divide investments by capital stock. The sample period is 1980:Q2-2005:Q1. Marginal q implies a firm's present value, and it can be interpreted as the firm's present discount value of profitover the future periods. We obtain time series data of marginal q by calculating under certain assumptions. We show the procedure of computing the marginal q in the Appendix.

The sample of the Company Statistics Seasonal Report is revised every 2nd quarter and thus its continuity is not maintained. Moreover, stock data is constructed by amassing flow data. And therefore, we have to adjust the data following the methods introduced by Ogawa (2003).

First, we calculated the amount of increase from every 1st quarter and 2nd quarter. And we assumed the number of the sample increased equally every quarter within the past 1 year. For example, when the amount that increases from the 1st and 2nd quarter in 1990 is N, we assumed the sample increased by N/4 every period in fiscal 1989: it increased by N/4 in fiscal 1989: 2Q, 1989:3Q, 1989:4Q and 1990:1Q. Then, we multiplied the assumed amount of increase and flow per one firm, and added it to the total flow of each period.

[3]The electric machinery industry is considered to play an important role. However, the kinds of firms belonging to this industry, namely the definition of this sector, altered in the sample periods we set. And thus, time-series data of electric machinery does not have continuity. Therefore, we exclude electric machinery here.

[4]In this study, we utilize quarterly data of the depreciation rate, total depreciation, investments and capital stock from the Company Statistics Seasonal Report published by the Ministry of Finance of Japan. However, we acquire the data of deflator of investment goods from the Statistics National Account (93SNA) and earning rate of 10-year government bond, an index of the long-term interest rate, from the International Financial Statistics(IFS). The interest rate is deflated by the deflator of investment goods. We utilize data of the real effective exchange rate from the Bank of Japan's financial statistics.

In order to obtain the real value of capital stock, we calculated the book value in 1980:Q1, the start point of the sample[5]. According to the National Wealth Survey of 1970, the average duration (vintage) of manufacturing industries is 7 years. An economic white paper (the Cabinet Office of the Japanese Government 1999) shows that vintage in the current period (Vin_t) with annual data is defined by the following equation:

$$Vin_t = (1 - Vin_{t-1})(K_{t-1} - RE_t) + \frac{I_t}{2}/K_t. \tag{1}$$

RE_t denotes removal of capital at period t. By calculating with the rate of retirement of equipment printed in the Quarterly Report on the National Account of 1980 (Economic Planning Agency 1981), the vintage of manufacturing industries in 1980 was 8.3 years. Then, we maintained that the book value of capital stock in 1980:Q1 is the price of 8.3 years before: in 1971:Q4.

We calculated the data series of the real value of capital stock after 1980:Q1 using the perpetual inventory method. We calculate capital stock by the following equation:

$$K_t = (1 - \delta)K_{t-1} + I_t. \tag{2}$$

δ denotes the depreciation rate. Here, investments are deflated by the *current* price. This enables us to obtain data series of the real value of capital stock after 1980:Q1[6].

Investments and marginal q are seasonally adjusted by X-12 ARIMA.

2.2 LA-VAR model

The LA-VAR (Lag-Augmented VAR) model was developed by Toda and Yamamoto(1995). With this procedure, we can estimate the VAR model without considering the degree of integration of variables in the model, and the model specification does not depend on the existence of cointegration relationship. Here, we show the details of this procedure.

We suppose that vector x_t contains two variables x_{1t} and x_{2t}, and x_t is written as

$$x_t = (x_{1t} \quad x_{2t})'.$$

[5] The details of this method are introduced in Section 3C in Ogawa et al.(1996).

[6] The data series of 93SNA is available only after 1980. And thus we calculate the vintage with 68SNA, which is available before 1980, and connect to 93SNA at 1980:Q1.

Then, we set the 2-variable VAR(p) model as

$$x_t = A_0 + \sum_{i=1}^{p} A_i x_{t-i} + u_t. \tag{3}$$

This u_t is an error term whose expectation is 0. And p is the optimal length of lags selected by certain criterion: for example, SBIC or AIC.

x_{1t} and x_{2t} obey the integrated process with order d at most. Then, we transform the VAR model into the following equation:

$$x_t = A_0 + \sum_{i=1}^{p+d} A_i x_{t-i} + u_t \tag{4}$$

When the VAR model is equation (2), estimated coefficients have consistency regardless of the order of integration and the existence of cointegration. Therefore, we can verify Granger causality based on equation (2).

2.3 Empirical Results by LA-VAR model

Firstly, we perform a unit root test of each variable. Here, we employ the Dickey=Fuller GLS test (Elliott, Rothenberg and Stock, 1996). The results are shown in Table 2. They indicate that these variables are integrated order 1 at most.

Next, we estimate the VAR model. Using Equation (1) considering the time trend, the optimal length of lags of all industries is 1 following SBIC. Therefore, the length of lags in Equation (2) is 2 for all according to the LA-VAR method.

Then, we estimate Equation (2) and verify the Granger's causality for each industry.

Granger's causality of each industry is shown in Table 3. In Table 3, we show how each variable Granger-causes only marginal q and investments. Here, we focus on the firms' investments but not on the fluctuation in the financial markets. In line with our aims, the long-term rate and exchange rate are regarded as exogenous. And thus we do not observe the predictabilityon these variables. Table 3 shows that it is shown that marginal q (Mq_t) does not Granger-cause investments (I_t/K_{t-1}) in the chemical and iron-steel industries.

And with others, empirical results show that marginal q Granger-causes investments. The significance level is 10 percent here[7].

2.4 Vector Error Correction Model and Empirical Results

Here, we perform a cointegration test with the Maximum eigenvalue test by Johansen (1988) and Johansen and Juselius (1991) firstly. We suppose that the linear trend is contained in the VAR and cointegration vector. But, following the results of unit root testshown in Table 2, for IK in the iron-steel industry, the null of unit root is rejected with a 5 % significance level. However, KPSS test (Kwiatkowski et al. 1992) statistics considering constant and linear trends indicate that IK in the iron-steel industry is I(1) variables with a 5% significance level[8]. Therefore, we regard these variables as I(1).The results of the tests are shown in Table 4. It indicates that the null hypothesis of no cointegrating rank cannot be rejected in the material industry (chemical and iron-steel). In contrast, the null of no cointegrating rank can be rejected in non-material industries (production machinery and transportation equipment), and it is shown that these industries have one cointegration vector. The estimated cointegrating vector is shown in Table 5, and it indicates the estimated coefficient of Tobin 's marginal q is positive and significant in each industry in non-material industries[9].

Then, we verify Granger 's causality of Tobin's marginal q to investment. Considering the results of the maximum eigenvalue test, we adopt the difference model for the material industry and the VECM for the non-material industry. The results of Granger's causality test are shown in Table 6. It is shown that the null hypothesis of no causality cannot be rejected in the material industry. And for the transportation equipment, marginal q Granger-causes investment-capital ratio. But for the production machinery, the null

[7] In this footnote, we mention the causality between other variables. Long-term rate Granger-causes marginal q only in production machinery, and investments cause marginal q in transportation equipments. The exchange rate does not Granger-cause investments and marginal q in all industries. In relation to the effects of exchange rate, the results we obtain are quite different from those of Matsubayashi(2011). Model specification is then considered to be the main cause of difference.

[8] The KPSS test statistics are 0.171 for level and 0.088 for 1st difference. The critical values are 0.216 (1%), 0.146 (5%) and 0.119 (10%) considering the constant and linear trend.

[9] According to the results in Table 5, the coefficient of the real long-term rate is not significant in each industry. And the sign restriction of the real effective exchange rate is not satisfied, either.

hypothesis cannot be rejected. Thus, only the empirical result for production machinery is not consistent with that of the previous section[10].

Here, there seems to be a tendency that marginal q of the machinery industry have predictability for their own investments significantly. In the next section, we focus on the causality from marginal q to investments and discuss them.

3 Discussion

In the previous section, we verified the predictability of Tobin's marginal q on investments. And in the transportation equipments industry, marginal q Granger-causes investments; however, it does not in materials. And in the production machinery industry, it is ahown that marginal q Granger-causes investments with the LA-VAR model, but it does not with the VECM. In this paper, we focus on how marginal q Granger-causes investments, as we mentioned in Section 1. Here, we discuss the causes of these differences.

As we showed in Section 1, Caballero(1991) developed the theoretical model in which firms with high irreversibility restrain their investments by uncertainty of demand. And Dixit and Pindyck(1994) showed that a firm does not carry out investments with uncertainty and disposal cost if Tobin's q does not reach the threshold value.

Figure 3 shows the uncertainty of demand, standard deviation of sales, of each industry from 1980 to 2004. In Fig.3, it is shown that the material industry, chemical industry and iron-steel industry, face higher uncertainty. And Figure 3 also shows that uncertainty of demand is especially low in transportation equipment.

As the study by Ogawa and Suzuki(2000) states, the material industry tends to have high irreversibility. Following Honda and Suzuki(2000), we calculate the periods of durability, a proxy of irreversibility, of each industry. The details are shown in Table 7. It shows that the periods of durability are 12.96 years in production machinery, 11.976 years in chemical and 15.55 years in iron-steel. In contrast, it is 9.448 years in transportation equipment. Thus, transportation equipment is relatively shorter; that is, iron-steel, chemical and production

[10]The exchange rate Granger-causes investments only in chemical, and marginal q only intransportation equipments. In this specification, we can show the effects of exchange rate in some induatries.

machinery have higher irreversibility whereas transportation equipment has lower.

Considering these facts, we can infer two causes of our empirical results. The first is that high uncertainty and high irreversibility restrain investments in material industries, as shown in Figure 1 and Table 1. And it is also shown that the production machinery is a little higher than transportation equipments. The second is that high uncertainty drives the threshold value of q higher than marginal q in two material industries with high disposal costs. In any case, it is difficult for firms to carry out their investments in response to fluctuation of marginal q. Therefore, the marginal q does not Granger-cause investments in material industries; it causes low predictability of marginal q into the capital investments. On the other hand, following the empirical results in the previous section, Granger's causality from marginal q to investment might exist but it is not robust in the production machinery industry. It can be thought that a little high uncertainty and long durable periods, high irreversibility, cause the weak evidence of causality.

The empirical results obtained in this study are consistent with Ogawa and Suzuki(2000); it shows that uncertainty caused the restraint of the material industry whose irreversibility is high.

4 Conclusion

In this paper, we compared the Granger's causality of four manufacturing industries utilizing the LA-VAR model and VECM. We focused on Granger's causality of marginal q to investments. Considering the empirical results obtained in this study, the following points were elucidated. Firstly, Granger's causality from marginal q to investment does not exist in the material industry whereas marginal q Granger-causes investment in the transportation equipment industry. Secondly, in the production machinery with high irreversibility, Granger's causality from marginal q to investment might exist, but it is not robust.

Following Caballero(1991) and Dixit and Pindyck(1994), we explained the background of these empirical results; uncertainty and irreversibility restrain their investments, or firms with uncertainty and high disposal cost do not invest in equipments if Tobin's q is below the threshold value. Here, we showed that the roles of uncertainty and irreversibility are important for predicting investments by Tobin's q; Granger's causality of Tobin's q to investments is limited in industries with high irreversibility and high uncertainty.

However, some problems remain. The first is the model specification. We have to utilize other variables related to firms' investment behavior. Second is the empirical methods. In this paper, we utilized LA-VAR and performed the verification paying attention to Granger's causality. As a future work, performing empirical analysis based on the impulse response function will bring other contributions.

Appendix: Tobin's Marginal q

In the Appendix, we show the method for calculating marginal q. The model of marginal q implies a relationship between investments and their shadow price derived from the firms' profit maximization problem. In this paper, we used the method introduced in Ogawa(2003).

The marginal q (Mq_t) is the discount value of marginal profit additional investments, and it is explained as follows:

$$Mq_t = \frac{1}{P_t^I} E_t[\sum_{j=0}^{\infty} \beta_{t+j}(1-\delta)^j \pi_{t+j}.] \tag{5}$$

Here, P_t^I is the price of investment goods, π_t is profit rate, maximum profit over capital stock, at period t, β_{t+j} is the discount factor at $t+j$, δ is the depreciation rate and E_t is expectation operator with information set available at t. And when r_t is interest rate, β_{t+j} is defined as

$$\beta_t = \frac{1}{1+r_t}. \tag{6}$$

Here, we assume that r_t and π_t obey the independent random walk process, and they can be written as

$$r_{t+1} = r_t + \mu_t$$

and

$$\pi_{t+1} = \pi_t + \nu_t.$$

We can rewrite Equation (5) as follows:

$$Mq_t = \frac{\pi_t}{P_t^I} \frac{1 + r_t}{r_t + \delta}.$$

We assume δ is 0.0772, which is the calculated value for all industries shown in Hayashi and Inoue(1991).

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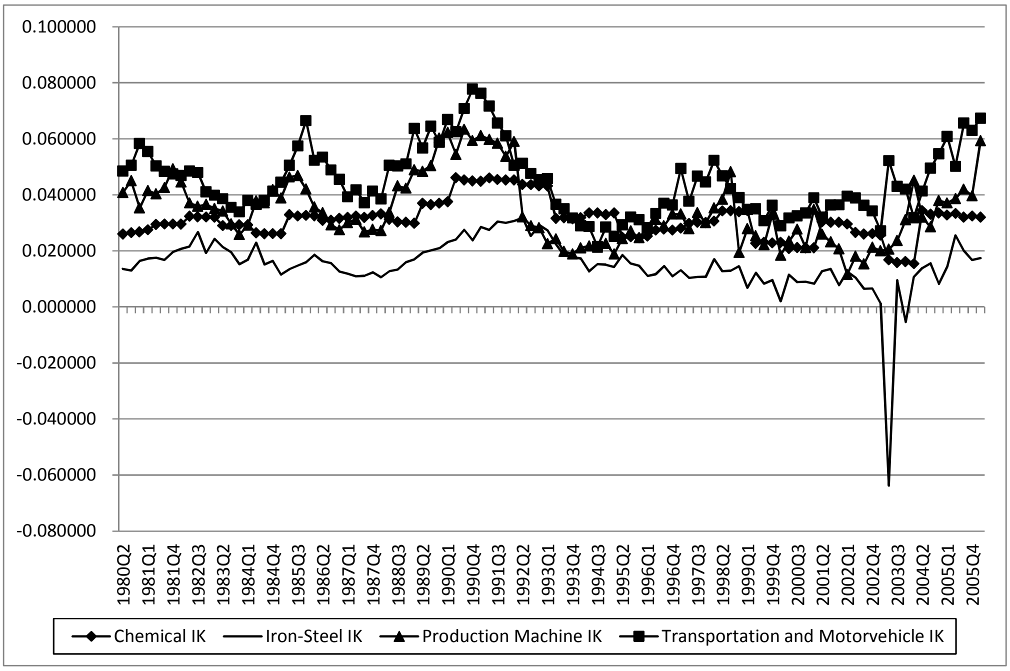
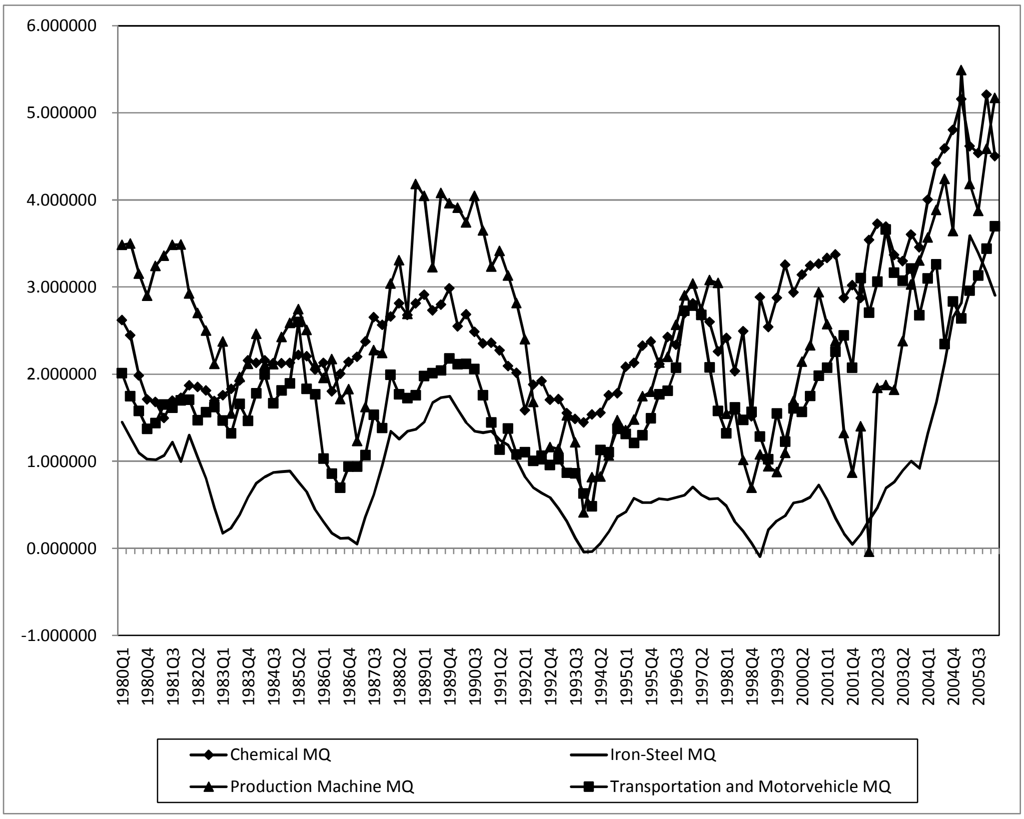
Fig.1 Investment-Capital Ratio



Source: Company Statistics Seasonal Report (The Ministry of Finance, Japan)

Fig.2 Marginal q



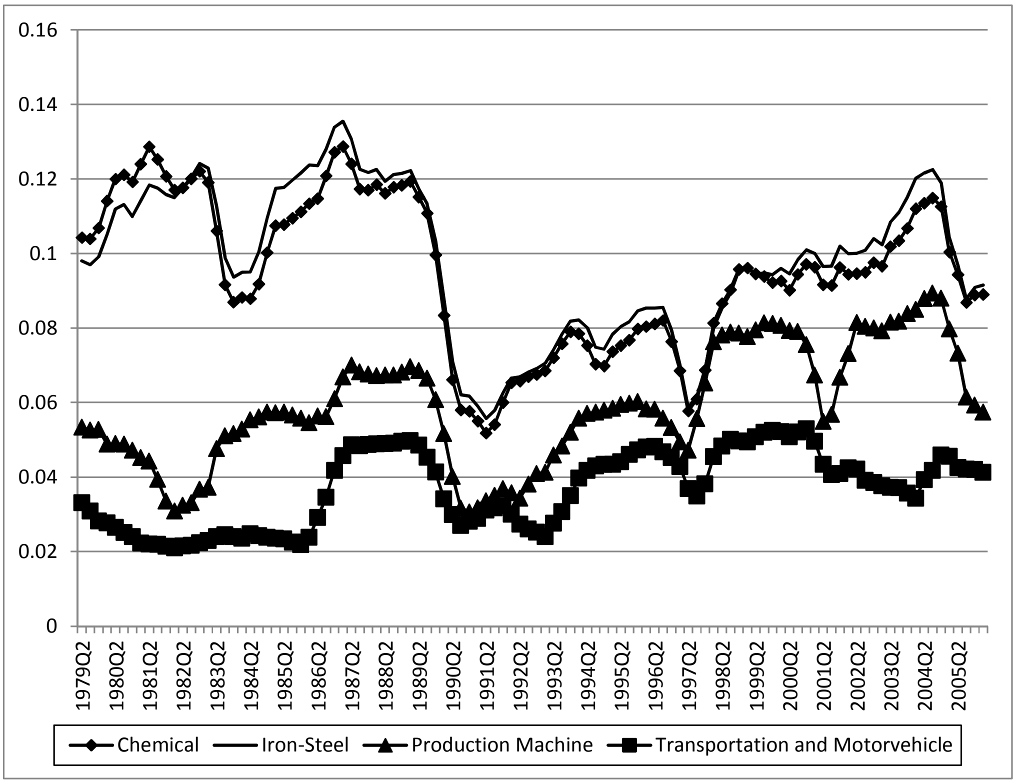
Source: Company Statistics Seasonal Report (The Ministry of Finance, Japan)

Table 1

Average values of IK			
Chemical	Iron-Steel	Production Machine	Transportation and Motorvehicle
0.031	0.015	0.035	0.045

Average values of MQ			
Chemical	Iron-Steel	Production Machine	Transportation and Motorvehicle
2.568	0.861	2.452	1.817

Fig.3 Uncertainty (Standard Deviation of Sales)



Source: Company Statistics Seasonal Report (The Ministry of Finance, Japan)

Table 2 Unit Root test

DF-GLS test(with const. and linear trend)

I/K

	X			⊿X		
Chemical	−2.437		(0)	−10.266	***	(0)
Iron and Steel	−3.568	**	(1)	−18.188	***	(0)
Production Machinery	−2.346		(1)	−12.564	***	(0)
Transportation Equipments	−2.509		(2)	−5.859	***	(1)

Mq (Marginal Q)

	X			⊿X		
Chemical	−0.434		(2)	−2.918	*	(2)
Iron and Steel	−1.702		(5)	−3.068	**	(4)
Production Machinery	−2.247		(3)	−3.069	***	(2)
Transportation Equipments	−2.398		(0)	−12.263	***	(0)

Real Effective Exchange Rate (REEX)

	X			⊿X		
	−2.441		(0)	−6.301	***	(0)

Real Long-term Rate (LR)

	X			⊿X		
	−1.634		(0)	−8.404	***	(0)

(Note)

Numbers in the parentheses are length of lags following SBIC.

*** denotes significant at 1%(critical value is −3.584) , ** denotes

** denotes 5%(−3.033) and * denotes 10% (−2.743).

Critical values are followed by Elliott et al.(1996).

Table 3 Granger Causality with LA-VAR model (F-test Statistics)

Chemical (Number of lags=2)

	F-test stat. DF=(2,88)	X2: I/K		X2: MQ	
X1	MQ	0.848		142.416	***
		(0.432)		(0.000)	
	REEX	0.923		0.967	
		(0.401)		(0.385)	

Iron and Steel (Number of lags=2)

	F-test stat. DF=(2,88)	X2: I/K		X2: MQ	
X1	MQ	2.293		470.794	***
		(0.107)		(0.000)	
	REEX	0.655		0.592	
		(0.522)		(0.556)	

Production Machinery (Number of lags=2)

	F-test stat. DF=(2,88)	X2: I/K		X2: MQ	
X1	MQ	8.973	***	59.699	***
		(0.003)		(0.000)	
	REEX	0.170		1.125	
		(0.844)		(0.330)	

Transportation Equipments (Number of lags=2)

	F-test stat. DF=(2,88)	X2: I/K		X2: MQ	
X1	MQ	6.811	***	56.353	***
		(0.002)		(0.000)	
	REEX	0.712		2.200	
		(0.493)		(0.117)	

(Note) Null hypothesis: X1 does not Granger cause X2.
When DF=(2,88) , critical values of 5% significant level is 3.1065.
Numbers in the parentheses are p-values.
*** denotes significant at 1% and ** denotes 5%.

Table 4　Cointegration test(Max eigenvalue test)

<Chemical>

Null Hypothesis	Eigenvalue	Test stat.	Prob.
Rank=0	0.190	20.6734	0.5985
Rank=1 at most	0.143	15.08533	0.6268
Rank=2 at most	0.056	5.619892	0.97
Rank=3 at most	0.043	4.313582	0.6964

<Iron−Steel>

Null Hypothesis	Eigenvalue	Test stat.	Prob.
Rank=0	0.228	25.31877	0.2682
Rank=1 at most	0.143	15.10914	0.6246
Rank=2 at most	0.082	8.356175	0.7885
Rank=3 at most	0.029	2.893646	0.8889

<Machinery>

Null Hypothesis	Eigenvalue	Test stat.	Prob.
Rank=0	0.272	31.114	0.066*
Rank=1 at most	0.152	16.21	0.526
Rank=2 at most	0.075	7.649	0.852
Rank=3 at most	0.038	3.759	0.777

<Tanspotation Equipments>

Null Hypothesis	Eigenvalue	Test stat.	Prob.
Rank=0	0.277	31.818	0.054*
Rank=1 at most	0.143	15.083	0.627
Rank=2 at most	0.132	13.826	0.266
Rank=3 at most	0.049	4.883	0.613

(Note) * denotes rejection of the hypothesis at the 10% level. We utilize MacKinnon-Haug-Michelis (1999) p-values. These critical values of 5% are 32.118(rank=0), 25.823(rank=1 at most), 19.387(rank=2 at most) and 12.518(rank=3 at most).

Table 5 Cointegration Vector

<Machinery>

	MQ	REEX	LR
Estimator	−0.045	−0.0002	−0.0001
Standard error	0.008	0.00012	0.0014

<Tanspotation Equipments>

	MQ	REEX	LR
Estimator	−0.155	−0.0009	0.004
Standard error	0.036	0.0004	0.003

Table 6 Granger Causality

Iron and Steel (1st difference with lag=1)

	F-test stat.	X2			
	DF=(2,91)	MQ		IK	
X1	MQ			0.169	(0.682)
	REEX	0.689	(0.409)	0.350	(0.555)

Chemical (1st difference with lag=1)

	F-test stat.				
	DF=(2,91)	MQ	X2	IK	
X1	MQ			0.348	(0.556)
	REEX	0.614	(0.404)	4.340	(0.040)**

(Note) Null hypothesis: X1 does not Granger cause X2.
Numbers in the parentheses are p-values.
*** denotes significant at 1% .

Production Machinery (VECM with lag=1)

	Chi-square test stat.	X2			
	DF=1	MQ		IK	
X1	MQ			0.192	(0.661)
	REEX	0.696	(0.404)	0.003	(0.958)

Transportation Equipments (VECM with lag=1)

	Chi-square test stat.	X2			
	DF=1	MQ		IK	
X1	MQ			5.642	(0.018)***
	REEX	4.014	(0.045)**	0.075	(0.785)

(Note) Null hypothesis: X1 does not Granger cause X2.
Numbers in the parentheses are p-values.
*** denotes significant at 1% .

Table 7 Period of Durability

Period of Durability (Proxy of Irreversibility)		Industry
(industry)	(years)	
Chemical	11.976	Material
Iron and Steel	15.55	
Machinery	12.963	Non-Material
Transportation and Motorvehicle	9.448	

Source: Company Statistics Seasonal Report (The Ministry of Finance, Japan)