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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 obtain the empirical results that the null hypothesis of no Granger's causality from marginal q to investments is accepted for the chemical and iron-steel, and it is rejected for the production machinery and transportation equipment; however, for the transportation equipment industry, it isn't robust. Following the earlier studies, it is considered that uncertainty and irreversibility restrain their capital investments. These results indicate that the material industries, with higher uncertainty and irreversibility, could not adjust their capital investments in response to the fluctuation of Tobin's q, while the others could do. They are consistent with theoretical implications.

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

JEL Classification Numbers: C32, E22

I. 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

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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.

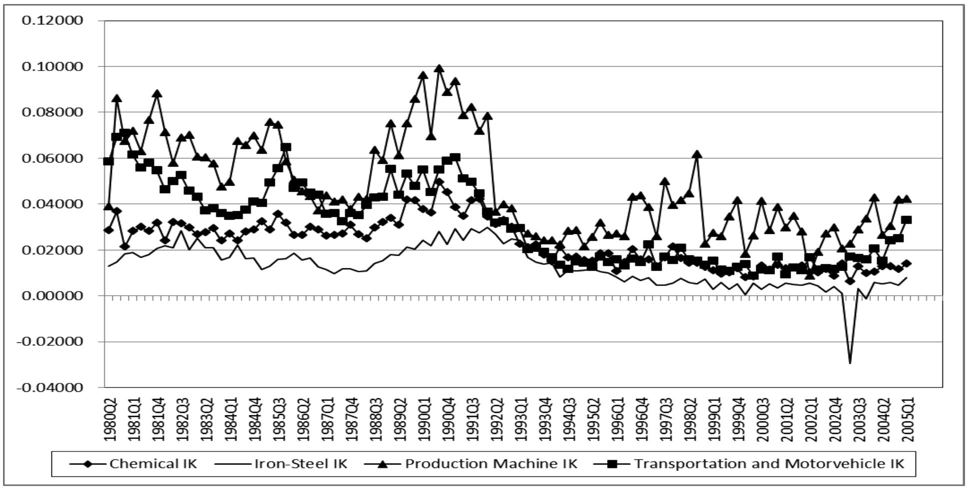
However, firms cannot adjust their capital investments and accumulation of stock immediately even if Tobin's q fluctuates; firms adjust them after a few periods. In other words, we can predict the firms' future investments by observing the fluctuation of q. In order to analyze the trend of macroeconomics, 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. The study by 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."

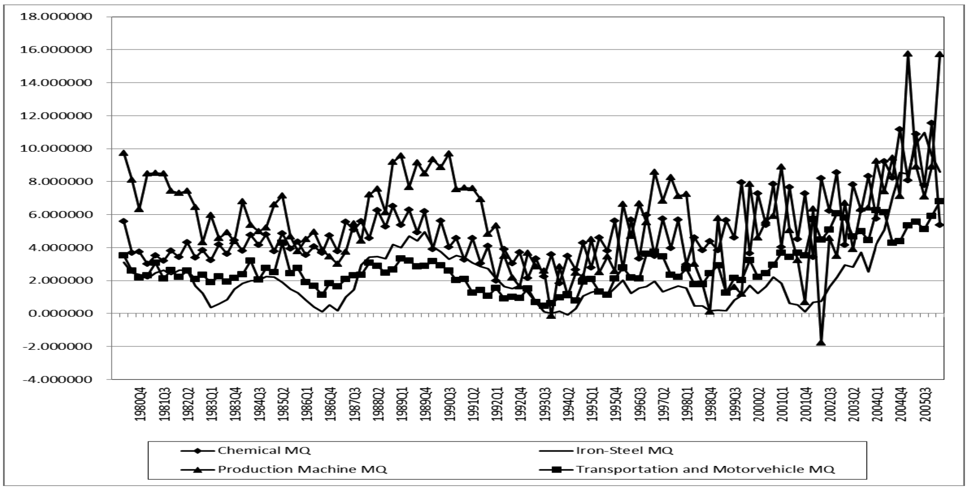
Thus, the firms' capital investments, especially in the material industries with large-sized equipments, might respond slowly when their Tobin's q increases. The empirical study by Ogawa and Suzuki(2000) shows that the materials industry in Japan significantly restrains the investments in response to 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, the former employs 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 industries (the material 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.



Source: Company Statistics Seasonal Report, Ministry of Finance,Japan
Fig.1 Investment-Capital ratio



Source: Company Statistics Seasonal Report, Ministry of Finance,Japan
Fig.2 Marginal q

Table1

Average values of IK

Chemical	Iron-Steel	Production Machine	Transportation and Motorvehicle
0.023	0.013	0.048	0.031

Average values of MQ

Chemical	Iron-Steel	Production Machine	Transportation and Motorvehicle
4.925	2.348	5.724	2.768

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

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, the Vector Error Correction Model (VECM) and difference model. 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; however, 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, production machinery and transportation equipments including motorvehicles, 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.

II. Empirical Analysis

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 3-variable LA-VAR model that consists of marginal $q(Mq_t)$, investments over capital in the last period(I_t/K_{t-1})

and real effective exchange rate($REER_t$)[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 profit over 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 flow data by calculating per capita (firm).

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. 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

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

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). We ignore the coefficients in last d lagged vectors in the model; these can be regarded as zeros.

3. Empirical Results by LA-VAR model

Firstly, we perform a unit root test of each variable. Here, we employ the Phillips-Perron test (Phillips and Perron, 1988). 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), 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'

Table 2 Unit Root test (Phillips-Perron test with const)

I/K

	X		⊿X		
Chemical	−1.422	(5)	−16.261	***	(4)
Iron and Steel	−2.466	(3)	−16.993	***	(0)
Production Machinery	−2.350	(5)	−13.725	***	(4)
Transportation Equipments	−1.853	(3)	−11.465	***	(4)

Mq (Marginal Q)

	X		⊿X		
Chemical	−0.656	(5)	−6.136	***	(3)
Iron and Steel	−1.624	(4)	−12.648	**	(3)
Production Machinery	0.550	(4)	−13.519	***	(5)
Transportation Equipments	−2.332	(3)	−11.590	***	(3)

Real Effective Exchange Rate (REEX)

	X		⊿X		
	−2.240	(4)	−8.270	***	(2)

(Note)
Numbers in the parentheses are length of lags following SBIC.
*** denotes significant at 1%(critical value is −3.498), and
** does 5% (−2.891).
Critical values are followed by MacKinnon(1996).

Table 3 Granger Causality (LA-VAR model)

Chemical (Optimal Number of lags=2)

	Wald test stat.	X2		
	DF=2	I/K		MQ
X1	MQ	0.205		
		(0.902)		
	REEX	1.334		3.332
		(0.513)		(0.189)

Iron and Steel (Optimal Number of lags=1)

	Wald test stat.	X2		
	DF=1	I/K		MQ
X1	MQ	1.644		
		(0.200)		
	REEX	0.139		0.000
		(0.709)		(0.984)

Production Machinery (Optimal Number of lags=1)

	Wald test stat.	X2		
	DF=1	I/K		MQ
X1	MQ	16.285	***	
		(0.000)		
	REEX	0.031		0.817
		(0.861)		(0.366)

Transportation Equipments (Optimal Number of lags=1)

	Wald test stat.	X2		
	DF=1	I/K		MQ
X1	MQ	0.157		
		(0.692)		
	REEX	0.007		3.116
		(0.934)		(0.077)

(Note) Null hypothesis: X1 does not Granger cause X2.
The Wald test statistics obey χ-square distribution.
Numbers in the parentheses are p-values.
*** denotes significant at 1%.

Table 4 Cointegration test(Trace test)

<Chemical>

Null Hypothesis	Test stat.	p-values
Rank=0	35.315	0.232
Rank=1 at most	13.722	0.681
Rank=2 at most	4.148	0.721

<Iron-Steel>

Null Hypothesis	Test stat.	p-values
Rank=0	34.722	0.257
Rank=1 at most	9.358	0.949
Rank=2 at most	3.603	0.799

<Production Machinery>

Null Hypothesis	Test stat.	p-values
Rank=0	41.067	0.076
Rank=1 at most	13.345	0.711
Rank=2 at most	5.316	0.552

<Tanspotation Equipments>

Null Hypothesis	Test stat.	p-values
Rank=0	48.303**	0.013
Rank=1 at most	17.706	0.364
Rank=2 at most	5.951	0.467

(Note)
** denotes rejection of the hypothesis at the 5% level.
We utilize MacKinnon-Haug-Michelis (1999) p-values.
The critical values (5%) are 42.915 when null hypothes is rank=0, 5.872 when rank=1 and 12.518 when rank=2.

Table 5 Cointegration Vector

<Transportation Equipments>

	IK	MQ	REEX
Estimator	1	−0.073	−0.001
Standard error	−	0.014	0.0003

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 predictability on 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, iron-steel and transportation equipments industries. And with production machinery, empirical results show that marginal q Granger-causes investments. The significance level is 5 percent here[7].

4. Vector Error Correction Model and Difference Model

Here, we perform a cointegration test with the Maximum eigenvalue test by Johansen (1988) and Johansen and Juselius (1990) firstly. We suppose that the linear trend is contained

Table 6 Granger Causality (VECM or 1st difference)

Chemical **(1st difference with lag=1)**

	Wald test stat. DF=1	X2 IK	X2 MQ
X1	MQ	3.391(0.066)	
	REEX	2.747(0.098)	1.614(0.204)

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

	Wald test stat. DF=1	X2 IK	X2 MQ
X1	MQ	0.012(0.911)	
	REEX	0.768(0.381)	0.001(0.972)

Production Machinery **(1st difference with lag=1)**

	Wald test stat. DF=1	X2 IK	X2 MQ
X1	MQ	11.113(0.001) ***	
	REEX	0.479(0.489)	1.180(0.277)

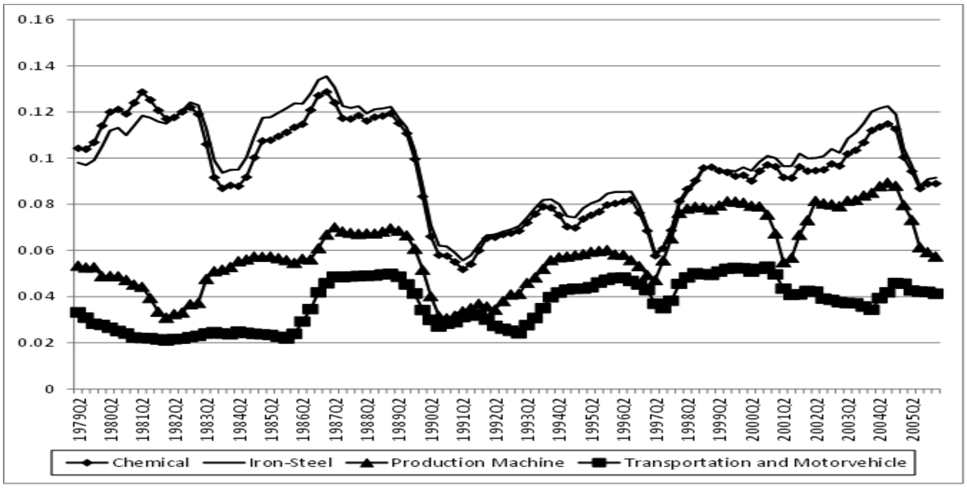
Transportation Equipments **(VECM with lag=1)**

	Wald test stat. DF=1	X2 IK	X2 MQ
X1	MQ	6.183(0.013) **	
	REEX	0.478(0.489)	2.468(0.116)

(Note) Null hypothesis: X1 does not Granger cause X2.
Numbers in the parentheses are p-values.
The Wald test statistics obey Chi-square distribution.
*** denotes significant at 1% and ** does 5%.

in the VAR and cointegration vector. 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 product machinery, chemical and iron-steel. In contrast, the null of no cointegrating rank can be rejected only in transportation equipments, and it is shown that this industry has, at most, 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[8].

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 production machinery, and the VECM for the transportation equipments 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: chemical and iron-steel. And for the transportation equipment and production machinery, marginal q Granger-causes investment-capital ratio. Thus, only the empirical result for transportation equipments is not consistent with that of the previous section[9].



Source: Company Statistics Seasonal Report, Ministry of Finance,Japan

Fig.3 Uncertainty (Standard Deviation of Sales)

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.

III. Discussion

In the previous section, we verified the predictability of Tobin's marginal q on investments. And in the machinery industries, marginal q Granger-causes investments; however, it does not in material industries. And in the transportation equipments industry, it is shown that marginal q Granger-causes investments with the VECM, but it does not with the LA-VAR model. 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

Table 7 Period of Durability (Proxy of Irreversibility)

(industry)	(years)	Industry
Chemical	12.08	Material
Iron and Steel	15.59	
Machinery	12.95	Non-Material
Transportation and Motorvehicle	9.45	

Source:Company Statistics Annual Report(The Ministry of Finance,Japan)
(Note)
Here, we calculate remaining duration assuming fixed percentage method of depreciation with residual value of 10%.

iron-steel industry, face higher uncertainty. And this also shows that uncertainty of demand is low in machinery industries.

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 iron-steel 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. 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 in the material industries to carry out their investments in response to fluctuation of marginal q, even though marginal q is high especially in the chemical. 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 in the machinery industries, though it is not robust in the transportation equipments industry.

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.

IV. Conclusion

In this paper, we compared the Granger's causality of four manufacturing industries utilizing the LA-VAR model. And we also utilize VECM or difference model. We focused on Granger's causality of marginal q to investments. Considering the empirical results obtained in this study, the following points were elucidated. Granger's causality from marginal q to investment does not exist in the material industries whereas marginal q Granger-causes investment in the machinery industries. And in the transportation equipments, 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 the material 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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Note

[1] For example, please see Mankiw(2012) and Obstfeld and Rogoff(1996).

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

[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). Price level is the deflator of investment goods. We utilize data of the real effective exchange rate from the Bank of Japan's financial statistics.

[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.

[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]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.

[9]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.

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