|||| 研究ノート ||||

THE IMPACT OF UNCERTAINTY ON INVESTMENT IN JAPANESE MANUFACTURING INDUSTRIES

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Abstract

Various theories suggest different channels via which the level of uncertainty affects the investment decision for firms, although the sign of the investment-uncertainty is ambiguous. In this paper, ARCH estimators are used to model the conditional variances of Japanese manufacturing industries' sales as proxies for uncertainties. These measures are then employed in simple neoclassical models of investment decision. The effects of uncertainty on investment vary across industries in Japan. In general, however, the effects are positive in the high economic growth era although they are rather negative after the high growth era in the post-war Japan.

1. INTRODUCTION

The theoretical relationship between investment and uncertainty has been the subject of controversy for a long time. Different models emphasize the different effects, some pointing to a positive relationship and some to a negative relationship.[1)] In the models of Oi (1961), Hartman (1972) and Abel (1983), the assumption that labor is flexibly adjusted relative to capital plays a crucial

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1) Dixit and Pindyck (1994) is the excellent reference to this literature.

role. Since under this assumption the marginal product of capital is convex in output price and wage rate, a mean-preserving spread in the distribution of the price leads a competitive risk-neutral firm to increase investment, which is verified by Jensen's inequality. However, this result is somewhat counter-intuitive. In order to get what most people believe to be true, i.e. a negative correlation between investment and uncertainty, we need to add some element of "concavity" and/or asymmetry to the model.

The main class of models that predict a concave marginal revenue product of capital is the class of models with irreversible investment. Pindyck (1988) and Bertola and Caballero (1994) have shown that increased uncertainty reduces the optimal rate of investment. The irreversible nature of investment implies that the firm regrets having too much capital equipment after the resolution of uncertainty. This arises not only from the strict irreversibility but also from asymmetric adjustment costs for investment, that is, the cost of adjusting capital stock downward is much larger than the upward adjustment.[2] However, as Caballero (1991) correctly pointed out, asymmetric adjustment costs are not sufficient to yield the result. Another important condition is required that ensures some linkage between current and future investment like decreasing returns to scale and/or downward sloping demand. Only when the above two conditions are met, the irreversibility effect can dominate the convexity effect.[3]

Risk-aversion is another line to invalidate the convexity of the marginal product of capital of the competitive firm with linearly homogenous technology. Needless to say, with enough concavity in the utility function, Oi-Hartman-Abel

2) Irreversibility can be considered as especial case of asymmetric costs where the downward cost is infinite.

3) Abel and Eberly (1994) present the detailed discussion concerning this topic using the model that nest the model of Abel (1983) and an irreversible investment model.

Jensen's inequality argument can be turned around. For example, Nickell (1977) shows this in a partial equilibrium context and Craine (1989) in a general equilibrium. Although the theories present various channels through which uncertainty affects investment, they do not answer the question of which effect is dominant over the others. Under different environments different effects may play a crucial role. In this sense, only empirical investigations can provide the answer to the above question.

In spite of the aforementioned conflicting theoretical predictions, an enough number empirical attempts have not been done on the relationship between investment and uncertainty, and the results are far from conclusive. This is partly because of difficulty to estimate "uncertainty." Different studies uses different measures of uncertainty since there is no unique way in which the firms actually preview the uncertainty. For example, Brainard, Shoven and Weiss (1980) use a sample of 187 firms from the years 1958 to 1977 to assess he effects of a CAPM-based measure of risk on investment via Tobin's (average) Q, the ratio of the market value to the book value of the existing capital stock. They perform individual cross-section regressions of Q on their measure of risk, finding both positive and negative coefficients on risk, only some of which are significant.

Ferderer (1993) employs the term structure of interest rates to derive a measure of the risk premium on long-term bonds. He finds that this measure of uncertainty has a significant negative effects on aggregates investment even after controlling for user cost and Tobin's Q. His approach has the advantage that it uses a forward-looking measure of uncertainty that matches the forward looking nature of investment.

The above results cast some doubt on the Oi-Hartman-Abel story or suggest that the irreversibility and/or risk-aversion effects are dominate over the convexity effect. Leahy and Whited (1996) test an implication of models with irreversible investment using the variance of the firm's stock return for each firm as a measure of uncertainty. Their study on the full sample indicates that the uncertainty has a negative impact on investment. Also, they focus on two implications of the convex marginal product theories. First, the high substitutability between labor and capital should lessen the negative effect of uncertainty on investment by increasing convexity of the marginal product of capital. To test this implication, they split the sample into two sub-samples, the high and low substitutability sample. Contrary to the theories, they find that uncertainty is more harmful for investment, the more variable is the labor-capital ratio.

Second implication, as is shown in Abel (1983), is that higher labor-capital ratios should reduce the undesirability of uncertainty. The intuition behind this result is that the higher is labor's share, the greater is the convexity in returns induced by varying the firm's input. To test this implication, they split the sample on the basis of the level of the industry labor-capital ratios. They shows again that the effects of uncertainty, contrary to theory, is more negative in the high labor-capital ratio sample.[4)]

However, taking into consideration that most theoretical models focus on the price or demand uncertainty, the measures used in the former studies may not be appropriate to test the theoretical predictions. More specifically, we have to focus on the price and/or demand uncertainty to test the theory since the heart of Hartman-Abel result is that the marginal revenue product of capital is a convex function of random variable, like output price, wage rate and demand for output. As a measure of uncertainty, for example, Leahy and Whited use the volatilities of the stock return, which is essentially equal to the average product of capital and to the marginal product of capital under certain assumptions about technology and market conditions. If we considered the marginal

4) For recent developments in empirical investigations on the investment-uncertainty, see Carruth, Dickerson and Henley (2001).

revenue product of capital as a random variable instead of price and/or demand, we would ignore the channel through which the convexity increases investment. The same argument can be applied to the case in which one uses the volatilities of the Tobin's Q as the measure of uncertainty.

The empirical implementation in this paper attempts to investigate the theoretical implications of Oi-Hartman-Abel argument more directly than those in the above studies. The comprehensive surveys on the empirical studies of investment functions such as Jorgenson (1971) and Chrinko (1993) point out that the most important determinant of investment is the sales (or output). Therefore, it is quite natural to guess that the demand uncertainty is one of the most important factors influencing the investment decisions as long as the demand play a crucial role in the determination of investment. The investment model is similar to the Neoclassical model in the sense that the demand or output is a key. In this paper, as the first step, the variances of changes in sales are considered as the measure of demand uncertainty. Since the variances must be forward-looking and time-variant to be consistent with the forward-looking decisions on investment, we adopt ARCH (Autoregressive Conditional Heteroskedascity) model on the time series of the firms to estimate a forecast of the changes in sales and their conditional variances.[5)]

In addition, this paper tries to shed light on the role of irreversibility in the relationship between uncertainty and investment from a different angle from in Leahy and Whited. The main reason that irreversibility makes the relationship between uncertainty and investment negative is that the firm worries about the excess-capacity after resolution of uncertainty. If the demand for its output grows very rapidly, then excess-capacity is not a problem for the firm in the sense that the output demand catches up with its capacity even if it has some

5) Price (1995, 1996) applies a similar model to investigate the effects of uncertainty on the business fixed investment in the UK manufacturing sector.

temporal excess-capacity. Therefore, it is natural to think that in the growing industry or economy the convexity effect can dominate the irreversibility effect. As is well-known, before the first Oil Crisis the Japanese economy grew very fast and after that its growth rate decreased sharply in the Post World War II era. If the convexity effect existed, the effect of uncertainty on investment should be more positive in the period of before first Oil Crisis than in the period of after that. We split the sample into two sub-samples to test this implication.[6)]

The organization of this paper is as follows. Section 2 briefly discusses the investment models and the data used to carry the estimations. The results are presented in Section 3. The final section contains some concluding remarks.

2. THE INVESTMENT MODEL

There are two distinct modelings of investment competing in the literature. The break runs between the more traditional Jorgenson approach to modeling investment and the more modern Q approach. The Q model has encountered some problems in its empirical performance despite its theoretical appeal. The Jorgenson approach still widely satisfies most practitioners who forecast investment using econometric models in spite that this approach has been rejected by most theorists in favor of the Q approach.[7)]

Our main interest is not in the investment function itself but in the relationship between uncertainty and investment. In order to examine the impact of

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6) Ogawa and Suzuki (2000) employ three different measures of uncertainty to estimate the investment-uncertainty relationship in some Japanese manufacturing sectors using the panel data and find the evidence for the negative relationships. They also find that the main cause of negative relationships probably comes from the irreversible nature of investment.

7) For the Jorgenson model see Jorgenson (1963) and for the Q theory of investment see Hayashi (1982).

uncertainty on investment, however, we need the empirical investment equations. According to the Jorgenson approach, the modeling of investment is the modeling of the joint process of investment, and output, and the cost of capital (capacity utilization is sometimes added to improve serial correlation). Investment is empirically explained by a distributed lag of these variables. If the Jorgenson approach had high empirical performance, we could infer that output and the cost of capital are the most important determinants of investment and therefore its uncertainties have effects on investment. In addition, the comprehensive surveys on the empirical studies of investment functions by Jorgenson (1971) and Chrinko (1993) point out that the most important determinant of investment is the sales (or output). Therefore, to investigate the impact of uncertainty on investment, the conditional variances of the sales are introduced into a simple Jorgensonian neoclassical model. As the first step, we use the ARCH (Autoregressive Conditional Heteroskedascity) model to estimate a forecast of the changes in sales and their conditional variances.[8]

Estimates of the impact of uncertainty on investment are based upon the following model:

(1) $$I_t - \delta K_{t-1} = a_0 + \sum_{j=T}^{j=T+N} \{a_j \Delta S_{t-j} + b_j h_{S\,t-j}\} + \varepsilon_{It},$$

(2) $$\Delta S_t = \sum_{j=1}^{n} d_j \Delta S_{t-j} + \varepsilon_{st},$$

where I_t is the investment rate, δ is the economic deprecation rate of capital, K_t is the capital stock, S_t is the sales, h_{St} is the time-varying conditional variance of the sales, T to T+N correspond the delivery lags and Δ is the first difference operator. The ε's are assumed to be white noise stochastic processes.

We impose the ARCH (1) structure on the variance of the residual in (2). Defining $\varepsilon_{1t} = [\varepsilon_{It},\ \varepsilon_{St}]'$,

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8) For the ARCH model, see Engle (1982).

(3 a)　$\varepsilon_{1t} \mid \varepsilon_{1t-1} \sim N(0, H_{1t})$,

(3 b)　$H_{1t} = \begin{bmatrix} \sigma_{It}^2 & 0 \\ 0 & h_{St} \end{bmatrix}$,

(3 c)　$h_{St} = \theta_0 + \theta_1 \varepsilon_{St-1}^2$.

We estimated the above functions for Japanese manufacturing industries using quarterly data (1995 [1]-1994 [1]). We split the sample into two sub-samples: the high-growth period (1955 [1] to 1973 [4]) and the steady growth period (1975 [1] to 1994 [1]) to examine the implication of irreversible investment.[9)] The higher growth rate of sales should lessen the irreversibility effect and hence the effect of uncertainty on investment should be more positive in the high growth period than in the steady growth period.

We first estimated (2) taking (3) into account by the maximum likelihood and generated the time series of h_{St}. The final models are selected by Akaike Information Criterion (AIC). For both sample periods, we found significant ARCH effects for all manufacturing (MFT), which is a single-digit industry, and three two-digit industries: general machinery (GEM), electric machinery (ELM) and chemical and allied products (CAP).[10)] The results for the high-growth period are shown in Table-1 and those for the steady growth period in Table-2.[11)]

9) We dropped the year of 1974 from the sample since this year can be considered as a 'transitional' period from the high growth to the steady growth. The other reason to split the sample is that the structural change might have happened to the Japanese economy after the first Oil Crisis.

10) In addition to these industries, four other two-digit industries were included in the preliminary set of estimations. However, we did not succeed in obtaining satisfactory results for them. We focused on the two-digit industries since the sales fluctuations may have been governed by micro-specific factors.

11) The average quarterly growth rates of sales are as follows;
In the high growth period, MFT: 3.1%, GEM: 4%, ELM: 5.3%, CAP: 3.1%,
in the steady growth period, MFT: 0.7%, GEM: 0.7%, ELM: 2.3%, CAP: 1.1%.

Table-1

(1) All Manufacturing (MFT):

$$\Delta S_t = 0.514875\,\Delta S_{t-1} + 0.406657\,\Delta S_{t-2} + \varepsilon_{St},$$
$$\quad (5.02443) \qquad (3.75627)$$

$$h_{St} = 0.403518 + 0.558591\,\varepsilon^2_{St-1},$$
$$(12.1564) \quad (3.08613)$$

Log of likelihood function = −47.2244, Number of observations = 73.

(2) General Machinery (GEM):

$$\Delta S_t = 0.947766\,\Delta S_{t-2} + 0.133734\,\Delta S_{t-3} - 0.30158\,\Delta S_{t-4} + \varepsilon_{St},$$
$$(12.8913) \qquad (2.19425) \qquad (-3.99753)$$

$$h_{St} = 0.35095 + 1.10249\,\varepsilon^2_{St-1},$$
$$(4.57793) \quad (4.99618)$$

Log of likelihood function = −71.52, Number of observations = 71.

(3) Electric Machinery (ELM):

$$\Delta S_t = 0.319113\,\Delta S_{t-1} + 0.228798\,\Delta S_{t-2} + 0.352105\,\Delta S_{t-3} + 0.246834\,\Delta S_{t-4} + \varepsilon_{St},$$
$$(3.08891) \qquad (1.867) \qquad (2.38286) \qquad (2.05923)$$

$$h_{St} = 0.22659 + 0.765449\,\varepsilon^2_{St-1},$$
$$(10.5217) \quad (4.71569)$$

Log of likelihood function = −11.9418, Number of observations = 71.

(4) Chemical and Allied Products (CAP):

$$\Delta S_t = 0.537627\,\Delta S_{t-1} - 0.063004\,\Delta S_{t-2} + 0.547273\,\Delta S_{t-3} + \varepsilon_{St},$$
$$(4.94194) \qquad (-0.571074) \qquad (8.12131)$$

$$h_{St} = 0.346701 + 1.20475\,\varepsilon^2_{St-1},$$
$$(5.20306) \quad (6.00219)$$

Log of likelihood function = −61.311, Number of observations = 72.

*) t-Values are in the parentheses.

Table-2

(1) All Manufacturing (MFT):

$$\Delta S_t = 0.247003\,\Delta S_{t-1} + 0.42784\,\Delta S_{t-2} + \varepsilon_{St},$$
$$(2.36727) \qquad (3.83558)$$

$$h_{St} = 1.03643 + 0.36194\,\varepsilon^2_{St-1},$$
$$(7.20151) \quad (1.13234)$$

Log of likelihood function = −122.984, Number of observations = 74.

(2) General Machinery (GEM):

$$\Delta S_t = 0.35584\,\Delta S_{t-2} + 0.216872\,\Delta S_{t-3} + \varepsilon_{St},$$
$$(2.55201) \qquad (1.82979)$$

$$h_{St} = 1.4982 + 0.524795\,\varepsilon^2_{St-1},$$
$$(7.54563) \quad (2.98393)$$

Log of likelihood function = −156.214, Number of observations = 73.

(3) Electric Machinery (ELM):

$$\Delta S_t = 0.437698\,\Delta S_{t-1} + 0.337613\,\Delta S_{t-2} + \varepsilon_{St},$$
$$(2.84759) \qquad (2.32381)$$

$$h_{St} = 1.37861 + 0.49903\,\varepsilon^2_{St-1},$$
$$(12.5494) \quad (3.05931)$$

Log of likelihood function = −149.727, Number of observations = 74.

(4) Chemical and Allied Products (CAP):

$$\Delta S_t = 0.33245\,\Delta S_{t-1} + 0.103948\,\Delta S_{t-2} + 0.233628\,\Delta S_{t-3} + \varepsilon_{St},$$

(2.59687) (1.00714) (2.98203)

$$h_{St} = 1.3158 + 0.633721\,\varepsilon^2_{St-1},$$

(9.24042) (4.05691)

Log of likelihood function = −150.676, Number of observations = 73.

*) t-Values are in the parentheses.

Second, we run the OLS regression of (1) using the sales data and the generated series of h_{St}.

For the sales data, we used an index of shipments published by Ministry of Economy, Trade and Industry (former: Ministry of International Trade and Industry) as *Industrial Statistics Monthly*. Since the original data was monthly, I used the average of every three month indices as the quarterly data.

The data for real gross investment, I_t, and capital stock, K_t, is taken from the "newly acquired fixed assets" series in *Report of Quarterly Data for Private Company Capital Stock* published by Cabinet Office of Japan (former: Economic Planning Agency).

Assuming that capital depreciation rate, δ, is constant through the sample period, we first run the following regression for each industry:

$$I_t + K_{t-1} - K_t = \delta K_{t-1} + \varepsilon_t,$$

where ε_t is assumed be i.i.d. normal. We could verify the constancy of δ for all candidate industries by the regression results. Second, we repeatedly computed K_t at 1994 [1] starting from the benchmark capital stock at 1955 [1] using the capital accumulation equation, $K_t = I_{t-1} + (1-\delta)K_{t-1}$, and the investment for various δ s.[12)]

12) The capital depreciation rate for each industry is as follows:
MFT: $\delta = 0.011$, GEM: $\delta = 0.014$, ELM: $\delta = 0.019$, CAP: $\delta = 0.012$

3. EMPIRICAL RESULTS

Table-3 presents empirical results for the neoclassical model in the high growth period. The lag lengths for explanatory variables were chosen using AIC.

Table-3

	MFT	GEM	ELM	CAP
Const.	−0.85185 (−3.44573)	0.027831 (2.94174)	0.026904 (4.68727)	0.040392 (2.8313)
ΔS_{t-3}	0.171599 (1.36399)		0.045246 (4.64133)	
ΔS_{t-4}	0.18843 (1.22432)	0.037231 (4.44468)	0.048675 (4.32109)	
ΔS_{t-5}	0.301052 (1.97328)	0.030219 (3.50891)	0.049577 (4.28837)	0.04705 (3.13831)
ΔS_{t-6}	0.282598 (1.90922)	0.015334 (1.91394)	0.058063 (4.25799)	0.051233 (3.22073)
ΔS_{t-7}		0.011723 (1.38144)		0.039044 (2.48228)
ΔS_{t-8}				0.047767 (3.15944)
h_{St-3}	0.811959 (1.44557)		−0.051934 (−1.55138)	
h_{St-4}	2.24892 (3.35452)	0.15262 (2.68306)	0.014845 (0.460591)	
h_{St-5}	2.20179 (3.35533)	0.503004E-02 (0.731736)	0.048344 (1.51088)	0.014642 (1.61473)
h_{St-6}	1.71643 (2.57872)	0.841805E-02 (1.228)	−0.016748 (−0.581281)	0.010415 (1.12389)
h_{St-7}		0.011739 (1.88334)		0.018515 (2.15919)
h_{St-8}				−0.108835E-02 (0.110531)
R^2	0.734472	0.715454	0.825145	0.73543
$\bar{R}^2$	0.697847	0.674065	0.800166	0.696947
N	67	64	65	64

*) $\bar{R}^2$=Adjusted R^2, N=Number of observations, t-Values are in the parentheses.

First of all, the neoclassical model has high explanatory power in the high growth period. The coefficients on ΔS_{t-j} are all positive and most of them are statistically significant. These results indicate that the sales are the crucial determinant of investment in this period.

Second, most of the coefficients on h_{St-j} are positive and some of them are statistically significant. Especially for all manufacturing, most coefficients are significant. These results imply that the convexity effects can dominate the irreversibility effect in the high growth period, which is consistent with our inference. If the demand for its output grows very fast, then the firm does not worry about temporal excess capacity and hence the irreversibility effect becomes negligible. Therefore the relationship between uncertainty and investment becomes positive in the high growth period.

However, the electric machinery looks an exception for the above argument. The coefficients on h_{St-j} are all positive but not significant in spite that its sales growth rate is higher than any other industry. This industry's capital depreciation rate is also the highest and hence rate of the economic obsolescence of the capital equipment is high compared to those of other industries.

Table-4 shows empirical results for the neoclassical model in the steady growth period. Again, the lag lengths for explanatory variables were chosen using AIC.

The explanatory power of the neoclassical model for this period is surprisingly poor except for electric machinery.[13] The signs of the coefficients on h_{St-j} are mixing: some are positive, some negative, and all of them are not statistically significant at all. Together with the very low explanatory power of the model, we can say nothing about the relationship between uncertainty and investment. The results just tell us that the demand factors are no longer the important determinants of investment in the steady (or low) growth period.

13) This is partly because this industry's sales growth is very high in this period.

Table-4

	MFT	GEM	ELM	CAP
Const.	2.21593 (1.1446)	0.176832 (2.43826)	−0.01191 (−0.110233)	0.199372 (3.73472)
ΔS_{t-3}	−0.054893 (−0.374373)		0.020891 (1.4438)	
ΔS_{t-4}	0.032158 (0.21066)	0.740785E-02 (0.681138)	0.021137 (1.39026)	
ΔS_{t-5}	0.11952 (0.714375)	0.42679E-02 (0.363146)	0.033786 (1.96386)	−0.172729E-02 (−0.016897)
ΔS_{t-6}	0.159273 (0.966935)	0.013688 (1.16885)	0.030976 (1.75077)	0.421611E-02 (0.331422)
ΔS_{t-7}		0.012544 (1.12494)		0.013227 (1.04239)
ΔS_{t-8}				0.021762 (1.69144)
h_{St-3}	0.113898 (0.129159)		0.01806 (0.747041)	
h_{St-4}	0.144256 (0.161314)	0.99246E-02 (0.794911)	0.020752 (0.745794)	
h_{St-5}	0.254223 (0.294291)	0.832376E-02 (0.659142)	0.034803 (1.1872)	−0.28941E-02 (−0.300243)
h_{St-6}	−0.241449 (−0.282338)	0.688408E-02 (0.543356)	0.04765 (1.58196)	0.697972E-02 (0.669322)
h_{St-7}		−0.518639E-02 (−0.421736)		0.649062E-02 (0.633661)
h_{St-8}				−0.430627E-02 (−0.542199)
R^2	0.047924	0.179637	0.455118	0.084092
$\bar{R}^2$	−0.081172	0.062442	0.381236	−0.046753
N	68	65	68	65

*) $\bar{R}^2$=Adjusted R^2, N=Number of observations, t-Values are in the parentheses.

4. CONCLUDING REMARKS

This paper investigates the empirical relationship between uncertainty and investment using Japanese manufacturing industry data. Our results indicate that an increase in uncertainty increases investment in the high growth period primarily through the channel of convexity of the marginal product of capital.

However, this conclusion is not to deny the importance of irreversible investment but just to demonstrate that different effects play a key role under different situations in the determination of the sign of uncertainty-investment relationship. Although we can not obtain any satisfactory result for the steady (or low) growth period, the irreversibility effect may play an important part in that period.

The results obtained in this paper have an important implication for the business cycle and growth theory. The uncertainty may have different effects on investment in different phases in business cycles: positive during booms mainly via convexity effect and negative during slumps because of irreversibility and/or risk-aversion effects.

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