Econometric Analysis of Investment Behavior in Japanese Electric Power Industry

Tomohiro Inoue* and Mika Goto

Socio-economic Research Center, Central Research Institute of Electric Power Industry

1-6-1, Ohtemachi, Chiyoda-ku, Tokyo 100-8126, Japan

Abstract

This study examines an investment behavior of Japanese electric power companies from the applicability of economic theory toward investment. For the research purpose, this study utilizes a firm-level annual data set from 1990 to 2009 and estimates a Tobin's q type investment function of the industry. In addition, to identify specific features regarding the investment behavior of the electric power industry, this study compares the industry to other Japanese four manufacturing industries. Our estimation results indicate that the investment of Japanese electric power companies is partly explained by the economic theory of investment based upon the Tobin's q theory. In contrast, the results on the other manufacturing industries indicate their investment behaviors are consistent with the economic theory. Such differences observed in our empirical results are because the electric power industry needs to satisfy business constraints imposed by government regulation such as an approval of a tariff system and an obligation of electricity supply to customers. To further investigate another unique feature regarding the electric power industry, this study estimates an investment function for generation and transmission/distribution network divisions, respectively. The estimation results indicate differences between the two divisions in the applicability of economic investment theory.

Key Words: Investment Behavior, Electric Power Industry, Manufacturing Industries, Tobin's q Theory

* Corresponding author.
Phone: +81 3-3201-6601, Fax: + 81 3-6362-4977, Email: t-inoue@criepi.denken.or.jp

1. Introduction

The electric power industry is a typical capital-intensive industry where large-scale facilities and equipments are required for their businesses from generation to retail supply of electricity. An important characteristic of the industry is government regulation that historically restricts electric power companies by means of an approval of an electricity tariff system, entry and exit in the industry, and supply obligation to end users. Because of the supply obligation, electric power companies need to maintain enough capacity for generation (GEN) and transmission/distribution (TD) network so that they can provide electricity for all customers even at a peak demand period in summer or winter. Consequently, when an electricity demand is low, the electric power companies need to maintain excess capacity compared to the level just required to meet the excess demand. Since the characteristics of capital usage are different from the other manufacturing industries, many previous studies in economics and finance have excluded the electric power industry from their research scopes.

Meanwhile, it is true that a considerable number of scholars are interested in economic characteristics of the electric power industry. They have examined economies of scale and economies of scope or vertical integration of the industry, all of which are well-known characteristic of the industry (Christensen and Greene, 1976; Kaserman and Mayo, 1991; Gilsdorf, 1994). They measured a company-level economies of scale and that of each division within the company; generation, transmission and distribution, along with economies of scope between those divisions. The economies of scale and scope are important economic concepts for the industry because they are closely related to the natural monopoly issue. The issue explains a policy rationale regarding why the electric power industry is regulated rather than open competition for improving economic efficiency. Another group of scholars have examined a possible over-investment of electric power companies under rate of return (ROR) regulation (Averch and Johnson, 1962; Tawada and Katayama, 1990), because they can increase revenues by investment that consists of rate base for electric power companies.

A research agenda that we have not yet fully investigated so far is whether the electric power industry invests based upon the recent economic theory on investment. This issue is very different from the investment strategy of manufacturing industries even if there are many previous studies of the investments. The scarcity of such studies on the electric power industry is associated with the belief that electric power companies need to invest in facilities and equipments for satisfying their supply obligation, regardless of economic incentives on whether the investment is profitable or not. The belief is strengthened by the fact that they make a long-term investment planning based upon the forecast of a demand growth. In addition, Japanese government often requested them to accelerate their investment as part of government economic measures after the collapse of so-called “bubble economy” occurring from the end of the 1980’. Such requests on investment had been acceptable for electric power companies because a certain level of return on capital investment was fully protected before the liberalization of the retail business and it was gradually implemented since 2000. Moreover, even after the liberalization, the basic structure of electricity tariff has remained unchanged. This implies their fundamental stream of costs and revenues is not largely different from before the deregulation, although explicit price regulation has been removed for all customers with an exception of households and very small businesses since 2005.

In addition to the above concerns, it is important to describe that since major electric power companies in Japan are investor-owned companies, they cannot escape from shareholder's evaluation on financial soundness and opportunities of corporate growth. Therefore, it is not anticipated that they completely deviate from the economic theory on investment. Indeed, deregulation stimulated promotion toward further efficiency in their operation and requested their corporate efforts to seek growth opportunities. However, since costs incurred by the investments are recovered from the electricity tariff under ROR regulation, electric power companies cannot result in their investments as expected by economic efficiency.

The purpose of this study is twofold. One of the two concerns is that we examine the investment behavior of Japanese electric power companies by estimating Tobin's q type investment functions, using an unbalanced panel data set concerning the nine companies. It is envisioned that this empirical study contributes to making an empirical bridge between many previous empirical studies on investment for manufacturing industries and a limited number of studies on an electric power industry. In addition, this study estimates investment functions for each functional division, or GEN (Generation) and TD (Transmission and Distribution), to reveal different characteristics with respect to their investment strategies. The other concern is that this study examines differences between the electric power industry and the manufacturing industries based upon the estimation results concerning the investment functions, particularly from a perspective of applicability of the Tobin's q theory.

The reminder of this paper is organized as follows: Section 2 specifies the Tobin's q type investment function utilized in this study. Section 3 describes a data set and an estimation method. Section 4 summarizes empirical results. Section 5 concludes this study along with future extensions.

2. Specification of investment function

This study estimates the investment functions of electric power industry and manufacturing industries. The investment theory, initiated by Jorgenson (1963), was based upon neoclassical economics and then further developed by several researchers who incorporated adjustment costs of investment. Combining the investment theory in neoclassical economics with Tobin's q theory, Abel (1980) proposed the Tobin's q type investment function. Under the Tobin's q theory, firm's investment is positively influenced by the Tobin's q, which is defined by the ratio of sum of discounted present value of marginal revenue from capital to capital price.

As an extension of such previous studies that have assumed liner relationship between firm's investment and Tobin's q, this study considered a nonlinear relationship between them by incorporating a second-order variable of the q ratio as an explanatory variable. Such a nonlinear relationship was proposed by Eberly (1997) and Barnett and Sakellaris (1998) by assuming non-convex adjustment cost and discontinuous response of investment to the q ratio. Suzuki (2001) applied the same type of investment function with nonlinearity of the q ratio to Japanese manufacturing data and estimated the investment function. The study investigated a relationship between capital investment of firms and marginal q ratio by using a logistic function.

In this study, we also examine what factors influence firms' investment other than the Tobin's q. In particular, we are interesting on investigating impacts of various financial factors and revenue uncertainty on firms' investment because recent studies for manufacturing industries have investigated influences of an imperfect capital market because of information asymmetry and an uncertainty of future revenue streams on investment. Fazzari, Hubbard and Petersen (1988) firstly consider the influences by adding financial variables to neoclassical investment model. We follow their approach.

The investment function we estimate in this study can be specified as follows:

$$\begin{aligned} IK_{i,t} = {} & \alpha_0 + \alpha_1\, IK_{i,t-1} + \alpha_2\, IK_{i,t-2} + \alpha_3\, q_{i,t} + \alpha_4 \left(q_{i,t}\right)^2 \\ & + \alpha_5\, CFK_{i,t} + \alpha_6\, LK_{i,t} + \alpha_7\, UNCER_{i,t} \\ & + u_i + \varepsilon_{it}, \end{aligned} \qquad (1)$$

where $i =$ firm's index, $t = 1990, \ldots, 2009$, $u_i \sim N(0, \sigma_u^2)$, $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$,

$$IK_{i,t} = \frac{I_{i,t}}{K_{i,t-1}}, CFK_{i,t} = \frac{CF_{i,t}}{K_{i,t-1}}, LK_{i,t} = \frac{LAND_{i,t}}{K_{i,t-1}}.$$

Here, I is an amount of capital investment expressed in real terms, K is a capital stock at the end of the period in real terms, q is the Tobin’s marginal q ratio, CF is a cash flow in real terms, $LAND$ is a land stock at the market price. The CF represents influences of imperfect capital markets, and $LAND$ represents firm’s credit capability as collateral, which are both included in the model as financial factors. The $UNCER$ describes variation in revenue in real terms.

The variation in revenue is calculated by applying two methods. The first method calculates sample standard deviations regarding revenues of data pertaining to the past five years ($UNCER1$). The second method calculates standard deviations regarding error terms of autoregressive equations using data with past ten years ($UNCER2$).

Specifically, $UNCER1$ is defined as follows:

$$UNCER1_{i,t} = \sqrt{\frac{1}{5} \sum_{j=t-5}^{t-1} \left(\Delta \log S_{i,j} - \overline{\Delta \log S_i}\right)^2},$$

where $S_{i,t}$ is total revenue in real terms for the firm *i* in period *t*, and $\Delta \log S_{i,t} = \log S_{i,t} - \log S_{i,t-1}$. The $UNCER2$ is defined as follows:

$$\Delta \log S_{i,t} = h_0 + h_1 \Delta \log S_{i,t-1} + h_2 \Delta \log S_{i,t-2} + \eta_{i,t},$$

$$UNCER2_{i,t} = \sqrt{\frac{1}{10} \sum_{j=t-10}^{t-1} \left(\eta_{i,j}\right)^2}.$$

Here, this study conducts 10-year rolling regressions and obtain the error term $\eta_{i,t}$ to calculate $UNCER2$.

In addition, this study uses one-period and two-period lagged dependent variables to explain the dependent variable. u is a firm-specific effect and ε is an error term.

In this study, we use Tobin’s marginal q, proposed by Ogawa and Kitasaka (1998), which is simplified formulation defined by Abel and Blanchard (1986) by assuming AR1 process of first-order difference of profit ratio. The Tobin’s q is described as follows;

$$
\begin{aligned}
q_{i,t} &= \frac{1-\tau_{i,t}}{(1-z_{i,t})P^I_{i,t}} \sum_{j=0}^{\infty} \left[\left(\frac{1-\delta_{i,t}}{1+wacc_{i,t}} \right)^j E_t(\pi_{t+j}) \right] \\
&= \frac{1-\tau_{i,t}}{(1-z_{i,t})P^I_{i,t}} \left(1 + \frac{1-\delta_{i,t}}{wacc_{i,t}+\delta_{i,t}} \right) \left[\pi_{i,t} + \frac{\left(1+\frac{1-\delta_{i,t}}{wacc_{i,t}+\delta_{i,t}}\right) a_{i,t} + b_{i,t}\, \Delta\pi_{i,t}}{1+\frac{wacc_{i,t}+\delta_{i,t}}{1-\delta_{i,t}} - b_{i,t}} \right],
\end{aligned}
\tag{2}
$$

where $\Delta\pi_{i,t} = \pi_{i,t} - \pi_{i,t-1}$,

$\Delta\pi_{i,t} = a_{i,t} + b_{i,t}\, \Delta\pi_{i,t-1} + \mu_{it}$,

$\mu_{it} \sim N(0, \sigma_\mu^2)$.

Here, τ is an effective corporate tax rate, z is a rate of reduced tax per unit of capital due to a tax deduction effect by depreciation, P^I is a price of capital investment goods, δ is a rate of physical depreciation of capital, and $wacc$ is a weighted average capital cost that is calculated as follows:

$$wacc = DebtCost \times \left(\frac{Debt}{Capital}\right) + EquityCost \times \left(\frac{Equity}{Capital}\right).$$

Here, $DebtCost$ is calculated by an interest rate multiplied by (1-corporate tax rate), $EquityCost$ is sum of risk-free interest rate and risk premium multiplied by beta-value. We measure the risk-free rate by an interest rate of the interest-bearing 10-year government bond and assume risk premium to be 3%. $Equity$ represents net asset, and $Capital$ is a sum of debt and net asset or equity. The beta-value is calculated as a three-year beta value indexed by Nikkei Sougou Kabuka Shisuu, which is the Japanese representative share price index.

3. Data set and estimation

3.1 Data set

There are not many previous studies that examine the investment behavior of Japanese industries. Two exceptions are Tanaka (2004) and Takeda and Yajima (2005), which used data sets consisting of public-listed manufacturing companies in Japan and estimated the Tobin's q type investment functions of the industries. This study follows these preceding studies to prepare for a data set to estimate investment functions of Japanese electric power industry and four manufacturing industries.

The data source is "corporate financial data bank," which is constructed by the Development Bank of Japan. We select firms for which the data are available from 1977, and those which can be obtained at least in five continuous years after 1990. The estimation period is from 1990 to 2009. Table 1 shows descriptive statistics on data.

Table 1: Descriptive Statistics of Data

variable	obs.	mean	std. dev.	min	max
General Machinery					
IK	2671	0.1029	0.1512	0.0000	3.1719
q	2569	0.8629	6.8673	-83.7097	120.9269
LK	2664	1.4033	1.8722	0.0275	23.1279
CFK	2671	0.1251	0.4072	-10.6396	6.9436
UNCER1	2671	0.1314	0.1064	0.0087	1.4488
UNCER2	2671	0.1229	0.0819	0.0088	0.9617
Electric Machinery					
IK	2390	0.0973	0.0867	0.0000	1.0678
q	2290	0.6981	3.6154	-25.8306	23.4448
LK	2390	0.6115	0.6747	0.0130	9.5314
CFK	2390	0.1818	0.7961	-20.5587	2.5068
UNCER1	2390	0.0981	0.0873	0.0096	1.3202
UNCER2	2390	0.0938	0.0617	0.0239	0.8213
Transport Machinery					
IK	1799	0.1095	0.0922	0.0000	1.2805
q	1704	0.9160	2.2791	-18.9461	16.1111
LK	1799	0.8892	1.1941	0.0642	11.7592
CFK	1799	0.1302	0.2200	-6.6638	0.8587
UNCER1	1799	0.0847	0.0553	0.0109	0.4470
UNCER2	1799	0.0855	0.0475	0.0157	0.3676

variable	obs.	mean	std. dev.	min	max
Precision Machinery					
IK	510	0.0906	0.1093	0.0000	1.1803
q	467	0.2804	4.8152	-23.3329	24.7594
LK	510	0.6780	0.7249	0.0263	6.5239
CFK	510	0.0281	1.0928	-14.4175	2.5048
UNCER1	510	0.1152	0.1120	0.0119	0.9491
UNCER2	510	0.1054	0.0824	0.0105	0.6905
Electricity					
IK	180	0.0937	0.0857	0.0139	0.5512
q	177	0.7100	0.2980	-0.4393	2.0220
LK	180	0.2204	0.1619	0.0746	0.9941
CFK	180	0.0767	0.0115	0.0280	0.1225
UNCER1	180	0.0226	0.0106	0.0073	0.0621
UNCER2	180	0.0260	0.0097	0.0103	0.0776

Note: obs., std. dev., min and max stand out observation, standard deviation, minimum value and maximum value, respectively.

3.2 Estimation

A system GMM (generalized method of moments) method or Arellano-Bover/Blundell-Bond estimator (Arellano and Bover (1995), Blundell and Bond (1998)) is applied to estimate the investment function of Japanese electric power industry and four manufacturing industries. The advantage of the estimator is that it can overcome a well-known structural problem, or an endogeneity problem raised between independent and dependent variables. The system GMM estimator is an extension of the GMM estimator, which was proposed by Arellano and Bond (1991). The former method can improve the weak instruments problem of the latter issue by combining moment conditions of the difference equation with those of the level equation.

As for the instrumental variables of Model (1), this study employs lagged variables from the two-period to the nineteen-period with respect to the lagged dependent variables; $IK_{i,t-1}$ and $IK_{i,t-2}$, Tobin's q variables; $q_{i,t}$ and $(q_{i,t})^2$, cash flow variable, land variable, and uncertainty variable for the level equation. In addition, this study uses the same range of lagged difference variables of the lagged dependent variables; $IK_{i,t-1}$ and $IK_{i,t-2}$, Tobin's q variables; $q_{i,t}$ and $(q_{i,t})^2$, cash flow variable, and constant as instrumental variables for the difference equation.

4. Empirical results

Table 2 describes estimation results regarding investment functions for Japanese four manufacturing industries and electric power industry.

Table 2: Estimation Results of Investment Functions

Industries / Variables	General Machinery		Electric Machinery		Transport Machinery		Precision Machinery		Electricity	
IK(-1)	0.0212		0.1293	***	0.1766	***	0.0040		-0.0151	
	(0.0368)		(0.0346)		(0.0415)		(0.0430)		(0.0423)	
IK(-2)	-0.0287		0.0260		0.0800	**	0.1402	***	0.1109	***
	(0.0241)		(0.0240)		(0.0316)		(0.0492)		(0.0413)	
q	0.0008		0.0038	***	0.0064	***	0.0048	***	-0.1862	***
	(0.0010)		(0.0012)		(0.0018)		(0.0014)		(0.0318)	
q^2	-0.0000		0.0001		0.0006	***	0.0003	***	0.1514	***
	(0.0000)		(0.0001)		(0.0001)		(0.0001)		(0.0182)	
CFK	0.0458		0.0037		0.0193		-0.0030		3.2951	***
	(0.0306)		(0.0072)		(0.0216)		(0.0067)		(0.7484)	
LK	0.0511	***	0.0782	***	0.0270	***	0.0541	***	0.0855	***
	(0.0170)		(0.0178)		(0.0045)		(0.0083)		(0.0196)	
UNCER2	-0.1366		-0.3512	***	-0.4386	***	-0.0456		0.5460	
	(0.1218)		(0.1046)		(0.0932)		(0.0537)		(0.5280)	
Const.	0.0419	*	0.0605	***	0.0814	***	0.0370	***	-0.1600	***
	(0.0249)		(0.0139)		(0.0089)		(0.0120)		(0.0401)	
AR(3) Test	-0.7765		-0.2499		1.3182		-1.5285		-0.1187	
(p-value)	(0.4375)		(0.8027)		(0.1874)		(0.1264)		(0.9055)	
Num. of Obs.	2562		2290		1704		467		177	
Num. of Firms	145		130		97		27		9	

Note: (1) Resutls are obtained from System GMM (one-step, robust).
(2) Results with UNCER1 are omitted.
(3) Values in parentheses are standard deviations.
(4) Superscripts ***, **, and * indicate statistical significance at the level of 1%, 5%, and 10%, respectively.
(5) AR(3) Test means Arellano-Bond test for autocorrelation.

The results indicate that the Tobin's q ratio positively influences the investment, IK, for the manufacturing industries. An exception is the general machinery industry where the estimated parameters of the marginal q are not significant. Meanwhile, the first-order variable of the Tobin's q negatively influences the investment for the electric power industry, but the second-order variable positively influences it. That is, the level of investment decreases when the Tobin's q is under a certain threshold level, but it is changed to increases when the q becomes larger than the level. The threshold level of the Tobin's q is calculated as 0.615, which is slightly smaller than the average level of the q for the nine electric power companies from 1990 to 2009, 0.710.

The results show that the investment behaviors of four machinery industries are mostly consistent with the Tobin's q theory, while for the electric power industry, the behavior is not perfectly explained by the economic theory of investment when the q is less than the threshold value. However, it is consistent when the q is larger than the threshold value.

Here, it is important to note that the investment behaviors in the electric power companies may not be uniform among production stages or divisions such as GEN and TD network. That is, it is acceptable to anticipate that the investment in GEN and that of TD network divisions are different each other in several manners such as decision making on investment timing, volume in the investment, and duration for the construction. Therefore, the estimation on the investment function for each division provides us with further insight for investment analysis on electric power companies.

Table 3 indicates the estimation results for GEN and TD network divisions, respectively[1]. This study introduces deregulation dummy variable, $D2000$. The variable represents impacts of deregulation in retail business on the investment, which began in 2000 for extra large customers and further extended to smaller customers in a step-by-step manner.

The estimation result for generation division is the same with that for the total operation of electric power company described in Table 2. In other words, the coefficient of the first-order variable of the q ratio is negative and that of the second-order variable is positive. Both are statistically significant. The result of TD network division does not produce significant coefficients regarding the Tobin's q ratio, which indicates there is no clear evidence on the relationship between the q ratio and the investment.

Table 3: Estimation Results of Electric Power Industry

Functions	UNCER1				UNCER2			
Variables	Generation		Transmission/ Distribution		Generation		Transmission/ Distribution	
IK(-1)	-0.1385	***	0.1617	*	-0.1329	***	0.1446	
	(0.0186)		(0.0899)		(0.0190)		(0.0930)	
IK(-2)	0.0292		-0.0732		0.0455		-0.0826	
	(0.0495)		(0.0551)		(0.0584)		(0.0533)	
q	-0.3725	***	-0.0263		-0.3702	***	-0.0261	
	(0.0597)		(0.0177)		(0.0475)		(0.0163)	
q^2	0.2682	***	0.0093		0.2979	***	0.0145	
	(0.0290)		(0.0090)		(0.0265)		(0.0092)	
CFK	6.2014	***	0.6706	***	4.9071	***	0.5789	***
	(1.4556)		(0.2190)		(1.3231)		(0.1759)	
LK	0.0149		-0.0016		0.1274		-0.0104	
	(0.0649)		(0.0155)		(0.0882)		(0.0148)	
UNCER	-2.5207	***	-0.2348		-1.4157		0.5348	
	(0.4566)		(0.2321)		(1.2638)		(0.3931)	
D2000	-0.1533	***	-0.0574	***	-0.1140	**	-0.0556	***
	(0.0435)		(0.0155)		(0.0567)		(0.0167)	
UNCER*D2000	4.3956	***	-0.1724		2.4064		-0.1667	
	(1.2385)		(0.4647)		(2.0573)		(0.5106)	
Const.	-0.1622		0.0708	***	-0.1283		0.0594	***
	(0.1068)		(0.0096)		(0.0837)		(0.0131)	
AR(3) Test	0.7235		0.8032		-0.3190		0.4038	
(p-value)	(0.4694)		(0.4219)		(0.7497)		(0.6864)	
Num. of Obs.	177		177		177		177	
Num. of Firms	9		9		9		9	

Note: All notes are the same with Table 2.

[1] There are no previous studies that examined investment behavior of the electric power companies in Japan by estimating the investment functions. A few exceptions are Kinoshita (2006) and Madono, Nakanishi and Nemoto (1992). The former estimated the Tobin's q type investment function of the generation and the transmission/distribution network division, respectively. The results indicate a significant influence of the Tobin's q on the investment of the electric power companies, particularly in the estimation of the generation division.

5. Conclusion

This study examined the investment behavior of Japanese electric power industry and four leading manufacturing industries from the applicability of economic theory on investment. The comparison between electric power industry and manufacturing industries was a major research concern. For the purposes, this study estimated Tobin's q type investment functions for each industry. Furthermore, to examine GEN and TD network division separately, this study estimated the investment function for each division, respectively.

As a result of the estimation, this study has found that the investment behaviors of the four manufacturing industries are mostly consistent with the economic theory of investment, but the electric power industry is not always explained by the theory. As an example of such a difference, the Tobin's marginal q negatively influences investment of the industry until the q reaches a certain threshold value, but it turns out to be positive when the q exceeds the value. The same result was observed in GEN, while we could not find any significant estimation results on the q regarding the TD network.

These results imply that the investment of electric power industry, like the other manufacturing industries, is at least partly explained by the investment theory of the Tobin's q. That is, the investment of the electric power companies can be justified by economic efficiency over a certain range of Tobin's q data. Furthermore, it is important to separately estimate the GEN and the TD network division because characteristics of the investment for the two divisions are presumably different in several points. That is, this study revealed that the investment of TD network division could not be explained by the economic theory. Moreover, the estimation result on generation division is the same with that of the total operation of the industry. These results indicated that the coefficients of the Tobin's q variables were statistically significant, but negative in the first-order variable and positive in the second-order variable. The results indicated the investment increased until the q reached a certain threshold but the effect was reversed after the q became larger than the threshold. The inconsistency with investment theory may be attributed to a discontinuous investment decision making due to the irreversibility in capital investment. Those results imply that it is necessary for us to introduce a model which can deal with discontinuous influence of Tobin's q on the investment, as proposed by Abel and Eberly (1994). Such a direction is our future research agenda.

References

Abel, A.B. (1980) "Empirical Investment Equations: An Integrative Framework," *Carnegie-Rochester Conference Series on Public Policy*, 12, 39-91.

Abel, A.B. and O.J. Blanchard (1986) "The Present Value of Profits and Cyclical Movements in Investment," *Econometrica*, 54(2), 249-273.

Abel, A.B. and J.C. Eberly (1994) "A Unified Model of Investment under Uncertainty," *American Economic Review*, 84(5), 1369-1384.

Arellano, M. and S. Bond (1991) "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies*, 58(2), 277-297.

Arellano, M. and O. Bover (1995) "Another Look at the Instrumental Variable Estimation of

Error-components Models," *Journal of Econometrics*, 68, 29-51.

Averch, H. and L.L. Johnson (1962) "Behavior of the Firm under Regulatory Constraint," *American Economic Review*, 52(5), 1052-1069.

Barnett, S.A. and P. Sakellaris (1998) "Nonlinear Response of Firm Investment to Q: Testing a Model of Convex and Non-convex Adjustment Costs," *Journal of Monetary Economics*, 42, 261-288.

Blundell, R. and S. Bond (1998) "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, 87, 115-143.

Christensen, L.R. and W.H. Greene (1976) "Economies of Scale in U.S. Electric Power Generation," *Journal of Political Economy*, 84(4), 655-676.

Eberly, J.C. (1997) "International Evidence on Investment and Fundamentals," *European Economic Review*, 41, 1055-1078.

Fazzari, S.M., R.G. Hubbard and B.C. Petersen (1988) "Financing Constraints and Corporate Investment," *Brookings Papers on Economic Activity*, 1, 141-195.

Gilsdorf, K. (1994) "Vertical Integration Efficiencies and Electric Utilities: A Cost Complementarity Perspective," *Quarterly Review of Economics and Finance*, 34, 261-282.

Jorgenson, D.W. (1963) "Capital Theory and Investment Behavior," *American Economic Review* 53(2), 247-259.

Kaserman, D.L. and J.W. Mayo (1991) "The Measurement of Vertical Economies and the Efficient Structure of the Electric Utility Industry," *Journal of Industrial Economics*, 39(5), 483-502.

Kinoshita, S. (2006) "Econometric Analysis of the Effect on the Investment of Electricity Firms after the Regulatory Reform in Japan," mimeo (in Japanese).

Madono, S., Y. Nakanishi and J. Nemoto (1992) "Simulation Analysis of Investment Behavior of Japanese Electric Enterprise," *JCER Economic Journal*, 23, 116-127 (in Japanese).

Ogawa, K. and S. Kitasaka (1998) *Asset Market and Business Fluctuations: Econometric Analysis in Modern Japanese Economy*, Nikkei Publishing (in Japanese).

Suzuki, K. (2001) *Investment and Financial Market: Asymmetry of Information and Uncertainty*, University of Tokyo Press (in Japanese).

Takeda, Y. and Y. Yajima (2005) "Investment and Uncertainty: Econometric Analysis based on the Financial Data and Earnings Forecast Data of Listed Companies," *NLI Research Paper*, 36, 15-60 (in Japanese).

Tanaka, K. (2004) "Investment and Uncertainty in Japan: Investment Behavior under Irreversibility Product Market Competition and Capital Market Imperfections," *Economics Today*, 25(2) (in Japanese).

Tawada, M. and S. Katayama (1990) "On the Technical Efficiency under Regulation: A Case for Japanese Electric Industry," *The Economic Studies Quarterly*, 41(1), 34-47.