Analysis on the Factor of Price Volatility in Deregulated Electric Power Market

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Abstract. This paper presents agent-based simulation models of deregulated electricity market in order to investigate the possibility that the electricity price fluctuation is caused by the exercise of market power. Monopoly Market Model and Competitive Market Model are created. These models are based on Boxed Economy Foundation Model (BEFM) as model framework and are simulated on Boxed Economy Simulation Platform (BESP) as simulation platform. The result of these simulations shows two points of contention. First, both models can continue dominating a market and show the exercise of market power in the situation of electricity demanded increasing. Second, the growth of electricity generated often creates an increase in electricity price by the pricing system in Competition Market Model. It could lead to the misinterpretation that electricity generated decreases in market.

1 Introduction and Overview

The purpose of this study is to investigate the possibility that violent price fluctuation is caused by the exercise of market power of suppliers (electricity producers) on Japanese deregulated electricity market.

In these years, deregulated electric power markets have showed the violent price fluctuation and destabilization. Some studies have concluded that the exercise of market power of suppliers has been one of the causes of the violent price fluctuation [1]. In Japan, however, little is known about the influence from the exercise of market power on electricity price. Before the Japanese perfect deregulation of electric utilities in 2007, it is said that there is the need to investigate the relationship between the violent price fluctuation and the market power of suppliers in order to search how to

reduce the electric market instability. To satisfy these requirements, we focus the market power of suppliers (See Section 2).

Agent-based modeling and its simulation approach is employed in this analysis. We used Boxed Economy Foundation Model (BEFM) and Boxed Economy Simulation Platform (BESP) as the framework of agent-based modeling and simulation platform [2,3] (See Section 3).

Two different models are created: Monopoly Market Model and Competitive Market Model. Moreover each model was simulated under two different situations: Demand Stable situation and Demand Increase situation. The four cases were simulated (See Section 4 and Section 5).

The result of these four simulations is the following. Under Demand Stable situation, Monopoly Market Model shows the exercise of market power and Competitive Market Model does not show it clearly. However, under Demand Increase situation, not only Monopoly Market Model but also Competitive Market Model shows the exercise of market power of suppliers (See Section 5 and Section 6).

2 Background

In these years, deregulated electric power markets have showed the violent price fluctuation and destabilization. For instance, in USA, it has been showed that the California market has been one of the major failing examples and PJM market has been viewed as a textbook example (PJM is an abbreviation of Pennsylvania, New Jersey and Maryland) (See Fig.1).

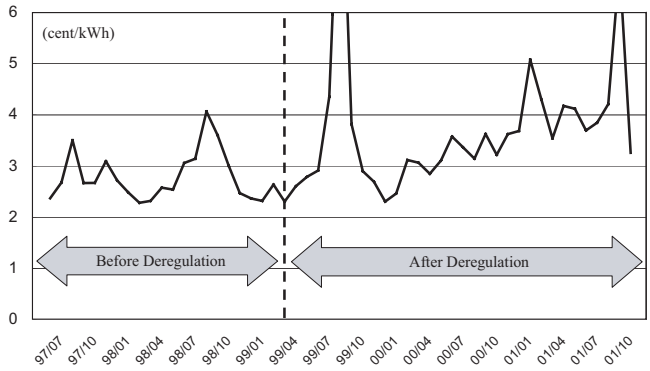

Fig. 1. Change in electric prices on PJM market before and after the deregulation [4]

After California energy crisis, the research of deregulated electric power market becomes very rich. These studies about California energy crisis can show two different standpoints. At First, some studies have concluded that the exercise of market power of suppliers has been one of the causes of the violent price fluctuation [1]. It is said that the market regulatory agency reported the action of the market power of suppliers. At second, on the contrary, the others have countered this conclusion. The

electric power companies insist that they have never exercised the market power. Harvey and Hogan [5] think the cause of the crisis is not only by the market power but also by the design of institutional arrangements. Today it is not settled the argument about the relationship between the price fluctuation and the market power. We should pay attention about the market power as the factor of the market destabilization.

In Japan, most studies state the implementation for design of institutional arrangements, like the reports of Ministry of Economy, Trade and Industry, and the federation of Electric Power Companies of Japan. However, little is known about the influence from the exercise of market power to electricity price, although the market power draws attention as one of the causes of violent price fluctuation.

Japanese deregulation of electric utilities is now proceeding gradually. It started in 1996 and the partial deregulation was carried out in 2000. Furthermore, it is planned that the perfect deregulation is put into execution in 2007. Before the perfect deregulation in 2007, it is said that there is the need to investigate the relationship between the violent price fluctuation and the market power of suppliers in order to search how to reduce the electric market instability.

3 Agent-based simulation platform and model framework: Boxed Economy Simulation Platform (BESP) and Boxed Economy Foundation Model (BEFM)

In designing electricity market models, we accept "Boxed Economy Simulation Platform (BESP)" as agent-based simulation platform and "Boxed Economy Foundation Model (BEFM)" as agent-based modeling framework.

BESP is proposed for simulating and analyzing models [2]. BESP is multi-platform software which is implemented in object-oriented Java language. Since BESP is designed as component-based architecture, the simulation builder can obtain the simulation program which suits his or her needs, only if he/she implements "model components" which have not been implemented yet, and arranges the necessary model components into the platform.

The model component is a software component that implements the model element based on BEFM [3]. BEFM is an abstract of the real society from the viewpoint of economy, and consists of 10 major elements. The main classes are Agent, Behavior, Relation, Goods, and Information. BEFM has defined the relationship to achieve the cooperation of the components, so that it is possible to make the model work even when components were developed independently. This mechanism makes components reuse to a high degree. As a result, we would cut down time and money for model development. Besides it would be possible to exchange parts of model with others. In addition, the simulation builders can make the models in parallel as long as they keep on the same framework, and they can concentrate on the components related to their interesting.

4 Conceptual modeling of electricity market

4.1 Modeling four factors of electric price fluctuation

There are four factors of electric price fluctuation: Transaction Type, Market Power, Transmission Grid Restriction and Uncertainty, as shown in Fig.2.

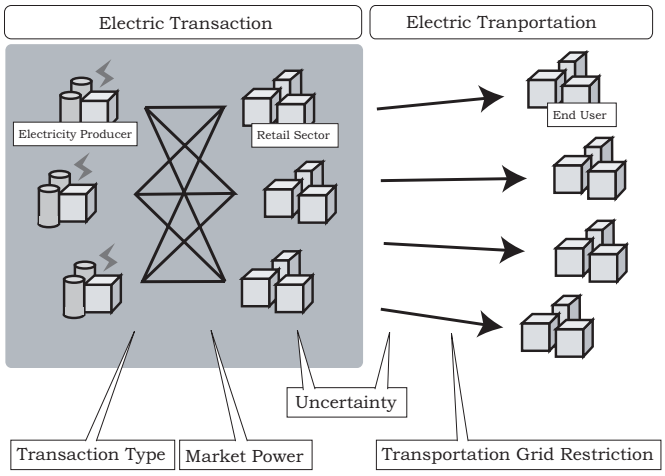

Fig. 2. Gray area is the concern of this study in electricity market with four factors of price fluctuation

1. Transaction Type
There are two main types of transaction in electricity market; Bilateral Transaction and Wholesaling Transaction. In this study, we focus the Bilateral Transaction, because this Transaction becomes mainstream in Japanese deregulated electricity market.
2. Market Power
According to the statement that gargantuan scale suppliers can exercise the market power, we described this factor by the supplier scale and the number of supplier. It is the main topic on this study.
3. Transmission Grid Restriction
It is the risk that heavy electric traffic incurs traffic cost on the transmission grid. We are not concerned here with it, because we would not like to examine the price fluctuation of the traffic risk but the interaction between suppliers and demanders.
4. Uncertainty
Demand predicament is most of the uncertainty causes the price fluctuation. We described the uncertainty as the demand predicament situation that energy demanded rises up.

4.2 Four simulations – Two models and Two situations

In this study, there are two models: Monopoly Market Model and Competitive Market Model, each composed of Agent, Relation, Behavior, Goods and Information. These models have two Agent Types: the electric power producer, which sells electricity to demander at supply side, and the retail sector, which buys electricity for selling end user at demand side (See Fig.3). Both suppliers and demanders have Behaviors and Information for trading electricity.

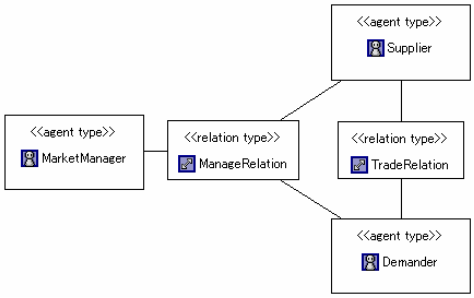

Fig. 3. Three Agent Types and two Relation Type in Electricity Market Model. Market Manager manages Supplier on Manage Relation. Supplier and Demander try to trade electricity on Trade Relation.

Monopoly Market Model consists of only one supplier and 300 demanders. It is modeled as the condition before the deregulation of electric utilities. Competitive Market Model consists of some suppliers and 300 demanders. It is modeled as the condition after the perfect deregulation.

Table 1. Four simulations of this study

	Demand Stable situation	Demand Increase situation
Monopoly Market Model	Case1: One supplier and 300 demanders	Case2: One supplier and 300 demanders
Competitive Market Model	Case3: 6 supplier and 300 demanders	Case4: 6 supplier and 300 demanders

The transaction type of these models is Bilateral Transaction that the suppliers and demanders trade electricity by individual bargaining. It seems to become mainstream in Japanese deregulated power market.

The price determination by the suppliers consists of mark-up ratio and marginal cost. The suppliers determine the proposed price for each demander by using mark-up ratio and marginal cost information. The demander receives the proposal from suppliers to choose acceptance, rejection or reservation. If the demander chooses rejection, there is the chance that the demander receives the better proposal from another supplier.

Each model was simulated under two different situations: Demand Stable situation and Demand Increase situation. Demand Stable situation is that the energy demanded

does not fluctuate rapidly but keeps stability. It is the present situation at Japanese electricity market. Demand Increase situation is that the energy demanded can fluctuate. It is the future situation that Japanese electricity market is deregulated perfectly and yardstick regulation is abolished. Total four cases were simulated in this study (See Table.1).

4.3 Comparison of our models and other existing models

Agent-based modeling and its simulation approach study has increased where it deals with the multiplicity of market participant. However, little is seen about modeling Bilateral Transaction between suppliers and demanders clearly. Models of this study consist of these elements.

Central Research Institute of Electric Power Industry (CRIEPI) is the most major institute by researching electric power market in Japan. CRIEPI has two kinds of models on the market mechanism of auction and the transmission grid restriction. By contrary, little is shown that the model focuses the negotiation between suppliers and demanders in CRIEPI.

Some studies investigate the comparison of pool and bilateral market mechanisms in England and Wales by using agent-based simulation [6,7]. They state the risk that empowering the market power of suppliers is caused by changing market mechanism. However, their model does not show the market mechanism clearly.

5 Modeling simulation of Monopoly and Competitive market

5.1 The simulation flow of both two models

Both two models consist of two kinds of agents. They are the supplier agents (electric producers) and the demander agents (retail sectors). Moreover, the market manager agent, manages each phase of simulation, is involved in these models (See Fig.3).

The supplier agent is the electric producer that generates and sells electricity to the demander agents. It calculates the priorities of each demander by the past consumption data and the success rate of contracts. And then it calls on each supplier in the order of descending the priorities. After calling on, it proposes the electric price by the mark-up ratio based on the priority and the marginal cost to the demander.

The demander agent is the retail sector that purchases electricity from the suppliers in order to meet the needs of the end users are its customers. After receiving the proposal, the demander agent chooses one from acceptance (contract), rejection and reservation. If the acceptance is chosen, the demander and the supplier would transact electricity with the proposed price. If the rejection is chosen, they would not transact. If the reservation is chosen, the demander would reserve the proposal for a certain period. After a certain period of time, the demander accepts the reserved proposal only through not receiving the better proposal.

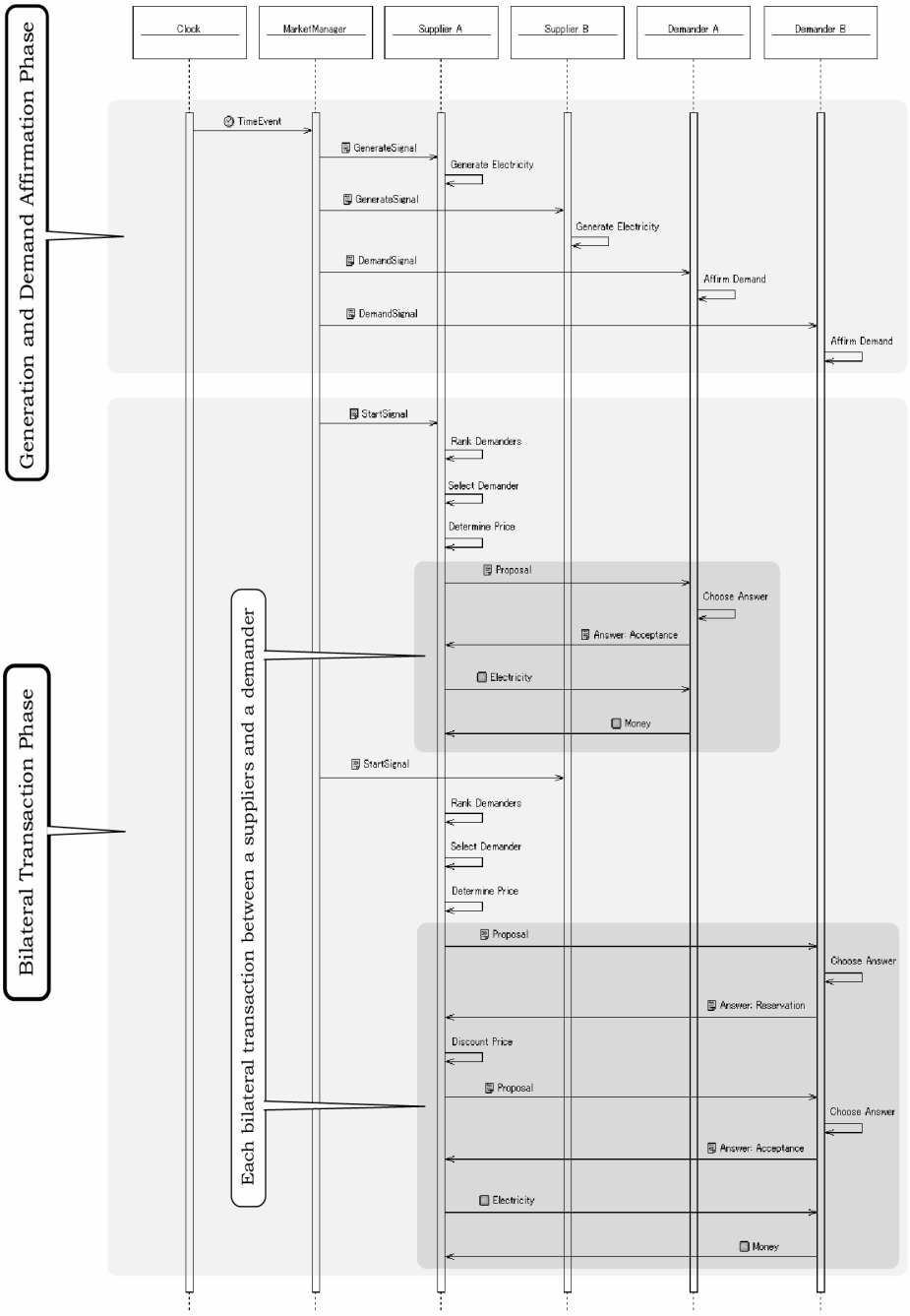

Fig. 4. Communication between suppliers and demanders

These simulations can divide two phases; the generation and demand affirmation phase and the bilateral transaction phase (See Fig.4). These simulations are run by repeating each phase one after the other. In the generation and demand affirmation phase, the suppliers generate sufficient electricity to meet demand and the demanders affirm the demand of end users (the amount is assigned as exogenous variable). And then, in the bilateral transaction phase, each supplier calls and proposes the electricity price to the demander individually and the demander decides to accept the proposal. This phase is continued until all the demanders can meet the needs of the end users. We count one step of the simulations by finishing these two phases.

5.1 Monopoly Market Model simulation: Case 1 and Case 2

Monopoly Market Model consists of only one supplier agent and 300 demander agents. This model describes the current Japanese condition that each big supplier has regional monopoly situation. In the model the supplier can manipulate the electricity price, since all the demander cannot help trading the only one supplier. We construct and simulate this model as the comparison of the Competitive Market Model.

The following Tables are the mark-up ratio and the marginal cost of supplier (See Table.2 and Table.3). The supplier determines the proposed price by these two valuables.

Table 2. Marginal cost of the big supplier in Monopoly Market Model

	Electricity Generated (kW)	Marginal Cost (Yen)
Nuclear	26.4 million	6.0
Coal	3.6 million	6.5
LNG	21.6 million	6.5
Oil	6.0 million	10.0
Hydroelectricity	2.4 million	14.0

Table 3. Mark-up ratio of the big supplier in Monopoly Market Model

	Mark-up ratio (%)	
Priority	Demand Stable situation	Demand Increase situation
A	0.50	0.80
B	0.80	1.10
C	1.10	1.40
D	1.40	1.70
E	1.70	2.00
F	2.00	2.30

$$\text{Proposed Price} = \text{Marginal Cost} / (1.0 - \text{Mark-up ratio}) \quad (1)$$

This model is simulated under Demand Stable situation and Demand Increase situation. The Demand Stable situation is that the demanders do not change their

energy demanded. The Demand Increase situation is, by contrast, that the energy demanded increases step by step.

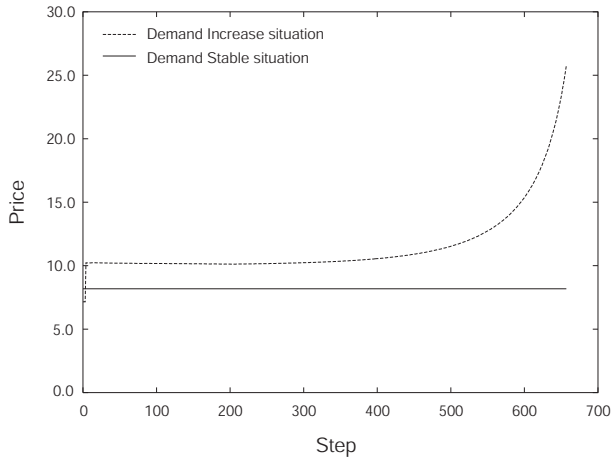

Fig. 5. Price Movements on Monopoly Market Model in Demand Stable situation and Demand Increase Situation

The result of the Demand Stable simulation shows that the electricity price becomes certain (See Fig.5). The current electric producer determines the price to secure enough profits, since they accept multiple costing. For this reason, the price does not show violent fluctuation although they create a monopoly. However, it is thought that the electricity price goes down by the competitive technology such as distributed generation. In this simulation the price does not goes down, since this model does not involve any technology factor.

The result of Demand Increase simulation shows that the price rises up by continuing demand predicament (See Fig.5). Moreover, it shows the time lag from the amount demanded rising to the price rising, unlike in the case of the pool market in which the price rises up in a moment by increasing the amount demanded. It is concluded that the supplier can exercise of the market power under the situation of monopoly and demand increase.

5.2 Competitive Market Model simulation: Case 3 and Case 4

Competitive Market Model consists of 6 supplier agents and 300 demander agents. Compared with Monopoly Market Model, the five suppliers are added to this model as new entrants under the deregulation of electric utilities. It describes the Japanese future condition that new entrants come to the electricity market in 2007. In this model the suppliers cannot manipulate the electricity price, unlike in case of Monopoly Market Model.

In this model, the demanders have a valid criterion in choosing the suppliers. The criterion consists of the price and the quality. This model makes the demanders to choose the suppliers by the price and the quality is that the questionnaire conducted

by CRIEPI shows the demanders give priority to these two elements in both Japan and USA (See Fig.6).

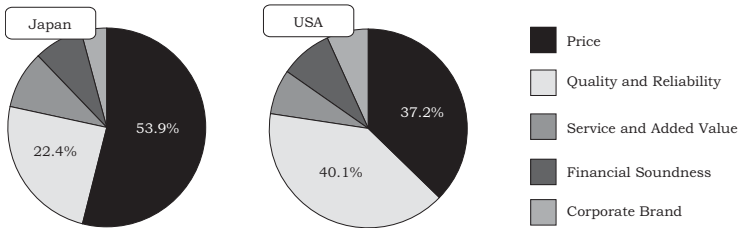

Fig. 6. Questionnaire about the valid criterion of demanders in choosing suppliers

One of the suppliers is the existing major producer and the others are the new entrants. The major producer has the same mark-up ratio and marginal cost as Monopoly Market Model. The following Tables are with the parameters of the five new entrants (See Table.4).

These parameters are based on the following statements. It is stated that the most remarkable features of the new entrants is few electricity generated and lower mark-up ratio. In the present Japanese market, the share of the new entrants is about 1.5 percent (120,000 kW) and it seems to become 4,580,000 kW in 2010. For the reason stated above, these five agents increase their electricity generated as simulation advances in this model. Furthermore, the new entrants win the trading contract with competing with the existing major producer, since they hold down their mark-up ratio and marginal cost. Therefore, we reflect this condition in these parameters.

Table 4. Marginal cost and Mark-up ratio of the new five entrants in Competitive Market Model

	Electricity Generated (kW)	Marginal Cost (Yen)	Mark-up ratio (%)			Quality
			Priority	Demand Stable	Demand Increase	
New Entrant A	0.8 million	8.19	A	0.45	0.85	7
			B	0.70	1.08	
			C	1.00	1.40	
			D	1.30	1.70	
			E	1.60	2.00	
			F	1.90	2.30	
New Entrant B	0.5 million	8.00	A	0.40	0.90	6
			B	0.60	1.10	
			C	0.90	1.40	
			D	1.20	1.70	
			E	1.50	2.00	
			F	1.80	2.30	

New Entrant C	0.3 million	8.00	A	0.40	0.95	4
			B	0.60	1.15	
			C	0.90	1.45	
			D	1.20	1.75	
			E	1.50	2.05	
			F	1.80	2.35	
New Entrant D	0.2 million	7.50	A	0.25	0.85	3
			B	0.45	1.05	
			C	0.75	1.35	
			D	1.05	1.65	
			E	1.35	1.95	
			F	1.65	2.25	
New Entrant F	0.2 million	8.19	A	0.50	1.10	2
			B	0.80	1.40	
			C	1.10	1.70	
			D	1.40	2.00	
			E	1.70	2.30	
			F	2.00	2.60	

This model is also simulated under Demand Stable situation and Demand Increase situation, like Monopoly Market Model.

The result of the Demand Stable simulation shows that entering new entrants and their electricity generated increasing fall in price, compared with Monopoly Market Model (See Fig.7). However, the average price rises up at 100th and 200th step, since the new five entrants increase their electricity generated. They improve their share and supply the surplus of electricity to the demanders which receive lower priority than the earlier demanders. And then they propose the higher price to the later demanders than before.

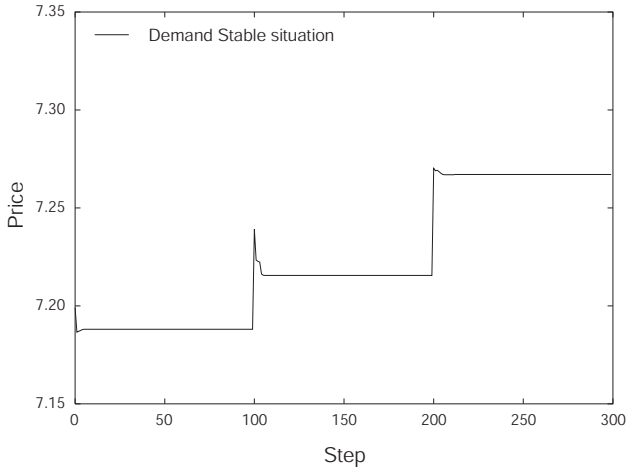

Fig. 7. Price Movements on Competitive Market Model in Demand Stable situation

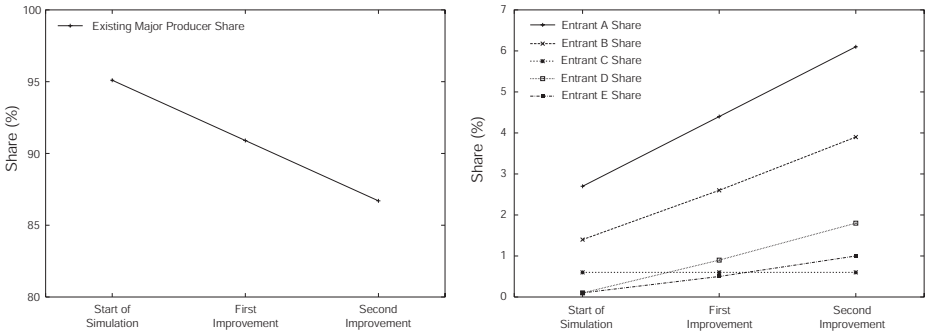

Fig. 8. Share of suppliers at simulation start, first and second improvement of electricity generated by five new entrants in Demand Stable situation

The result of Demand Increase simulation shows that the price rises less sharply than Competitive Market Model in the same situation (See Fig.9). It is difficult for the suppliers to exercise the market power, because of entering the five new entrants.

At the beginning of this simulation, the existing major producer keeps about 94% of the market share. Between 100th step and 200th step, its share increases and keeps 97% although it does not improve its electricity generated (See Fig.10). The new entrants improve less their electricity generated than the increasing amount of demand. Between 200th step and 300th step, the share of the existing major producer decreases and keeps 95%. The electricity generated of the new entrants overtakes demand and they begin to eat away at the share.

It is concluded that the existing big produce can continue dominating a market and exercise the market power until the new entrants overtake demand increasing in Demand Increase situation.

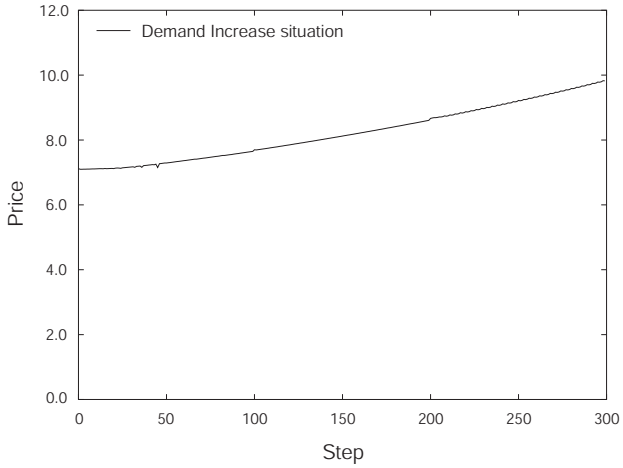

Fig. 9. Price Movements on Competitive Market Model in Demand Increase situation

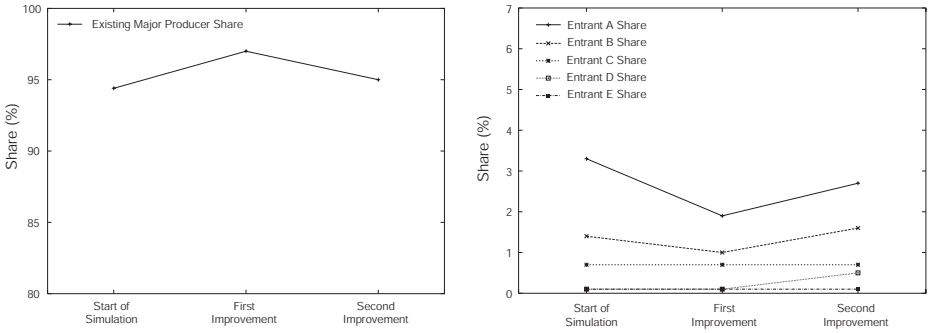

Fig. 10. Share of suppliers at simulation start, first and second improvement of electricity generated by five new entrants in Demand Increase situation

6 Conclusion

In the proceeding argument we have summarized the importance of focusing the exercise of the market power in order to investigate the price fluctuation deregulated electricity market. The deregulated markets show the price fluctuation in California and PJM. It is thought that such fluctuation is caused by the exercise of the market power. However, little is known about the influence from the market power on electricity price in Japan. There is the need to investigate the relationship between the fluctuation and the market power in order to search how to reduce the electric market instability.

To satisfy this requirement, agent-based modeling and its simulation approach was employed in this analysis. We accept Boxed Economy Foundation Model (BEFM) as the modeling framework and Boxed Economy Simulation Platform (BESP) as simulation platform.

In concluding, we should note the two points of contention: the exercise of the market power and the relationship between electricity price and electricity generated.

First, both Monopoly Market Model and Competitive Market Model show that the suppliers can exercise the market power in Demand Increase situation. In particular Competitive Market Model, the existing big producer can continue dominating a market and exercise the market power until the new entrants overtake demand increasing. In Demand Stable situation, Competitive Market Model shows that it is difficult for the suppliers to exercise the market power by entering the new entrants.

Second, it was found the possibility that the growth of electricity generated creates an increase in electricity price by the pricing system, which determines electricity price by mark-up ratio and marginal cost, in Competitive Market Model. The new entrants improve their electricity generated and supply the surplus of electricity to the demanders who receive lower priority than the earlier demanders. And then the new entrants propose the higher price to the later demander than before. It could lead to the misinterpretation that electricity generated decreases in market.

7 Acknowledgements

We wish to thank Yuu Yamada, Keio University, for his encouragement and guidance throughout this research. However, any mistakes that remain are our own. This article is based on the master's thesis of the second author [8].

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