IERCU

Institute of Economic Research, Chuo University

Discussion Paper No.192

Structural Changes of the Electricity Market in Japan: A Theoretical Perspective of Consumers' Eco-friendly Behaviour

Kimihito ISE
Japan Electric Power Information Centre, Inc.
&
Masahiro YABUTA
Faculty of Economics, Chuo University

September 2012

IERCU Discussion Paper

INSTITUTE OF ECONOMIC RESEARCH
Chuo University
Tokyo, Japan

Structural Changes of the Electricity Market in Japan: Theoretical Perspectives of Consumers' Eco-friendly Behaviour

Kimihito ISE*
Research Director
Japan Electric Power Information Center, Inc.
15-33, Shibaura, 4-chome, Minato-ku, Tokyo, 108-0023, Japan
E-mail: ise-kimihito@jepic.or.jp

Masahiro YABUTA*
Faculty of Economics
Chuo University
742-1 Higashinakano, Hachioji, Tokyo, 192-0393, Japan
E-mail:yabuta@tamacc.chuo-u.ac.jp

ABSTRACT

After the Fukushima-Daiichi accident of atomic power stations in 2011, drastic changes of the electricity market in Japan have occurred; a tendency towards promoting renewable energies such as solar power and wind power, and a structural change of the electricity market from regional monopoly to competition. As far as a market structure is concerned, not only its structural change towards competitiveness but also the energy development towards renewable power sources which consumers can choose to follow their choice behaviour are important. This paper analyses the welfare aspects of the structural changes of electricity market in Japan, mainly from theoretical viewpoints. Modelling the changing pattern of Japanese electricity market consists of three dimensions; firstly, the Beltrand competitive market where consumers freely choose a traditional thermal power or a renewable power. Secondly, markets where consumers can partially choose a power source due to a green-energy program. Thirdly, a regional monopolistic market where a regional monopoly such as Tokyo Electric Power Company (TEPCO) provides electricity and consumers has no choice among energy-sources. Actually, the development pattern of the Japanese electricity market has moved from the third and will change to the first. For each dimension, the vertical differentiation models are applied in which consumers' environmentally friendly behaviour expresses their willingness to pay for the renewable-energy sources. Major concern of the paper is consumers' welfare aspects corresponding to the development pattern of electricity market in Japan.

Key words: Product differentiation, Electricity market, Renewable resources, Consumers' Eco-friendly behaviour
Category & Number: 10
JEL Classification Code: L15; L94; Q20;

* The views and opinions expressed here are their own, and not those of other people, institutions with which they are affiliated.

1. Introduction

This paper analyses the consumers' welfare aspects when they choose energy sources in the electricity market in Japan. After the Fukushima-Daiichi accident of atomic power stations in 2011, drastic changes of the electricity market in Japan have occurred; a tendency towards promoting renewable energies such as solar power and wind power, and a structural change of the electricity market from regional monopoly to competition. As far as a market structure is concerned, not only its structural change towards competitiveness but also the energy development towards renewable power sources which consumers can choose to follow their choice behaviour are important. This paper examines the effects of the structural changes of electricity market in Japan on the prices, the share of various power sources, and consumers' welfare, mainly from theoretical viewpoints. Currently, a regional monopoly such as TEPCO has occupied the integrated system of power generation and transmission in Japan. Hence, whereas TEPCO can choose its desirable power source as a mix of hydro, thermal, nuclear and renewable power, its consumers can neither help using the electricity of mixed power source provided by TEPCO without choosing a power source among the mixed sources. From a perspective of eco-friendly consumers' behaviour, for example, it is important whether what they consume is generated by eco-friendly, renewable-energy source or not. Debates of the electricity market reform in Japan have occurred with respect to the consumers' possibility to choose the green energy or traditional fossil energy, which inevitably leads to a reform of the market structure and its drastic change in the near future. Accordingly, major concern of the paper is the welfare aspects of consumers corresponding to the development pattern of electricity market in Japan.

Modelling the changing pattern of the Japanese electricity market includes three dimensions; firstly, a competitive market where consumers freely choose a traditional thermal power or a renewable power. Secondly, a market where consumers can partially choose power source thanks to a green-energy program. Thirdly, consumers have no choice between mixed energy-sources which a regional monopoly such as Tokyo Electric Power Company (TEPCO) provides, at present situation. Actually, the development pattern of the Japanese electricity market has moved from the third and will change to the first. For each dimension, a vertical differentiation model is applied in which consumers' environmentally-friendly behaviour expresses their willingness to pay for the renewable-energy sources and some policy measures are incorporated. In these dimensions, the paper analyses how the above-mentioned changes affect the electricity market, power source share, consumer surplus and environmental damage. In our analysis, we firstly evaluate the equilibrium in a competitive electricity market where consumers can freely choose a power source. After that, we compare the competitive equilibrium and the equilibrium that various regulatory frameworks bring. In this connection, regulatory measures of electricity market such as feed-in tariff, renewable portfolio standards and green electricity program are investigated. To simplify the model analysis of the development pattern of market structure, a model of product differentiation where electricity consumers have a different willingness to pay is employed.

The composition of the paper is as follows: **Section 2** gives a brief history of the recent development of Japanese electricity market, in particular, focusing on changes of its supply structure and power-source components. Development process of Japanese electricity markets can be classified into three dimensions from a schematic view: a monopoly in which green consumers have no choices among power sources, a semi-competition between the duopolistic firms with different power sources such as fossil-energy and solar-energy, and a competition between firms in which green consumers can choose a green power source regarding their willingness to pay for the green. **Section 3** reviews preceding works about the vertical differentiation of the products, mainly from the theoretical perspectives. Shaked and Sutton (1982) and Moorthy (1988), for example, developed a game theoretic vertical differentiation model to examine firm's strategic behavior of decision making concerning its product's quality. More recently, Cremar & Thisse (1999), Ripiinen (2005), Andre et al. (2009), Toshimitu (2010) and Lanbertini & Tampieri (2011) analyzed vertical differentiation models to examine the characteristics of the equilibrium in Cournot or Bertrand competition, and investigated the effectiveness of tax or subsidy to improve the social welfare. Assumptions of the heterogeneity of consumers' choice between high (green) and low (brown) production technology (or products) led to various conclusions depending upon both the market condition and the consumers' choice behavior. Applying their theoretical aspects of vertical differentiation, duopolistic competition and consumers' green choice to the development process of Japanese electricity market, **Section 4** examines how changes of the institutional design of the electricity market in Japan lead to the different outcomes concerning the social welfare. In this connection, the policy implications of promoting renewable power sources in the Japanese electricity market will be investigated. Finally, in **Section 5** summarizes the conclusions and further remarks.

2. Electricity Market in Japan

After the World War II, ten privately-owned electric power companies including Okinawa Electric Power have established. Currently, they are in charge of regional power supply services and are responsible for generating electricity and distributing it to the consumers in their respective service area allocated by the government policy. While the regional monopoly has been maintained, the electric power market in Japan itself has been slightly liberalized when the independent power producers (IPPs) were allowed to participate in the electricity wholesale electricity market in 1995. Then, the transmission/ distribution network owned by the electric power companies became open access in March 2000, and the retail market was partially liberalized to allow power producers and suppliers (PPSs) to sell electricity to extra-high voltage users requiring more than 2MW. The scope of liberalization was expanded in April 2004 to users requiring more than 500kW, and subsequently in April 2005 to users requiring more than 50kW. Accordingly, by 2011, the scope of liberalization covers approximately 60% of total electricity demand in Japan. In spite of such liberalization, the actual share of power generation by newcomers was only less than 1% in 2010.

Along with the effort for making the market competitive, Japanese government has also introduced measures to increase use of renewable energies in the electricity sector. From April of 2003 to the end of June of 2012, a Renewable Portfolio Standard (RPS) policy had been implemented, which mandated the electricity retailers to use renewable energies of a certain percentage of their power source. In addition, an excess electricity purchasing scheme, that is so called the Feed-in Tariff (FIT), was introduced in November 2009. Under the scheme of the FIT, the electric power companies purchase the surplus energy at a fixed price that photovoltaic power (PV) generators do not use themselves. Since July 2012, electric power companies are obliged to purchase all power generated by facilities using renewable energy sources such as photovoltaic, small- and medium-scale hydroelectric, wind, geothermal, and biomass except the residential photovoltaic power generation systems at fixed prices during a period determined by the government. Currently, as for PV, the tariff is 42 yen and the duration is 20 years. As for the residential photovoltaic power generation systems, the excess electricity is being purchased by electric power companies. In this connection, RPS was discontinued when the FIT was introduced in 2009.

In addition to various regulatory measures, electric power companies and other entities have voluntarily launched some incentive measures to encourage consumers to use more eco-friendly energy such as a green electricity fund and a carbon-offset. For example, an electricity consumer donates 500yen per month to an electric power company, and it contributes same amounts in order to promote eco-friendly activities such as environmental education at public schools and constructing power stations sourced by renewable energies. At the end of FY2009, the fund has facilitated around 1% of the total photovoltaic power generation capacity (24MW compared to 2,627 MW). However, electric power companies have closed the fund system after the FIT was introduced.

Despite the above-mentioned efforts, the share of electricity production from renewable sources including hydro was only about10% in 2010. After the Fukushima-Daiichi accident of atomic power stations in 2011, some advisory bodies to the Japanese government have started discussing an energy plan, and through discussions, the government proposed an energy plan with three scenarios for 2030 to the public, and by reflecting the opinions, is trying to formulate a new energy policy by 2012. Each scenario envisages increasing the ratio of renewable energies to around 25 to 35%. Moreover, the governmental committees are now discussing the electric power system reform, including a fully opened retail electricity market and a system in which consumers can choose a producer who uses the eco-friendly renewable energies based on their environment-oriented tastes. The conclusion will be drawn by the end of 2012. In short, the Japanese electricity market is heading to liberalization, in which the possibility of consumers' choice for green power will be guaranteed and the use of renewable power sources by generators will be accelerated.

3. A Review

As already mentioned, this paper is concerned about the structure of the Japanese electricity market, which is determined by competitive situations among firms to produce electricity and consumers' choice behaviour among power sources. To identify the market structure in which firms produce a different quality of goods or use a different technology, there are two types of the differentiation model; the horizontal differentiation model and the vertical differentiation model (Lancaster (1979)). Take an example when a consumer purchases a car. Cars have many different attributes such as design, performance and safety, which are not related to the difference in the relative merits of the products. Even if the price of cars is the same, consumers may choose a different car because its design is different. Then, the different attributes (design) of consumption goods have different consumer, leading to the case of a horizontal differentiation[1].

On the other hand, in the vertical differentiation model, all consumers make the same choice if products were provided in the same price. If there is no difference in the product information that consumers receive, it will be an endpoint solution. Then, assume that only an environmental attribute is different for cars and there are clear differences in merits or demerits of the products; a green product and a brown product. In front of the products with the same price, consumers may always choose a green product because of the environmental superiority. Then, the products are vertically differentiated. However, if the price of a brown product is lower than the green product due to a low production cost, some consumers may choose the brown product. In the vertical differentiation model, the differences in the merits of products such as the environment will lead to a different pattern of consumers' choice. In this case, a (green) consumer chooses an eco-friendly car even if its price is high, but a (brown) consumer purchases a not eco-friendly car because its price is lower than green car. Shaked and Sutton (1982) and Moorthy (1988), for example, developed a game theoretic vertical differentiation model to examine firm's strategic behavior of decision making concerning its product's quality. More recently, Cremar & Thisse (1999), Ripiinen (2005), Andre et al. (2009), Toshimitu (2010) and Lanbertini & Tampieri (2011) analyzed vertical differentiation models to examine the characteristics of the equilibrium in Cournot or Bertrand competition, and investigated the effectiveness of tax or subsidy to improve the social welfare. Assumptions of the heterogeneity of consumers' choice between high (green) and low (brown) production technology (or products) led to various conclusions depending upon both the market condition and the consumers' choice behavior.

Shaked and Sutton (1982) and Moorthy (1988) investigated the firms' strategy concerning a quality decision of the products using the two-stage game framework. It is investigated that in the

[1]A pioneering research of horizontal differentiation is Hotelling (1929).

full market coverage, where the products are provided to all consumers, a Cournot competition may lead to non-existence of equilibrium (Motta (1993)). In the vertical differentiation model, many studies assumed the Bertrand competition between firms and the full market coverage. André et al. (2009) showed that a Bertrand competition between duopolies, when a lump-sum tax was imposed on the brown technology, would make both firms employ the green technology. Lanbertini and Tampieri (2012) extended the André's analysis so as to include a Cournot competition with a restriction of production scale. Accordingly, the market structure such as Bertrand competition, the policy measures to affect the equilibrium are important in the vertical differentiation models. Moreover, Cremer et al. (2003), Lombardini-Riipinen (2005) and Bansal (2008) investigated the vertical differentiation models to examine the environmental policies including tax and subsidy in the presence of green consumers.

Table 1 shows a stream of the recent arguments about the application of the vertical differentiation models to various aspects including the products' coverage in the market, the competition among firms and policy measures to attain the social optimality. Applying their theoretical aspects of the vertical differentiation, duopolistic competition and consumers' green choice to the development process of Japanese electricity market, this paper examines the institutional design of the electricity market in Japan and analyzes the different outcomes concerning the social welfare.

Table 1 A stream of the recent studies on the vertical differentiation analysis

Authors \ Classification	Coverage Full Partial	Competition Bertrand Cournot	Policy Regulation Tax Subsidy	Notes
Shaked and Sutton (1982)	Partial	Bertrand	-	Assuming two firms and the non-existence of production cost, it is proven that the firms will choose distinct products' qualities, and that both will enjoy a positive profit at the equilibrium. The intuitive idea behind this result is that, as their qualities become closer and closer, the price competition between two firms will reduce the profit of both firms.
Motta (1993)	Partial	Bertrand Cournot	-	The author analyses two types of models of vertical differentiation in order to study the influence of price and quantity competition in the Nash equilibrium solution. The author shows that an optimal product differentiation is higher in Bertrand competition rather than in Cournot, because the competition will be fiercer in Bertrand than in Cournot without differentiation.
Cremer and Thisse (1994)	Partial	Bertrand	Tax	Following a specification introduced by Mussa and Rosen (1978), they show that a uniform ad valorem tax, where the same rate applies to all variants of the product, lowers both equilibrium qualities, distorts the allocation of consumers between firms, and lowers the consumer prices of both variants. A small uniform tax is always welfare improving over the non-tax equilibrium.
Lombardini-Riipinen (2005)	Full	Bertrand	Tax, Subsidy	Using the similar theoretical model as Cremer and Thisse (1994) has developed, it examined the effectiveness of the emission tax, ad valorem tax and subsidy for eco-friendly consumers. Unlike Cremer and Thisse (1994), it incorporated the environmental externalities in the analysis. Its main conclusion is that the combination of a uniform ad valorem tax and an emission tax can lead to the social optimum. It also showed that the same result is obtained by coupling a uniform ad valorem tax and a subsidy to consumers who choose the green products.
Bansal (2008)	Partial	Bertrand	Tax, Subsidy	Using the approach similar to Lombardini-Riipinen (2005) and assuming a more general variable cost function, it analyzed effects of ad valorem taxes/subsidies and emission taxes on firms. It showed that the optimal policy shifts from ad valorem taxes to an ad valorem subsidy as the magnitude of the damage parameter associated with the environmental externality increases.
André *et al*.(2009)	Partial	Bertrand	Tax	In the similar theoretical framework as of Shaked and Sutton (1982), it extended the model to treat the environmental quality as a discrete variable rather than a continuous one. Then, it supported the Porter Hypothesis in a vertically differentiated duopoly model with Bertrand competition, where firms choose to adopt the green standard under the regulation policy that a lump-sum tax is levied on the brown technology.
Toshimitsu (2010)	Partial	Cournot	Subsidy	The author considered the effects of the environmental subsidy on the outside market, i.e., a market with implicit alternatives for consumers (a bicycle, always green goods, outside the car market both with eco-friendly cars and not). From this idea, it obtained the unique result that the subsidy for clean cars degrades the environment.
Lambertini and Tampieri (2011)	Partial	Cournot	-	The authors extended the analysis carried out by André et al.(2009), assuming Cournot competition between firms. The background of their idea is that several car manufacturers are massively investing in R&D, without the taxation on brown technologies. They indicated that a sufficiently low asymmetry in costs drives firms to the green outcome without regulations.

4. Model Analysis

4.1 Features of the Model

Considering a historical background of the Japanese electricity market in Section 2, this chapter examines how to enhance the effective expansion of renewable energies, mainly from the theoretical perspectives. The feature of the model utilized here is that it reflects the consumers' various willingness to pay for power sources, taking both the cost structure of the producers and the market structure in the Bertrand competition into consideration. The purpose of this chapter is to construct the model framework with consumers' choice behaviour in order to show how the price and the share of the power sources are determined at the equilibrium, and to analyse what factors affect the social welfare. While the electricity cannot be physically differentiated, the model assumed that consumers have a different willingness to pay for every different power sources for generating electricity generation such as renewable energy or fossil fuel energy. Hence, the model developed here features the Bertrand-competition between the thermal power firm and the solar power firm.

4.2 Structure of the Model

As preceding works reviewed in section 3 show, the differences of production methods in terms of the environmental aspects such as CO_2 emission will affect the consumers' choice behaviour through some sort of process (Bansal (2008), Eriksson (2004), Yabuta and Scott (2010)). The reason why the eco-friendly goods affect the consumption pattern of consumers is because consumers take the environmental attributes into consideration when they purchase and use them. Among various factors affecting the consumer behaviour, the idea of 'altruism' must be important. An improvement of the environment that a consumer contributes by purchasing and by using products can enhance the individual utility of a consumer. This is partly because the consumer can enjoy a good environment, and partly because he/she can enjoy a kind of reputation from others that he/she has contributed to the environment (Andreoni (1989), Cornes and Sandler (1994), and Kotchen (2005, 2007)). We introduced an altruism factor into the model which affects consumers' choice behaviour.

Assume that a thermal power firm (i=1) and a solar power firm (i=2) compete in the electricity market. There is so much difference in cost functions of both firms. The typical thermal power firm represents economies of scale where the large facilities are needed to supply enough amounts of services. The generating capacity is 750 MW-1,350 MW in average[2]. The average cost of production is 10-11 yen/ kWh[3]. In contrast, the generating capacity per site of solar power facilities is much smaller. The average generating capacity of mega solar plants to which the Feed-in Tariff is applied, as of end of July 2012, is around 3MW[4]. The average generation cost is about 30-46 yen/ kWh[5]. In this situation, it is clear that the electricity company utilizes only a thermal generation as a supply source. However, the reason why solar power facilities are actually generating electricity could be that there are some policy supports to solar power firms, or there are consumers who highly appreciate the environmental attributes of the solar power.

4.2.1 Supply of Electricity

With respect to the environmental attribute of each firm, e_i denotes efforts on environment, and $e_1 > e_2$ is assumed. Here the opportunity cost, c, of the solar power firm is assumed to be larger than g, the thermal power firm's opportunity cost[6]. The total amounts of generation are normalized to 1. Then the profit of each firm is given by

(1) $\pi_1 = x(p_1 - (1 - s)(c + e_1)),$

(2) $\pi_2 = y(p_2 - (g + e_2))$

where x is the generation share of solar power firm, y (= 1 - x) is the generation share of thermal power firm, p_i is the price paid by consumers, and s is a subsidy rate.

4.2.2 Consumption of Electricity

---

[2]The average generating capacity is calculated based on LNG and coal power plants that started to operate in recent seven years (The Energy and Environment Council (2011))
[3]The cost is calculated based on the model plant of coal and LNG as of 2010 of which capacity utilization rate is 50-80% (The Energy and Environment Council (2011).
[4]Calculation was done based on the data downloaded from Agency for Natural Resources and Energy HP.
[5]The figures were calculated based on the model plant of 1.2MW as of 2010 (Cost Review Committee HP)
[6]It is also assumed that $(1-s)\,c > g$, meaning that the average cost of the solar power firm is actually greater than the thermal power firm to generate 1kw of electricity. The reality is that a solar power firm changes its capacity utilization to adjust the production, while a thermal power firm adjusts the production by changing its quantities of fuel input. This is the reason why the costs (c, e_1) of solar power firm are assumed to be larger than those of the thermal power firm.

At least, from the consumers' viewpoints, there is no difference in the electricity power generated. The difference in consumers' choice behaviour mainly comes from the difference in power sources that each power firm utilizes. It must be important for the consumers whether the power source is the eco-friendly solar or the not-eco-friendly thermal, the latter emitting more CO_2 than the solar power. However, whether consumers can make a choice between solar and thermal is depending on the structure of the electricity market. Until recently, the market had a structure where consumers couldn't choose generation methods freely. Consumers in Tokyo, for example, couldn't help using mixed electricity provided by TEPCO without being informed the structure of the power sources. As described below, the introduction of the green electricity program could allow the consumers to choose the generation methods partially following their willingness-to-pay. Accordingly, it is notable that the recent development of the electricity market in Japan will change the market structure towards making the consumers' free-to-choose possible. In this connection, it is important that a consumer who has a sufficiently high willingness to pay for the solar power should know exactly that the electricity which he/she consumes is generated by the solar power. If the information on power sources is not available, consumers cannot evaluate their willingness to pay for the environment. As long as the information of the solar power is available and a sufficient amount of the solar power is provided, consumers can choose a power source based on their marginal willingness to pay. Here, each consumer's marginal willingness to pay is expressed by

(3) $W_i = \theta e_i, i = 1,2$

where θ is a consumer's actual evaluation on e_i and assumed to be uniform distribution bounded in $[\underline{\theta}, \overline{\theta}]$. Then the average is $\mu = (\underline{\theta} + \overline{\theta})/2$ and the variance is $\sigma = (\overline{\theta} - \underline{\theta})^2/12$. In general, whereas the environmentally-conscious consumers to have a large θ will choose the solar power firm, the environmentally-unconscious consumers will choose the thermal power firm. In consumer's equilibrium, we assume that

$$(4)\ \overline{u} - p_1 + \theta e_1 + \rho(e_1 - e_2) = \overline{u} - p_2 + \theta e_2$$

where $\overline{u}$ is the intrinsic utility obtained from a single unit of electricity, irrespective of the variant's unit emission level, and ρ is the marginal utility of social-related evaluation, which gives consumers who choose the solar power a sense of satisfaction via social recognition for their contribution to preserve the environment. If the market structure does not allow consumers to choose a power source, no difference of their evaluation on power sources occurs. Accordingly, consumers will choose only the thermal power because of the low price. However, if some subsidies are paid for the solar power, there may be a case in which one chooses solar power, and the other will choose thermal power.

4.2.3 Market Structures

Considering the above-mentioned points, in particular, a relationship between the market structure and the consumers' free choice of the power sources, the following three types of markets are worth analysis (see Figure 1).

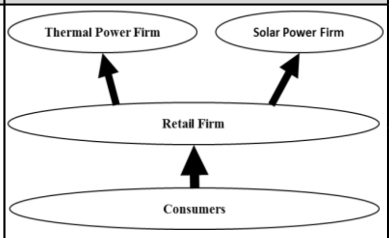
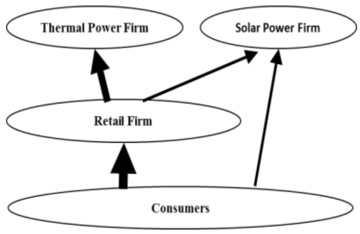
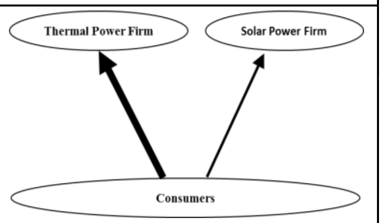
(1) Consumers know there are two types of power sources. However, the consumers cannot choose a power source, because only the mixed electricity is supplied. In this market, the objective of the policy maker is the composition of power sources. In order to enhance the share of solar power in the total power sources, the FIT or the RPS will be introduced.

(2) Consumers know there are two types of power sources. As in (1), while the mixed electricity supplied, the consumers can choose solar power under the green electricity program.

(3) Consumers know there are two types of power sources. The consumers can freely and directly choose one of the power sources according to their willingness to pay for the environment.

From a viewpoint of the consumers' free choice, the above mentioned classification of the electricity market is close to the idea of Eriksson (2004). Most of proceeding studies, including Eriksson, analyse the consumers' choice between green and brown technologies. Although technology substitutions are difficult in the electricity sector, the preferences of consumers can be reflected into the generation mix which consists of thermal, solar power, etc. Assume that production technology of the firms to generate electricity cannot change flexibly, and there are two types of the firm; a thermal power firm and a solar power firm. Then, there will be the competition between them to determine the share of power source to generate electricity.

Figure 1 Framework of Model Markets

Case	Choice of Consumers	Condition of Competition between Firms	Scheme for Introducing Solar Power	Reference Figures
(1)	actually impossible	Regulation of Price/ Quota	Subsidy for Solar Power	
		Bertrand	FIT or RPS	
(2)	partly possible	Regulation of Price/ Quota	Subsidy for Solar Power Green Electricity Program	
		Bertrand	FIT or RPS	
(3)	possible	Bertrand	Subsidy for Solar Power	

4.3 Model Analysis

4.3.1 A case where consumers can choose a supplier

(Competitive Model: Case (3) of Figure 1)

In this case, while consumers choose a supplier freely in the electricity market, each power source firm is competing in the market. Thus,

(5) $\theta^* = \frac{p_1 - p_2}{e_1 - e_2} - \rho$

is obtained based on consumers' behaviour so that the consumers are indifferent between choosing electricity generated by solar power and thermal power. Hence, the share of demand for solar power can be given by (6).

(6) $x(p_1, p_2) = [\overline{\theta} - \theta^*]/[\overline{\theta} - \underline{\theta}] = \left[\left(\overline{\theta} + \rho\right)(e_1 - e_2) - (p_1 - p_2)\right]/\left(\overline{\theta} - \underline{\theta}\right)(e_1 - e_2).$

In the model, each power firm has a strategic variable; the price of electricity it supplies. The analysis is suited to the situation where the demand and supply are determined based on the price as a strategic variable of each firm[7]. The consumers choose a power source under these prices. In the Bertrand-Nash competition, the reaction functions of each firm are given by

(7)$p_1 = \left[p_2 + \left(\overline{\theta} + \rho\right)(e_1 - e_2) + (1 - s)(c + e_1)\right]/2,$

(8)$p_2 = \left[p_1 - \left(\underline{\theta} + \rho\right)(e_1 - e_2) + (g + e_2)\right]/2,$

respectively. From (7) and (8),

(9) $p_1^* = \frac{(2\overline{\theta} - \underline{\theta} + \rho)(e_1 - e_2) + 2(1 - s)(c + e_1) + (g + e_2)}{3},$

and

(10) $p_2^* = \frac{(\overline{\theta} - 2\underline{\theta} - \rho)(e_1 - e_2) + (1 - s)(c + e_1) + 2(g + e_2)}{3}$

are obtained. Then the difference in prices between both power firms becomes

(11) $p_1^* - p_2^* = \frac{[\{(\overline{\theta} + \underline{\theta} + 2\rho)\}(e_1 - e_2) + (1 - s)(c + e_1) - (g + e_2)]}{3} = \frac{(\overline{\theta} + \underline{\theta} + 2\rho + 1 - s)e_1 - (\overline{\theta} + \underline{\theta} + 2\rho + 1)e_2 + ((1 - s)c - g)}{3}.$

Taking (5), (6) and (11) together leads to

(12) $x^* = \frac{(2\overline{\theta} - \underline{\theta} + \rho)(e_1 - e_2) - [(1 - s)(c + e_1) - (g + e_2)]}{3\left(\overline{\theta} - \underline{\theta}\right)(e_1 - e_2)}.$

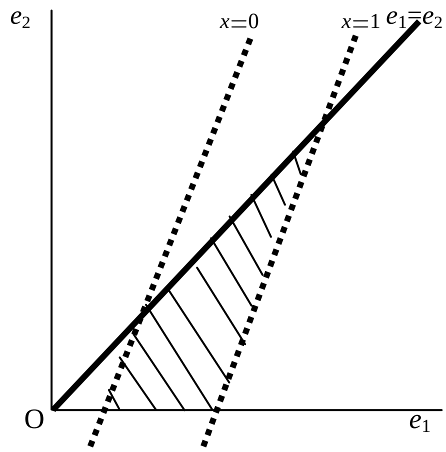
From (12), under the assumption of $e_1 > e_2$, the condition which enables the solar power to be consumed becomes (13);

(13) Numerator of $x^* = Ae_1 - Be_2 + C,\quad A = B + s > B = 2\overline{\theta} - \underline{\theta} + \rho - 1, C = -\left((1 - s)c - g\right).$

[7] The model assumes that each power firm adjusts the electricity price so as to maximize its profit, instead of its generation level. This is because of the difficulty of the output adjustment of the electricity.

where C < 0 under the assumption of the cost function(i.e. (1-*s*)>*g*). As a result of the Bertrand competition, the solar power firm can generate electricity at the shaded portion circled by the curbs of *x*=0 and *x*=1 under the condition of $e_1>e_2$ (see Fig-2). Consider the conditions where each power source is utilized by using (6) and (12). When only the thermal power is utilized, i.e. when no consumer prefers the solar power to thermal power, $(\overline{\theta}+\rho)(e_1-e_2)=p_1{}^*-p_2{}^*$ holds. On the other hand, when only the solar power is utilized, i.e. when every consumer chooses the solar power firm, $(\underline{\theta}+\rho)(e_1-e_2)=p_1{}^*-p_2{}^*$holds. This means that the difference between prices of solar and thermal power depends on consumer's actual evaluation on e_i (marginal willingness to pay for e_i), and on marginal utility of social-related evaluation. For example, the price of the solar power is expensive compared to the price of the thermal power, the share of the solar power becomes smaller. In this relation, the expansion of the subsidy rate, *s* in (12), makes the difference of prices smaller and the share for the solar power larger.

Fig-2 Bertrand competition and the solar power



4.3.2 A case where consumers can partly choose a supplier

(Green Electricity program: Case (2) of Figure 1)

Here let us discuss the case where consumers can partly choose a power source through a green electricity program. Assume the energy-based green electricity program that is operated in US and

Europe, and in the green program, consumers can purchase the green power directly from the solar power firm. As shown in Figure 1, customers mainly purchase a mixed power from the thermal power firm (hereafter the retail firm) which are obliged to buy some amount of electricity generated by the solar power firm. Then, consumers' equilibrium is expressed as

(14) $\bar{u} - p_1 + \theta e_1 + \rho(e_1 - e_2) = \bar{u} - \tilde{p}_2 + \theta e_2$,

where $\tilde{p}_2$ is the price of the mix electricity by solar and thermal power[8]. In (14), θ^{**} where consumers are indifferent between purchases of solar and mixed power is obtained:

(15) $\theta^{**} = \frac{p_1 - \tilde{p}_2}{e_1 - e_2} - \rho.$

The demand share for *x* by the solar power firm and for *y* by the retail firm is

(16) $x(p_1, \tilde{p}_2) = (\overline{\theta} - \theta^*)/(\overline{\theta} - \underline{\theta}) = [(\overline{\theta} + \rho)(e_1 - e_2) - (p_1 - \tilde{p}_2)]/(\overline{\theta} - \underline{\theta})(e_1 - e_2)$,

(17) $y = 1 - x(p_1, \tilde{p}_2) = (\theta^* - \underline{\theta})/(\overline{\theta} - \underline{\theta}) = [(p_1 - \tilde{p}_2) - (\underline{\theta} + \rho)(e_1 - e_2)\ ]/(\overline{\theta} - \underline{\theta})(e_1 - e_2).$

In the following, let us analyse the equilibrium in which the retail firm is required to utilize a certain amount of the solar power (i.e. $\bar{z}$ in (18) below under FIT or RPS).

4.3.2.1 Electricity Market in which FIT and Green Electricity Program is introduced

Here, assume that the retail firm purchases electricity from the thermal power firm which belongs to the same firm group, and is obliged to buy a certain amount of electricity, $\bar{z}$, at $\overline{p}_1$, which is higher than $\tilde{p}_2$ from the solar power firm through the FIT. In this case, the solar power firm has two options. One is that the solar power firm supplies electricity to the retail firm. The other is that the firm supplies electricity directly to consumers who reveal a high marginal willingness to pay. In order to buy electricity directly from the solar power firm, consumers have to offer p_1 higher than $\overline{p}_1$ to the solar power firm, leading to $\overline{p}_1 < p_1$. Under this condition, the solar power firm supplies a residual of electricity, $\bar{z}$, at the price of $\overline{p}_1$ to the retail firm after supplying the electricity *x* directly

[8]In case consumers fully recognize that the mixed electricity by solar and thermal power is supplied, (14) is rewritten as $u - p_1 + \theta e_1 + \rho(e_1 - e_2) = u - \tilde{p}_2 + \theta e_2 + \rho'(e_1 - e_2)$ and (15) is rewritten as $\theta^{**} = [(p_1 - \tilde{p}_2)/(e_1 - e_2)] - (\rho - \rho')$. As a result, electricity consumption share of *x* is considered to decrease.

to the consumers[9]. In this case, the profit function of the solar power firm is given by

(18) $\pi_1 = x[p_1 - (1-s)(c+e_1)] + \bar{z}[\overline{p}_1 - (1-s)(c+e_1)]$.

The profit function of the retail firm is given by

(19) $\pi_2 = \tilde{p}_2 y - (y-\bar{z})(g+e_2) - \overline{p}_1\bar{z}] = (y-\bar{z})p_2 + z\overline{p}_1 - (y-\bar{z})(g+e_2) - \overline{p}_1\bar{z}$

where $(g+e_2)$ is the cost of the thermal power firm assumed in 4.3.1. $\overline{p}_1\bar{z}$ denotes the purchase cost from the solar power firm. y (=1- x) shows the supply share of the retail firm, and the generation share of the thermal power firm is expressed as $y-\bar{z}$. The price of the retail firm, i.e., the price of the mixed electricity by solar and thermal power, is set at $\tilde{p}_2 = \left[(y-\bar{z})p_2 + \bar{z}\overline{p}_1\right]/y$.

In the following, the solar power firm (i=1) and the retail firm (i=2) determine each price under given $\overline{p}_1$ and $\bar{z}$. As discussed in 4.1, the reaction functions of each firm are

(20) $p_1 = \left[\tilde{p}_2 + \left(\overline{\theta} + \rho\right)(e_1 - e_2) + (1-s)(c+e_1)\right]/2$,

(21) $\tilde{p}_2 = \left[p_1 - \left(\underline{\theta} + \rho\right)(e_1 - e_2) + (g+e_2)\right]/2$,

respectively. From (20) and (21), each price at the equilibrium is given as

(22) $p_1^{**} = \frac{\left(2\overline{\theta} - \underline{\theta} + \rho\right)(e_1 - e_2) + (g+e_2) + 2(1-s)(c+e_1)}{3}$,

(23) $\tilde{p}_2^{**} = \frac{\left(\overline{\theta} - 2\underline{\theta} - \rho\right)(e_1 - e_2) + 2(g+e_2) + (1-s)(c+e_1)}{3}$,

and their difference is given as

(24) $p_1^{**} - \tilde{p}_2^{**} = \frac{\left(\overline{\theta} + \underline{\theta} + 2\rho\right)(e_1 - e_2) - (g+e_2) + (1-s)(c+e_1)}{3} = \frac{\left(\overline{\theta} + \underline{\theta} + 2\rho + 1 - s\right)e_1 - \left(\overline{\theta} + \underline{\theta} + 2\rho + 1\right)e_2 + \left((1-s)\mathrm{c} - \mathrm{g}\right)}{3}$

Taking (16), (17) and (24), the demand share for x and for y is

(25) $x^{**} = [\left(2\overline{\theta} - \underline{\theta} + \rho\right)(e_1 - e_2) - \{(1-s)(c+e_1) - (g+e_2)\}]/3\left(\overline{\theta} - \underline{\theta}\right)(e_1 - e_2)$,

(26) $y^{**} = (1-\mathrm{x})^* = [\left(\overline{\theta} - 2\underline{\theta} - \rho\right)(e_1 - e_2) + (1-s)(c+e_1) - (g+e_2)]/3\left(\overline{\theta} - \underline{\theta}\right)(e_1 - e_2)$.

Taking (23), (24) and $\tilde{p}_2 = \left[(y-\bar{z})p_2 + \bar{z}\overline{p}_1\right]/y$,

[9] We assume here that the purchase price $(\overline{p}_1)$ and quantities $(\bar{z})$ are regulated under the FIT. The reason is that the quantities in addition to the price are regulated in the countries where large amounts of renewable energies are introduced. Also in Japan, the quantities have to be regulated in the technical reason, for example lack of network capacities. That' why we assume the quantities are also fixed.

(27) $p_2^{**} = (y^{**}\tilde{p}_2^{**} - \bar{z}\bar{p}_1)/(y^{**} - \bar{z})$

is obtained. Considering analyses in 4.3.1 and in 4.3.2, it is notable that the price and the quantities at which the consumers purchase directly from the solar power firm are identical in both cases. In addition, the price and the quantities at which the thermal power firm of 4.3.1 and the retail firm of 4.3.2 supplies are also identical. The difference is the quantities that the solar power firm supplies. This is because the solar power firm can supply $\bar{z}$ in addition to *x* in 4.3.2.1 where FIT is enforced. In this case, whereas the quantities that the solar power firm supplies are $(x^{**} + \bar{z})$, the quantities that the thermal power firm supplies decrease by $\bar{z}$.

4.3.2.2 Electricity Market in which RPS and Green Electricity Program is introduced

Here, assume that the retail firm (*i*=2) purchases electricity from the thermal power firm which belongs to the same firm group, and is required to purchase a certain amount of electricity, $\bar{z}$ at $(p_2 + m)$ from the solar power firm (*i*=1) under the RPS scheme[10]. As in the previous case, the solar power firm has two options. One is that the solar firm supplies electricity to the retail firm. The other is that the firm supplies electricity directly to the consumers who express a high marginal willingness to pay. In this case, the profit functions of the solar power firm and the retail firm are given by

(28) $\pi_1 = x[p_1 - (1-s)(c+e_1)] + \bar{z}[\tilde{p}_2 + m - (1-s)(c+e_1)]$,

(29) $\pi_2 = \tilde{p}_2 y - (y - \bar{z})(g + e_2) - (\tilde{p}_2 + m)\bar{z}$.

From (28) and (29), the reaction functions of each firm are

(30) $p_1 = \left[\tilde{p}_2 + \left(\overline{\theta} + \rho\right)(e_1 - e_2) + (1-s)(c+e_1)\right]/2$,

(31) $\tilde{p}_2 = [p_1 - \left(\underline{\theta} + \rho\right)(e_1 - e_2) + (g + e_2) - \bar{z}(\bar{\theta} - \underline{\theta})(e_1 - e_2)]/2$,

respectively. From (30) and (31), the prices at the equilibrium and their differences are given as

[10] Under the RPS, the retail firms are required to purchase a certain amounts of electricity generated by renewable energies. In general, the purchase price consists of the competitive price that reflects physical value, and of the environmental value. Therefore, we assume here the purchase price consists $\tilde{p}_2$ that is the weighted average of p_1 and p_2, and of *m* as an environmental value.

(32) $p_1^* = \frac{(4\overline{\theta}-\underline{\theta}+3\rho)(e_1-e_2)+(g+e_2)+4(1-s)(c+e_1)-\overline{z}(\overline{\theta}-\underline{\theta})(e_1-e_2)}{3}$,

(33) $\tilde{p}_2^* = \frac{2(\overline{\theta}-\underline{\theta})(e_1-e_2)+2(g+e_2)+2(1-s)(c+e_1)-2\overline{z}(\overline{\theta}-\underline{\theta})(e_1-e_2)}{3}$,

(34) $p_1^* - \tilde{p}_2^* = \frac{(2\overline{\theta}+\underline{\theta}+3\rho)(e_1-e_2)-(g+e_2)+2(1-s)(c+e_1)+\overline{z}(\overline{\theta}-\underline{\theta})(e_1-e_2)}{3}$.

Considering (16), (17) and (34) together, the demand shares for *x* and for *y* become

(35) $x^* = [(\overline{\theta}-\underline{\theta})(e_1-e_2)+(g+e_2)-2(1-s)(c+e_1)-\overline{z}(\overline{\theta}-\underline{\theta})(e_1-e_2)]/3(\overline{\theta}-\underline{\theta})(e_1-e_2)$

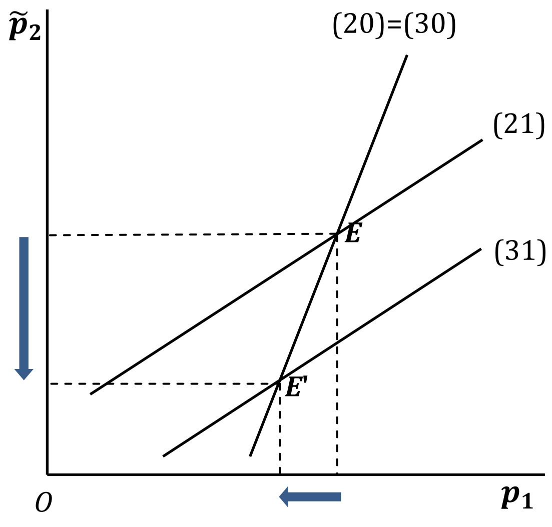
(36) $y^* = (1-\mathrm{x})^* = [2(\overline{\theta}-\underline{\theta})(e_1-e_2)-(g+e_2)+2(1-s)(c+e_1)+\overline{z}(\overline{\theta}-\underline{\theta})(e_1-e_2)]$

$/3(\overline{\theta}-\underline{\theta})(e_1-e_2)$

Then, the equilibrium prices in 4.3.2.1 and in 4.3.2.2 are shown in Figure 3.

With respect to the reaction function of the solar power firm, there is no difference in both cases. With respect to the retail firm, the reaction function shifts downwards from (21) to (31). In this relationship, whereas the slope of solar power firm in both cases is 2, the slope of the reaction function of the retail firm is 1/2. Therefore, the decrease of the electricity price of the solar power firm is smaller than the retail firm, and the difference of the prices between the solar power firm and the retail firm is larger in 4.32.1, as shown in (24) and (34). Therefore, the share of the retail firm becomes larger in 4.3.2.2 than in 4.3.2.1.

Fig.-3 Reaction Functions of Solar Power Firm and Retail Firm



4.3.3 A Case where consumers cannot choose a supplier

(Case (3) of Figure 1)

In the competitive markets, consumers can choose freely to purchase goods and services. A consumer chooses a car among various cars produced by many different companies in a competitive market, leading to their free-choice among eco-friendly cars. However, something is different in the electricity market in Japan. As already mentioned in Chapter 2, it is far from the competitive market due to a number of reasons in Japanese electricity market. Among them, one is a regional monopoly such as TEPCO to eliminate competition, and the other is the market system that makes consumers' choice among power resources impossible. On the contrary, the case (3) in figure 1 implies a 'free-to-choose" model.

Section 4.3.1, using (6), has discussed the condition where the solar power is purchased. As in 4.3.1, the condition is the same as in 4.3.2 where the green electricity program and the FIT are introduced. Actually, no demand for the solar power firm arises unless the numerator of (16), $(\overline{\theta}+\rho)(e_1-e_2)-(p_1-p_2)$, becomes positive. Therefore, the key variables are ρ, p_1 and $\tilde{p}_2$. When ρ becomes bigger, and when the difference between p_1 and $\tilde{p}_2$ becomes smaller, the demand share for the solar power firm becomes larger. As (25) shows, the subsidy to the solar power firm, s, makes the difference smaller. Because c is the marginal cost to install an additional solar panel of 1MW, increasing s makes c smaller. In this relation, it is notable that thanks to the combination of the subsidy to be paid for residents who install solar panels, and of the voluntary measure under which the electric power companies purchase surplus energy that the residential customer who install solar panels do not use themselves, Japan had ranked No.1 in the world for the photovoltaic power generating capacity through 1994. The self-consumption system to use solar panels supported by the subsidy is a kind of the combination of green electricity program and the subsidy. However, after suspending the subsidy, Japan lost the rank, and Germany has ranked at the

No.1 for the installing capacity since 2005. Under the background, Japan has started again the subsidy since FY2009.

4.4 Welfare Analysis

4.4.1 Framework

This section examines the welfare aspects of the electricity market focusing on the different market structure shown in Figure 1. In particular, the economic as well as the social surplus in the framework of 4.3.1 and 4.3.2.1 are investigated. The consumer surplus (*CS*) in 4.3.1 is defined as

(37) $CS_1 = \int_{\theta^*}^{\overline{\theta}} \left[\overline{u} - p_1 + \theta e_1 + \rho(e_1 - e_2)\right] d\theta + \int_{\underline{\theta}}^{\theta^*} [\overline{u} - p_2 + \theta e_2]\, d\theta.$

On the other hand, the consumer surplus in 4.3.2.1 is defined as

(38) $CS_2 = \int_{\theta^{**}}^{\overline{\theta}} \left[\overline{u} - p_1 + \theta e_1 + \rho(e_1 - e_2)\right] d\theta + \int_{\underline{\theta}}^{\theta^{**}} [\overline{u} - \tilde{p}_2 + \theta e_2]\, d\theta.$

The producer surplus (*PS*) in 4.3.1 is defined as the sum of solar power firm's surplus, PS_{11} and the thermal power firm's surplus PS_{12}. That is

(39) $PS_1 = PS_{11} + PS_{12}.$

In 4.3.2.1, the producer surplus is defined as the sum of solar power firm's surplus, PS_{21} and the retail firm's surplus PS_{22}. That is

(40) $PS_2 = PS_{21} + PS_{22}.$

A social aspect of the welfare has been investigated by many authors (Lonbardini-Riipinen (2005), Toshimitsu (2010) and Lambertini and Tampieri (2011)). Here the environmental burden in 4.3.1 is simply assumed as the excess emission of CO_2 from generating electricity:

(41) $E_1 = (\bar{e} - e_1)x + (\bar{e} - e_2)y$

where $\bar{e}$ denotes the environmental burden when both firms do not make any efforts on the environment. In 4.3.2.1, the environmental burden is assumed as

(42) $E_2 = (\bar{e} - e_1)(x + \bar{z}) + (\bar{e} - e_2)(y - \bar{z}) = (\bar{e} - e_1)x + (\bar{e} - e_2)y - [(\bar{e} - e_2) - (\bar{e} - e_1)]\bar{z}$

The subsidy for the solar power firm by the governments is given by (43) in 4.3.1 and (44) in 4.3.2.1, respectively;

(43) $\Omega_1 = xs(c + e_1)$,

(44) $\Omega_2 = xs(c + e_1) + \bar{z}s(c + e_1)$.

From (37), (39), (41) and (43), the total surplus in 4.3.1 is given by

(45) $W_1 = CS_1 + PS_1 - E_1 - \Omega_1$.

From (38), (40), (42), and (44), the total surplus in 4.3.2.1 is given by

(46) $W_2 = CS_2 + PS_2 - E_2 - \Omega_2$.

4.4.2 A Comparison of the Surplus

The consumer surpluses in 4.3.1 and in 4.3.2.1 are identical, because we confirmed in 4.3 that the value of p_1 in 4.3.1 and in 4.3.2 is identical, and $p_2 = \tilde{p}_2$, and $\theta^* = \theta^{**}$. Thus, the surplus of consumers who are supplied electricity directly from the solar power firm is computed as

(47) $CS_{11} = CS_{21} = A[6\overline{u}(e_1 - e_2) - A(e_1 - 2e_2) + 6(1 - s)(c + e_1)(e_1 - e_2) + 4(g + e_2)(e_1 - e_2) + 6\rho(e_1 - e_2)]/18(e_1 - e_2)^2$.

where $A = (2\bar{\theta} - \underline{\theta} + \rho)(e_1 - e_2) - [(1 - s)(c + e_1) - (g + e_2)]$. The surplus of consumers who are supplied from the thermal power firm in 4.3.1 and the retail firm in 4.3.21 are computed as

(48) $CS_{12} = CS_{22} = B[6\overline{u}(e_1 - e_2) - B(2e_1 - 3e_2) + 6(g + e_2)(e_1 - e_2)]/18(e_1 - e_2)^2$.

where $B = (\bar{\theta} - 2\underline{\theta} - \rho)(e_1 - e_2) + (1 - s)(c + e_1) - (g + e_2)$.

The producer surpluses of the solar power firm in 4.3.1(PS_{11}) and 4.3.2.1 (PS_{21}) are computed as

(49) $PS_{11} = A^2/9(\bar{\theta} - \underline{\theta})(e_1 - e_2)$,

(50) $PS_{21} = [A^2/9(\bar{\theta} - \underline{\theta})(e_1 - e_2)] + \bar{z}[\bar{p}_1 - (1 - s)(c + e_1)]$.

Comparing (49) and (50) together, it is clear that the latter is larger by $\bar{z}[\bar{p}_1 - (1 - s)(c + e_1)]$.

On the other hand, the producer surpluses of the thermal power firm (PS_{12}) and the solar power firm (PS_{22}) are calculated as

(51) $PS_{12} = B^2/9(\bar{\theta} - \underline{\theta})(e_1 - e_2)$,

(52) $PS_{22} = B^2/9(\bar{\theta} - \underline{\theta})(e_1 - e_2) - \bar{z}[\overline{p}_1 - (g + e_2)]$.

Comparing (51) and (52) together, it is found that the latter is smaller by $\bar{z}[\overline{p}_1 - (g + e_2)]$. Moreover, the environmental burden in (41) is larger than in (42), the difference between them being equal to $[(\bar{e} - e_2) - (\bar{e} - e_1)]\bar{z}$. The governmental spending for the solar power firm in (44) is clearly larger than in (43) and the difference is $\bar{z}s(c + e_1)$.

Summarizing the above leads to the difference of the social welfare in 4.3.1 and .4.3.2.1 is calculated as

(53) $W_2 - W_1 = \bar{z}[\bar{p}_1 - (1 - s)(c + e_1)] - \bar{z}[\overline{p}_1 - (g + e_2)] + \bar{z}[(\bar{e} - e_2) - (\bar{e} - e_1)] - \bar{z}s(c + e_1)$

$= \bar{z}(-c + g) < 0.$

Therefore, it is clear that the social welfare in the competitive market in 4.3.1 is larger than in the market in 4.3.2.1 where the mixed electricity is supplied under the FIT scheme in a green program system.

5. Conclusions and Further Remarks

This paper discussed the restructuring and development pattern of the structure of electricity market in Japan mainly from theoretical perspectives. One of the main issues is the possibility of the free choice of consumers between the electricity suppliers who generate electricity with different power sources. An important finding of the paper is that the social welfare in the case (2) in figure 1 where the FIT is enforced is lower than in case (3) of the competitive market, meaning that the social welfare is not enhanced as long as the mixed electricity is supplied. The other is that the demand for direct purchase of the solar power depends on the marginal willingness to pay for the environment, marginal utility of social-related evaluation, and the difference of prices between the solar power firm and the thermal power firm in the case (3) in figure 1, or the difference of prices between the solar power and the retail firm in the case (2). If the numerator of (6) and (16) is not positive, the demand for the direct purchase from the solar power firm does not arise.

The above mentioned findings are showing us the valuable implications to consider current discussion about the future energy policy in Japan. The most controversial issue is the share of power sources to which Japan should reach until 2030. The government conducted the public hearings on the generation mix across the nation, in order to set the new energy policy. However, if the share is determined from the political viewpoints, some opinions are neither reflected nor estimated. Some policies, such as the FIT and the subsidy which we investigated here, may be needed in order to reach the target. If the FIT which oblige some consumers to purchase the mixed power continuously is enforced, we will not be able to choose the optimal use of power sources[11]. Thus, any policy measures to increase the share of the renewable power source in the total should be supported by consumers' environmentally oriented behaviour. To support those policies, information disclosure on power sources is needed for the green consumers. This is because the optimal distribution of power sources cannot be attained without the market system in which consumers' preference, that is their marginal willingness to pay for the environmental attributes, is properly revealed.

Finally, we should address our future works. In this paper, we studied the electricity market using the vertical differentiation model under the assumption of full coverage, because electricity is one of essential goods. However, if total energy services are available in the future, the electricity does not have to cover 100% of energy needs, and the assumption of full market coverage could be relaxed. We would extend our research for those directions.

---

[11] The policy paper announced by the Energy and Environment Council on 14 September, 2012 indicates that the share of each power source should be determined as a result of the competition basis among power firms and the consumers' free choice. On the other hand, the paper also sets the numerical goal to triple the output of electricity generated from renewable energy sources from 110 billion kilowatt-hours in 2010 to 300 billion kWh by 2030. To reach the target, the paper envisages that FIT will be one of important policy measures. At any rate, it seems impossible that consequences of the free competition are compatible with the outcome of the regulatory policy. Thus, a considerable discrepancy may exist in the report (See, The Energy and Environment Council HP).

References

André, F.J., P. González and N. Porteiro (2009)"Strategic quality competition and the Porter hypothesis," *Journal of Environmental Economics and Management*,57, pp. 182-194.

Andreoni, J. (1989) "Impure altruism and donations to public goods: a theory of warm glow giving," *Journal of Political Economy*, 97, 1447-1458.

Bansal, S. (2008) "Choice and design of regulatory instruments in the presence of green consumers," *Resource and Energy economics*, 30, 345-368.

Cornes, R. and Sandler, T. (1994)"The comparative static properties of the impure public good model," *Journal of Public Economics*, 54(3), 403-421.

Cremer, H. and J. F. Thisse (1999) "On the Taxation of Polluting Products in a Differentiated Industry," *European Economic Review*, 43, 575-594.

Cremer, H., Gahvari, F., and N. Ladoux (2003) "Environmental taxes with heterogeneous consumers; an application to energy consumption in France," *Journal of Public Economics*, 87,2791-2815.

Eriksson, C. (2004) "Can Green Consumerism Replace Environmental Regulation? -a differentiated products example," *Resource and Energy Economics*, 26, pp. 281-293.

Haruna, S (2010), *Quality choice, vertical product differentiation, and labor-managed oligopoly*, http://ousar.lib.okayama-u.ac.jp/metadata/44386 (accessed April 17, 2012).

Hotelling, H. (1929)"Stability in Competition," *Economic Journal*, 39, pp.41-57.

Ise, K (2008), "Liberalization and CO2 emissions in the Electricity Supply: An Empirical Analysis Using Panel Data," *Planning Administration*, 31(1), pp.106-114. (in Japanese)

Kotchen, J. (2005) "Impure public goods and comparative statics of environmentally friendly consumption," *Journal of Environmental Economics and Management*, 49, 281-300.

Kotchen, J. (2007) "Private provision of environmental public goods: Household participation in green-electricity programs," *Journal of Environmental Economics and Management*, 53, 1-16.

Lambertini, L. and, A. Tampieri (2011), *Vertical Differentiation in a Cournot Industry: The Porter Hypothesis and Beyond*, http://www2.dse.unibo.it/wp/WP730.pdf (accessed April 30, 2012).

Lancaster, K. J. (1966), "A New Approach to Consumer Theory," *Journal of Political Economy*, 74, 132-157.

Lancaster, K. J. (1979), *Variety, Equity, and Efficiency*, Columbia University Press, New York.

Lombardini-Riipinen, C. (2005) "Optimal Tax Policy under Environmental Quality Competition," *Environmental & Resource Economics*, 32, 317-336.

Moorthy, K. S. (1988), "Product and Price Competition in a Duopoly," *Marketing Science*, 7 (2), 141-168.

Motta, M. (1993) "Endogenous Quality Choice: Price vs. Quantity Competition," *The Journal of Industrial Economics*, Volume XLI, pp.113-131.

OECD/ IEA (2011a) *Renewable Information: 2011 Edition*, IEA Publications.

OECD/ IEA (2011b)*Energy Balances of OECD Countries: 2011 Edition*, IEA Publications.

OECD/ IEA (2011c)*Energy Balances of Non-OECD Countries: 2011 Edition*, IEA Publications.

Porter, M. E. (1990)*the Competitive Advantage of Nations*, Free Press, New York.

Porter, M. E. (1991)"America's green strategy," *Scientific American*, 264, p. 96.

Schumpeter, J.A. (1942)*Capitalism, Socialism, and Democracy*, New York, Harper.

Shaked, A. and J. Sutton (1982) "Relaxing Price Competition through Product Differentiation," *Review of Economic Studies*, 49, pp. 3-13.

The Energy and Environment Council (2011), *Basic Principles Towards a proposal defining Options for a Strategy for Energy and the Environment*, http://www.npu.go.jp/en/policy/policy06/pdf/20120403/20120402_basicprinciples%20_en.pdf (accessed August 30, 2012)

The Federation of Electric Power Companies in Japan (2011), *Hand Book of Electric Power Industry*, Ohmsha. (in Japanese)

Toshimitsu, T. (2010)"On the paradoxical case of a consumer-based environmental subsidy policy," *Economic Modeling*, 27, 159-164.

Yabuta, M. and N. Scott (2010), *Ecotourist Behaviour as a Green Consumer*, http://www2.tamacc.chuo-u.ac.jp/keizaiken/discussno146.pdf (accessed April 30, 2012)

Advisory Committee for Natural Resources and Energy HP (http://www.meti.go.jp/committee/gizi_8/2.html (in Japanese, accessed April 30, 2012)).

Cost Review Committee HP (http://www.npu.go.jp/policy/policy09/archive02.html (in Japanese, accessed August 30, 2012))

Expert Committee on Electric Power System Reforms HP (http://www.meti.go.jp/committee/sougouenergy/sougou/denryoku_system_kaikaku/002_haifu.html (in Japanese, accessed August 30, 2012))

The Energy and Environment Council HP (http://www.npu.go.jp/policy/policy09/archive01_14.html#haifu (in Japanese, accessed September 15, 2012))