Should the Government Privatize Polluting Firms?

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This paper presents an analysis of whether a central government should privatize a polluting firm in a region under circumstances in which transboundary pollution occurs. This paper's characteristic feature is its consideration of circumstances under which the degree of influence that pollution emissions exert on the environment can be assessed on various levels. Theoretical studies of privatization and the environment in recent years include those of Beladi and Chao (2006)[1], who regard a monopoly public firm as considering the consumers' surplus and private profit when the firm chooses the output of a good. In contrast, in the analyses described herein, the public firm considers not only the consumers' surplus and the private profit, but also the environmental damage that occurs when the firm chooses the output of the good. Beladi and Chao (2006)[1] conclude that privatization will decrease the output of the good. In contrast, our analyses demonstrate that when the effect that emissions have on environmental damage is small (large), privatization will decrease (increase) the output of the good in the region. Based on results presented above, this paper presents a demonstration that when the effects that emissions have on environmental damage are large (small), then the optimal policy decision of the government is not (full) privatization. Moreover, when the effect is small, the optimal policy decision of the government is partial privatization.

1. Introduction

Recently, global warming has become an important problem. To reduce greenhouse gas effects, various environmental policies have been examined: environmental taxes, marketable permits, and direct environmental regulations. Public firm privatization has occurred not only in Japan but also in many countries. Privatization is probably an important policy to enhance efficient productive activity. This paper presents consideration of whether the privatization of polluting firms affects not only social welfare but also the environment.

For instance, we can readily recall that Fukushima Daiichi Nuclear Power Plant was nationalized after accident that occurred following March 11, 2011. Consequently, whether the central government should nationalize the polluting firm might depend on the extent and severity of the damage that the consequent emissions have on the environment. As another example, the transportation sector might be adequate. If a public firm constructs a freeway, then the use of automobiles is enhanced and carbon dioxide emissions will increase. It is therefore necessary to discuss the privatization of polluting firms, which is a topic that has not been addressed in conventional discussions of environmental policy. Here, in general, the level of marginal damage that the pollution emission exerts on the environment differs depending on the pollution emission type. Accordingly, it is important to ascertain whether privatization is efficient depending on the degree of damage that emissions inflict upon the environment.

As described herein, we analyze the influence of privatization of the polluting firm on the environment and social welfare, while particularly addressing different types and levels of the damage that emissions have on the environment under circumstances in which transboundary pollution occurs.

Theoretical studies of privatization and the environment in recent years include those of Beladi and Chao (2006)[1], and Wang and Wang (2009)[2]. In Beladi and Chao (2006)[1], pollution emissions occur concomitantly with the production of a good by a monopoly public firm. An environmental tax is imposed on the amount of the pollution emissions, and the influence of privatization of a monopoly public firm on the environmental damage caused by the pollution emission is analyzed. They show that public firm privatization will increase the environmental damage caused by the pollution emissions. The interpretation of this result is the following. The production of the good is expected to decrease because of privatization of the public firm. Additionally, the amount of the pollution emissions is expected to decrease. Under these circumstances, to alleviate an undersupply of the good, the government decreases the environmental tax rate. Consequently, the firm will increase production of the good because of the decreased environmental tax rate; the amount of pollution emissions will also increase.

For the analyses presented in Wang and Wang (2009)[2], a mixed duopoly market including public firms and private firms is assumed. The environmental tax is assumed to be imposed on the amount of pollution emissions created during production of the good supplied by each firm. The influence that privatization of public firms exerts on environmental damage is analyzed.

Results show that the environmental damage decreases because a decrease in the total output of the good supplied by the public firm and the private firm will decrease the amount of the pollution emissions caused by privatization. Furthermore, privatization might decrease the consumers' surplus. A decrease in government

revenues and an increase in the private firm profit might result. Those eventualities illustrate that privatization might decrease social welfare because a decrease in the consumers' surplus and in government revenue might be greater than the increase in private firm profit.

Previous studies devoted only insufficient attention to the differences of the marginal damage of emissions. In general, the level of the marginal damage that the pollution emissions inflict on the environment differs depending on the kind of pollution that is emitted. Previous studies examining the degree of the environmental damage by pollution emissions include that of Petrakis and Xepapadeas (2003)[3], who examined whether a polluting firm moves its base of productive activity to another country when an environmental tax is imposed on the amount of emissions, and examined the outcomes when the government can not commit to its tax rate.

Their results show that even if the government can not commit to the environmental tax rate, then social welfare in the home country will be improved. The interpretation of this result is the following. When the level of the environmental pollution is high, the government will raise the environmental tax rate, which is decided *ex post*. In these circumstances, a polluting firm moves the base of its productive activity to another country because the profit might decrease. Consequently, social welfare in the home country will be improved because a polluting firm moves the base of its productive activity to the other country.

These previous studies neglect consideration of circumstances under which emissions along with the production of the good spill over into other regions. Many cases of transboundary pollution exist. For instance, air pollutants (carbon dioxide, sulfuric oxides) have been examined in numerous studies.

Using conventional theory, many studies show decentralized decisions related to environmental policy under transboundary pollution, such as those of Markusen (1975)[4], Dasgupta *et al*. (1997)[5], and Hoel (1999)[6]. They show that inefficient resource allocation occurs because each local government chooses an environmental policy considering only the effect on the environment in the home region.

However, Wellisch (1994[7], 1995[8], 2000[9]), Silva (1997)[10], and Hoel and Shapiro (2003)[11] show that efficient resource allocation is realized under decentralized decision-making related to environmental policy. They analyzed the decentralized decision of the environmental policy, where the population is mobile across regions.

Consequently, previous studies examining the decentralized decision of the environmental policy neglect exploration of the privatization of polluting firms by the central government.

The first distinguishing feature of the analyses described in this paper is that the polluting firm is a monopoly firm in each region in our paper. The reason is that we specifically examine an electric power company or a gas company. In general, we know these companies as natural monopolies. Although an investigation of natural monopolies might be appropriate, we model a monopoly firm for simplification[*1].

A second distinguishing characteristic of our paper is that we analyze the circumstances under which the central government chooses to execute privatization of a polluting firm in each region. For instance, Fukushima Daiichi Nuclear Power Plant was nationalized after its accident. In general, the industry that has monopoly power in the market and which exerts a large impact on the environment in a region is regulated by the central government. We specifically examine such an industry in this paper.

Although Beladi and Chao (2006)[1] and Wang and Wang (2009)[2] respectively present analyses of privatization of polluting firm under a one-country model, they did not consider the mutual relations among regions near a polluting firm. Analyzing the mutual relations among regions in which a polluting firm is located is important because, as illustrated by the Fukushima Daiichi Nuclear Power Plant accident, pollution can strongly affect nearby regions in terms of the economy and environment.

Petrakis and Xepapadeas (2003)[3] describe analyses of the welfare effect of environmental tax, addressing the differences of the damage that the emissions give to the environment. The present study is an investigation of the welfare and environmental effects of privatization. Therefore, the purpose of this study differs from that undertaken by Petrakis and Xepapadeas (2003)[3]. Nevertheless, we refer to the model setting of environmental damage in that study to analyze privatization-related decision-making by the central government, addressing the differences of damage that the emissions give to the environment.

Previous studies conducted with a similar purpose to ours include those of Beladi and Chao (2006)[1] and Wang and Wang (2009)[2]. The important differences of models between those presented in our paper and in Beladi and Chao (2006)[1] are the following. Beladi and Chao (2006)[1] regard the monopoly public firm as considering the consumers' surplus and the private profit when the firm chooses the output of a good. Specifically, Beladi and Chao (2006)[1] do not consider the environmental damage in the firm's value. In contrast, in the present analyses, the public firm considers not only the consumers' surplus and the private profit but also the environmental damage that occurs when the firm chooses the output of the good. Because of difference in the model setting explained above, in Beladi and Chao (2006)[1], the greater the degree to which privatization is realized, the less the firm considers the consumers' surplus. In contrast, in our analyses, the more privatization is realized, the less the firm considers not only the consumers' surplus but also the environmental damage.

Consequently, results of our analyses show that when the effects of emissions on environmental damage are

slight, privatization will decrease the output of the good in the region. This result is the same as that described by Beladi and Chao (2006)[1]. However, when the effects of emissions on environmental damage are strong, privatization will increase the output of the good in the region. This result differs from that reported by Beladi and Chao (2006)[1].

Based on the results described above, we analyze whether a central government should privatize the polluting firm in each region under scenarios that include transboundary pollution. The main result is the following. When the effect that emissions have on environmental damage is large, the optimal policy decision of the government is not privatization. However, when the effect of emissions on environmental damage is small, the optimal policy decision of the government is full privatization. Moreover, when the effect of emissions on environmental damage is small, then the optimal policy decision of the government is partial privatization.

These results can be interpreted as the following. When the damage of emission effects on the environment is large (small), privatization will increase (decrease) the output of the good. Therefore, privatization will increase (decrease) the consumers' surplus and the private firm profit. However, an increase (decrease) in emissions will increase (decrease) the environmental damage. The degree of an increase (decrease) in the environmental damage will be greater than the degree of an increase (decrease) in the consumers' surplus and in the private firm profit. Consequently, the optimal policy decision of the government is not (full) privatization because privatization will decrease (increase) social welfare.

When the damage that emissions impose on the environment is small, then privatization will decrease the output of the good. Consequently, privatization will decrease the consumers' surplus and the private profit of the firm. However, a decrease in emissions will decrease the environmental damage. Here, if the level of privatization is small (large), then the degree of a decrease in the damage of the environment will be larger (smaller) than the degree of a decrease in the consumers' surplus and in the private firm profit. Therefore, if the level of privatization is small (large), then privatization will increase (decrease) social welfare. The optimal policy decision of the government is partial privatization.

This paper is organized as follows. Section 2 sets up the model for this paper. In section 3, the decision of the polluting firm is analyzed. The influence of privatization of the polluting firm is analyzed. Using these results, in section 4, we analyze whether the government should privatize the polluting firm. Section 5 presents this paper's results and proposes some problems that require future study.

2. Model

We consider a country with two homogeneous regions: region 1 and region 2. Each region has homogeneous residents and one firm[*2]. Residents in each region are standardized to one unit. Furthermore, because of the assumption of short-term economic conditions, no interregional migration occurs[*3]. Each firm produces a private good and each resident demands the private good. The production of the good results in pollution of the environment. Firms' emissions have transboundary spillovers. Inverse demand functions of the good of region i are assumed as shown below.

$$P_i = a - q_i \tag{1}$$

Therein, the term P_i denotes the market price of region i. Term q_i represents the demand for the good in region i. Under this inverse demand function, the consumers' surplus in region i is expressed as

$$CS_i = \frac{1}{2}q_i^2. \tag{2}$$

This paper presents analyses based on the assumption that the marginal cost of the firm in region i to supply the private good equals c. This marginal cost is the same level among the regions. The cost function of the firm in region i is $C(q_i) = cq_i$[*4]. The analyses presented in this paper are made on the assumption that if the output of the firm in region i is q_i, then emissions in region i are q_i. Moreover, if the degree of emissions is one, the degree of spillover is also one. Consequently, the total quantity of the emissions in region i is

$$s_i = q_i + q_j. \tag{3}$$

In eq. (3), the term s_i is the total quantity of the emissions in region i. Following Petrakis and Xepapadeas (2003)[3], the extent of the environmental damage is assumed as

$$D(q_i, q_j) = \frac{1}{2}\alpha s_i^2 = \frac{1}{2}\alpha(q_i + q_j)^2. \tag{4}$$

Here, α is the degree of environmental damage, and $0 < \alpha < \frac{3}{4}$ is assumed[*5]. Furthermore, α is the same in both regions.

The profit of the firm in region i is $\pi_i = P_i q_i - cq_i$. From eq. (1), the profit of the firm in region i is

$$\pi_i = Aq_i - q_i^2. \tag{5}$$

For this analysis, we assume that $A \equiv a - c(> 0)$.
The firm in region i aims to maximize its value, denoted by[*6]

$$V_i = k\pi_i + (1 - k)(CS_i + \pi_i - D_i). \tag{6}$$

Here, k is the degree of privatization based on the assumption that $0 \leq k \leq 1$. Using the consumers' surplus in region i, eq. (2) and the profit of the firm in region i eq. (5), the firm's value in region i is

$$V_i = -\frac{1}{2}(1 + k)q_i^2 + Aq_i - (1 - k)\frac{1}{2}\alpha(q_i + q_j)^2. \tag{7}$$

The welfare level in region i is defined as

$$W_i = \pi_i + CS_i - D_i \qquad (8)$$

Here, using the profit of the firm in region i eq. (5), and the consumers' surplus in region i eq. (2), and the extent of the environmental damage eq. (4), the welfare in region i is

$$W_i = Aq_i - \frac{1}{2}q_i^2 - \frac{1}{2}\alpha(q_i + q_j)^2. \qquad (9)$$

Furthermore, social welfare is definable as $SW = \sum W_i$. The game played between the firm in each region and the government is constructed using a two-stage decision-making process. In the first stage, the government chooses the level of privatization, $k(0 \leq k \leq 1)$, to maximize social welfare. Observing k, firms choose the level of output to maximize their own firm's value in the second stage.

By following the concept of backward induction, we solve the equilibrium from the second stage.

3. Decision of the polluting firm and privatization

The firm in region i determines the output of the good to maximize the firm's value V_i. Accordingly, the problem of the firm in region i is the following

$$\max_{q_i} V_i = (1-k)CS_i + \pi_i - (1-k)D_i.$$

We can derive the first-order condition as presented below.

$$(1-k)\frac{dCS_i}{dq_i} + \frac{dTR_i}{dq_i} = c + (1-k)\alpha(q_i + q_j) \qquad (10)$$

Here, the total revenue of the firm in region i is TR_i ($TR_i \equiv (a - q_i)q_i$). The left-hand side of eq. (10) is the sum of consumers' surplus's and total revenue's marginal increase from the supply of the good in region i. Consequently, the left-hand side of eq. (10) is the marginal benefit from the good in region i.

The right-hand side of eq. (10) is the sum of the cost and environmental damage marginal increase from the supply of the good in region i. Therefore, the right-hand side of eq. (10) is the marginal cost from the good in region i.

Therefore, eq. (10) is the condition under which the marginal benefit from the good equals the marginal cost from the good in region i. The firm in region i determines the output of the good to meet eq. (10), given the output of the good in the other region.

The output of the good in region i which meets eq. (10) in each region is the following.

$$q^r = \frac{A}{2\alpha + (1 - 2\alpha)k + 1} \qquad (11)$$

Here, the output of the good in region i denotes q^r. Equation (11) denotes the best reaction function of the firm in region i on the degree of privatization, which is

decided by the government. With regard to output q^r, the results of comparative static analyses indicate the following.

Proposition 1
When emissions only slightly affect environmental damage, $\alpha < \frac{1}{2}$, privatization will decrease the output of the good in region i.
When the effect of emissions on environmental damage is large, $\alpha > \frac{1}{2}$, then privatization will increase the output of the good in region i.
When $\alpha = \frac{1}{2}$, the output of the good in region i is always the same level, irrespective of the degree of privatization.

The interpretation of proposition 1 is the following.

First, for $\alpha < \frac{1}{2}$, from eq. (10), when the degree of privatization increases, the marginal benefit and the marginal cost of the good in region i decrease. Regarding reduction of the marginal benefit, the firm underevaluates the marginal benefit of the good because the greater the degree to which privatization is realized, the less the firm devotes consideration to the consumers' surplus and weights the private profit to supply the good. However, regarding the reduction of the marginal cost, the firm underevaluates the marginal cost of the good because the more privatization is realized, the less the firm considers the environmental damage by emissions to supply the good. Here, in the case of $\alpha < \frac{1}{2}$, because the effect of the environmental damage by emissions is small, the degree of underevaluation of the marginal cost by privatization is small and the degree of underevaluation of the marginal benefit is large. Consequently, in the case of $\alpha < \frac{1}{2}$, when the degree of privatization increases, the output of the good in region i will decrease.

For $\alpha > \frac{1}{2}$, from eq. (10), It is noteworthy that when the degree of privatization increases, the marginal benefit and the marginal cost of the good in region i decrease.

Interpretation of the decrease of the marginal benefit and the marginal cost is the same in the case of $\alpha < \frac{1}{2}$. The more privatization is realized, the less the firm considers the consumers' surplus and weights the private profit to supply the good. Moreover, the more privatization is realized, the less the firm considers environmental damage by emissions to supply the good. Here, for $\alpha > \frac{1}{2}$, the degree of underevaluation of the marginal cost by privatization is large and the degree of underevaluation of the marginal benefit is small because the effect of the environmental damage by the emission is large. Therefore, for $\alpha > \frac{1}{2}$, when the degree of privatization increases, the output of the good in region i is expected to increase.

For $\alpha = \frac{1}{2}$, from eq. (10), when the degree of privatization increases, the marginal benefit and the marginal cost of the good in region i will decrease. These circumstances are the same as those described above. Here, in the case of $\alpha = \frac{1}{2}$, the effect of underevaluation of the marginal cost by privatization is offset by the effect of underevaluation

of the marginal benefit. Consequently, in the case of α = ½, even if the degree of privatization increases, the output of the good in region i will not change.

In research by Beladi and Chao (2006)[1]) and others, the public firm considers the consumers' surplus and the private profit when the firm chooses the output of the good. Consequently, the more privatization is realized, the less the firm considers the consumers' surplus. Therefore, when the degree of privatization increases, the marginal benefit of the good decreases and the output of the good will decrease. In contrast, in the analyses presented herein, the public firm considers not only the consumers' surplus but also the environmental damage when the firm chooses the output of the good. Consequently, the more privatization is realized, the less the firm considers both the consumers' surplus and the environmental damage.

4. Decision of the government

In this section, we analyze the policy decision of the government. The government anticipates the reaction function of the firm in each region (eq. (11)) and decides whether to privatize each firm or not. Here, the government acts to maximize social welfare. The social welfare, which is the sum of the welfare in two regions, is the following

$$SW = Aq_1 - \frac{1}{2}q_1^2 - \frac{1}{2}\alpha(q_1+q_2)^2 + Aq_2 - \frac{1}{2}q_2^2 - \frac{1}{2}\alpha(q_2+q_1)^2. \quad (12)$$

From eq. (12), the first derivative of SW, with respect to k is derived as

$$\frac{dSW}{dk} = \{2A - 2(1+4\alpha)q^r\}\frac{dq^r}{dk}. \quad (13)$$

Consequently, inserting eq. (11) into eq. (13), eq. (13) is given as

$$\frac{dSW}{dk} = \frac{2A(-3\alpha+k-2\alpha k)}{2\alpha+(1-2\alpha)k+1}\frac{dq^r}{dk}. \quad (14)$$

Here, from proposition 1, $dq^r / dk > 0$ when marginal environmental damage exists between ½ < α < ¾. Consequently, it is apparent that $dSW / dk < 0$ when ½ < α < ¾. Therefore, we can reach the following conclusion.

Proposition 2

If ½ < α < ¾, then the optimal policy decision of the government is not privatization.

The interpretation of proposition 2 is the following. When the marginal damage of the emissions is ½ < α < ¾ because the damage from emissions on the environment is large, then privatization will increase the output of the good, as inferred from proposition 1. Therefore, privatization will increase the consumers' surplus and the private firm profit. However, an increase in emissions will increase the environmental damage. Here, when the marginal damage of the emissions is ½ < α < ¾,

the degree of increase in the environmental damage is expected to be greater than the degree of an increase in the consumers' surplus and in the private firm profit.
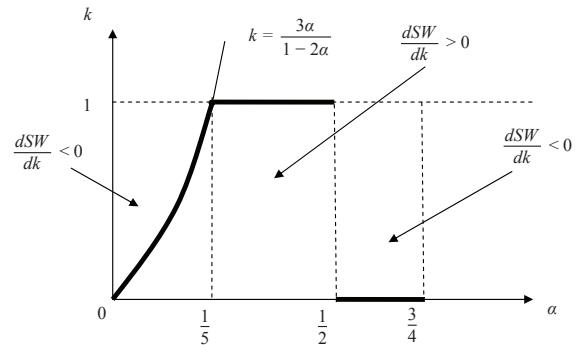
Consequently, privatization will decrease social welfare. When the marginal damage of the emissions is ½ < α < ¾, then the optimal policy decision of the government is not privatization.

Next, we consider the case in which the damage of emissions to the environment is slight. From proposition 1, $dq^r / dk < 0$ when the marginal environmental damage is 0 < α < ½. In this range of α, we can obtain the following relation from eq. (14).

$$k \geq (<) \frac{3\alpha}{1-2\alpha} \Leftrightarrow \frac{dSW}{dk} \leq (>)0$$

Figure 1 depicts this relation.

Consequently, from Figure 1, we can obtain the following conclusion.

Fig. 1　Optimal policy decision of the government.

Proposition 3

If ⅕ < α < ½, then the optimal policy decision of the government is full privatization.
If 0 < α < ⅕, then the optimal policy decision of the government is partial privatization.

The interpretation of proposition 3 is the following. When the marginal damage of the emissions is ⅕ < α < ½ because the damage that emissions inflict on the environment is small, then privatization will decrease the output of the good based on proposition 1. Consequently, privatization will decrease the consumers' surplus and the private firm profit. However, a decrease in the emissions will decrease the environmental damage. Here, when the marginal damage of the emissions is ⅕ < α < ½, the degree of a decrease in the environmental damage will be greater than the degree of a decrease in the consumers' surplus and in the private firm profit.

Results show that privatization will increase social welfare. When the marginal damage of the emissions is ⅕ < α < ½, then the optimal policy decision of the

government is full privatization.

When the marginal damage of the emissions is $0 < \alpha < \frac{1}{5}$ because the damage that emissions impose on the environment is small, then privatization will decrease the output of the good based on proposition 1. Consequently, privatization will decrease the consumers' surplus and the private firm profit. However, a decrease in emissions will decrease the environmental damage.

Here, when the marginal damage of the emissions is $0 < \alpha < \frac{1}{5}$, if the level of k is small, then the degree of a decrease in the environmental damage will be greater than the degree of a decrease in the consumers' surplus and in the private profit of the firm. Therefore, if the level of k is small, then privatization will increase social welfare. However, if the level of k is large, then the degree of the decrease in the environmental damage will be smaller than the degree of the decrease in the consumers' surplus and in the private firm profit. Therefore, in this case, privatization will decrease social welfare.

This result is unlike those presented for $\frac{1}{5} < \alpha < \frac{1}{2}$. Consequently, when the marginal damage of the emissions is $0 < \alpha < \frac{1}{5}$, the optimal policy decision of the government is partial privatization.

Accordingly, the salient implication of the analyses described in this paper is the following. Privatization of a firm that emits harmful (slightly harmful) pollutants will increase (decrease) the output of the good and the environmental damage. This environmental effect is greater than the effects of the consumers' surplus and the private profit of the firm. Therefore, regarding aspects of the efficiency and the environment, we consider that the government should not privatize a firm that produces harmful emissions and should privatize firms that emit some harmful pollutants. Privatization of a firm that produces few harmful emissions will decrease the output of the good and environmental damage. In this case, the government should privatize the firm partially to decrease the environmental damage.

5. Concluding Remarks

This paper presents analysis of whether the central government should privatize a polluting firm in a region under circumstances including transboundary pollution. Characteristics of these analyses are the following. First, in this paper, the polluting firm is a monopoly firm in each region. The public firm considers not only the consumers' surplus and the private profit but also the environmental damage that occurs when the firm chooses the output of the good. This paper's second characteristic is that it presents consideration of the degree of the influence that the exhaust of the pollution emissions imparts on the environment. Such damage can be of various levels.

This paper presents the following conclusions. When the effect that emissions impose on the environment is small (large), privatization will decrease (increase) the output of the good in the region.

These results are interpreted as follows. The greater

the degree to which privatization is realized, the less the firm considers the consumers' surplus and weights the private profit to supply the good. Moreover, the more privatization is realized, the less the firm considers the environmental damage caused by emissions.

These results, which demonstrate the influence that privatization exerts on the output of the good, differ depending on the degree of the environmental damage. The results therefore differ from those of previous studies. Furthermore, the results constitute an important discovery because the effects of privatization on social welfare differ depending on the degree of the environmental damage.

Regarding the problem of the optimal policy decision of the government, the results demonstrate the following. When environmental damage from emissions is large (small), the optimal policy decision of the government is not (full) privatization. Moreover, when the effect that emissions have on the environment is small, the optimal policy decision of the government is partial privatization. Especially, the partial privatization result differs from those of previous studies. It is a particularly interesting result.

We use a simple setup for these analyses. For that reason, this paper presents some problems along with the results. First, for these analyses, we assume two identical regions. Therefore, we assume circumstances under which firm technology is identical among regions. However, in general, firm structure and technology differ among regions. Therefore, in the future, we must analyze the problem of this paper under an asymmetric region model in which the degrees of privatization differ among regions.

For these analyses, we assume circumstances under which, if the degree of the emissions is one when the firm produces the output, then the degree of spillover is one. We undertake analyses in circumstances under which the spillover of the emissions is perfect. To realize a more general model, we must analyze the problem of this paper under circumstances where the spillover of the emissions is not perfect. Moreover, analysis of the problem presented in this paper under circumstances where the emissions spillover is of different levels among regions might be more adequate to describe real circumstances.

In this paper, we held up an electric power company as an example, and analyzed the privatization problem. Actually, an electric power company is a natural monopoly subject to price regulation by the government. Therefore, in a future study, we need to consider fixed costs and comparatively analyze average cost pricing and nationalization.

As explained in this paper, we analyzed the circumstances in which the central government decides to undertake privatization of a polluting firm in each region. We might be able to apply the model of our study to a two-country model. Consequently, based on

the analyses described in this paper, our future analyses will include an investigation of whether the decision of privatization policy in each country is efficient under circumstances where transboundary pollution occurs.

Moreover, we might be able to apply the model presented herein to the international trade framework. Therefore, we want to analyze whether the decision of privatization policy in each country is efficient or not under circumstances including cross-border consumption in the future.

(*1) Note: Analyzing price regulation and privatization is important, because natural monopolies' pricing policies are generally subject to government regulation. However, following Beladi and Chao (2006)[1], we model a simple monopoly firm in our paper because our focus is on how privatization affects the environment and influences social welfare.

(*2) Note: Beladi and Chao (2006)[1] analyzed the privatization of a monopoly polluting firm to address the environmental tax decision, using a one-country model. In contrast, we employ a two-region model with transboundary pollution.

(*3) Note: Markusen (1975)[4], Dasgupta et al. (1997)[5] also constructed a model, similar to ours. However, we might have to consider interregional migration while analyzing long-term economic conditions. For example, Wellisch (1994[7], 1995[8], 2000[9]) analyzed decentralized environmental policy decisions with a transregionally mobile population.

(*4) Note: Neary (1994)[12] does not assume a fixed cost or variable marginal cost.

(*5) Note: With this assumption, the social welfare from full privatization is positive. As regards the interpretation of this assumption, the degree of environmental damage might be low because we specifically examine air pollution herein.

(*6) Note: Beladi and Chao (2006)[1] do not incorporate

environmental damage into the firm's value. Generally speaking, the public firm might consider the environmental damage in the firm's value because the public firm is governed by residents. Naito and Ogawa (2009)[13] address environmental regulation in a partially privatized mixed duopoly, assessing environmental damage effects on the firm's value.

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