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AN ECONOMIC ANALYSIS OF THE WASTE AND RECYCLING POLICY OF JAPAN AND TAIWAN

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ABSTRACT

Over the past two decades, waste generation has increased at a rate similar to economic advances and caused serious environmental problems in many industrialized countries. These problems include the shortage of landfill sites, harmful substances from waste incineration facilities, and environmental risks such as air, water, and soil contamination from landfill sites and illegal dumping. In order to deal with these problems, the authorities have tried to intervene using a variety of waste management policies. Since the 1990s, they have strengthened the 3R (Reduce, Reuse, and Recycle) framework by treating waste as a valuable resource. In this way, Japan is steadily implementing approaches toward the establishment of a Sound Material-Cycle Society (hereafter SMS). To establish the SMS, various laws have been enforced to build systems of waste disposal and recycling concerning a variety of products: household appliances, automobiles, and personal computers for example. However, recycling policies for the same type of product widely vary among countries. Since its various policies have an influence on the establishment of the SMS, we need to research recycling policies among countries from an economic point of view.

Thus the purpose of this paper is to make an economic analysis of waste and recycling policy among countries. In particular, we address the personal computer recycling systems of Japan and Taiwan and make a policy evaluation of these systems from the viewpoint of social welfare. Our analysis shows two main results as follows. First social welfare cannot be maximized under the Japanese system. Second there is a possibility that social welfare is maximized under the Taiwanese system depending on the behavior of Resource Management Funds.

Key words: *Recycling, Waste, Waste management policy.*

JEL Classification: Q53, Q56

AN ECONOMIC ANALYSIS OF THE WASTE AND RECYCLING POLICY OF JAPAN AND TAIWAN

1. Introduction

Over the past two decades, waste generation has increased at a rate similar to economic advances and caused serious environmental problems in many industrialized countries. These problems include the shortage of landfill sites, harmful substances from waste incineration facilities, and environmental risks such as air, water, and soil contamination from landfill sites and illegal dumping. In order to deal with these problems, the authorities have tried to intervene using a variety of waste management policies.

After the end of World War 2, the issue of waste disposal was treated as a public sanitation issue in Japan. Thus the Public Cleaning Law was enacted in 1954, with a stated purpose of improving public health by sanitarily disposing of waste and cleaning the living environment. From the mid-1950s to the end of the 1970s, Japan's rapid economic growth resulted in major changes in lifestyles represented by televisions, refrigerators, and washing machines. These home appliances made our lives better; however, they also caused a new waste disposal problem. Because of technical difficulties in treating some substances such as plastics, it is said that nearly 40% of waste generated from home appliances was disposed of in landfills or dumped in mountainous areas. Moreover in the 1990s, the amount of waste which is difficult to dispose of properly (e.g., PET bottles) has increased and the variety of such waste has also increased. As a result of our useful and convenient lives, we faced a serious lack of landfills, and harmful substances such as chlorofluorocarbons and dioxin.

The authorities then decided to reinforce the waste policy instruments represented by recycling policy to tackle the new waste problem. Since 1991, they have strengthened the so-called 3R (Reduce, Reuse, and Recycle) framework by seeing waste as a valuable resource. In this way, Japan is steadily implementing approaches toward the establishment of a Sound Material-Cycle Society (hereafter SMS). [1] To establish the SMS, we must keep the order of priority to deal with waste. First we have to reduce the amount of waste from products. Next we have to utilize waste generated as resources to reduce the amount of waste disposed in landfills. Finally we need to do appropriate landfilling of waste that cannot be used as resources.

Hence various laws have been enforced to build systems of waste disposal and recycling concerning a variety of products: household appliances, automobiles, and personal computers for example. The basic goal of these laws is the promotion of recycling. More than other countries, the

[1] The SMS is the concept defined in the Basic Law for Establishing a SMS in 2000 and a society where the consumption of natural resources is minimized and the environmental load is reduced as much as possible.

progress of recycling is the central purpose of the waste management policy. However recycling policies for the same type of a product widely vary among countries. Since its various policies have an influence on the establishment of the SMS, we need to research recycling policies among countries from an economic point of view.

Therefore the purpose of this paper is to make an economic analysis of waste and recycling policy among countries. In particular, we address the personal computer (hereafter PC) recycling systems of Japan and Taiwan and make a policy evaluation of these systems from the viewpoint of social welfare.

In previous research, the most relevant study is Wen (2006). She examines the recycling policy in Taiwan and derives the optimal policy mix to internalize market failure. She interprets the recycling policy in Taiwan as a deposit-refund system by product taxes and recycling subsidies. This system has been theoretically examined by Dinan (1993), Palmer and Walls (1997), and Fullerton and Wolverton (2000). They researched what are the optimal policy instruments to internalize the social costs for the waste problems. On the other hand, we examine the actual policy instruments in Japan and Taiwan and evaluate the policy instruments in both countries from the viewpoint of efficiency.

However we will refer to her model to build the economic model under Taiwan.

This paper is organized as follows. The next section surveys the PC recycling systems of Japan and Taiwan and reveals the characteristics of these systems. In section 3, we build a basic model to do a policy evaluation of both systems. Section 4 does the policy evaluation of these systems from the viewpoint of social welfare. Lastly, we summarize results of our analysis and mention the implications for this study.

2. PC Recycling Systems of Japan and Taiwan

In this section, we survey the PC recycling systems of Japan and Taiwan, show the background of the systems in each country, and reveal the features of both systems.

2.1. PC Recycling Systems of Japan

Based on the Law for Promotion of Effective Utilization of Resources in 2001, PCs were designated as specified resources-saved products. After that, PCs were designated as specified resources-reconverted products. All businesses which manufacture and sell PCs or import and sell PCs (hereafter manufacturers) are obliged to collect and recycle their PCs. For this purpose, manufacturers built the PC recycling system voluntarily. Table 1 indicates the change of related actors before and after the PC recycling system of Japan.

Table 1: Change of Related Actors before and after the PC Recycling System of Japan

System	Manufacturers	Consumers	Municipalities
Before	No	Discard	Collection & Disposal
After	Collection & Recycle	Discard	Collection in part

Table 1 shows that the manufactures were not obliged to collect and recycle used PCs before this system. Instead the municipalities were responsible for the collection and disposal of discarded PCs. Therefore consumers discarded their used PCs disregarding the true costs of collection and disposal. However under the PC recycling system of Japan, manufacturers have to conduct collection and recycling of used PCs and built a collection route from consumers. Moreover they charged the consumers the fee for the costs of collection and recycling of discarded PCs when purchasing the PCs. This fee is added to the price implicitly. The municipalities have to collect used PCs as bulky refuse. They can ask the 3R (Reduce, Reuse, and Recycle) center which is organized by the manufacturers to take back and properly recycle the waste collected.

2.2. PC Recycling System of Taiwan

Let us begin with the background of the system in Taiwan. According to Lee et al. (2000), it is estimated that nearly 300,000 scrap personal computers are presently generated each year. The scrap PC recycling system has not been well developed when compared with the traditional scrap car recycling system in Taiwan before 1988. There is no single company which specializes in used PC recycling. However some local scrap recyclers take large quantities of used PCs from schools and stockbrokers. They remove the plastic and iron from the scrap PCs and can sell them to a local secondary recycling plant. The remaining non-recyclable materials including the harmful substances are disposed of in landfills or by illegal dumping. Therefore the harmful substances contained in scrap PCs may pollute the environment if they are inappropriately disposed of in landfills or mountain areas.

The PC recycling system of Taiwan is based on the Waste Disposal Act of Taiwan's Environmental Protection Administration (EPA). Prior to 1988, the discarded materials with the following properties had to be recovered and treated properly by manufacturers, importers, and sellers: 1) difficult to be collected and disposed of, 2) not containing readily decomposable substances, 3) containing hazardous substances, and 4) can be recycled. Based on the above conditions, the Taiwan EPA declared discarded PCs as a producer-responsibility product in 1997. Table 2 shows the change of related actors before and after the PC recycling system of Taiwan.

Table 2: Change of Related Actors before and after the PC Recycling System of Taiwan

System	Manufacturers	Consumers	Municipalities	RMF (by EPA)
Before	No	Discard	Collection & Disposal	No
After	Payment of fee	Discard	Collection & Deliver	Receipt of fee & Payment of subsidy

As Table-2 indicates, the responsibility of each related actor is the same as Japan before this system. On the other hand, there are many scrap recyclers of used PCs since the value of the resources is high. However after processing and recycling the used PCs they treat improperly the non-recyclable materials by disposing of them in landfills or illegal dumping. These materials may contain harmful substances which can seriously pollute the environment. Hence the EPA founded the Recycling Management Foundation (hereafter RMF) to promote recycling properly under the management of the regulation authority. The manufacturers are obliged to pay the recycling fee to the RMF according to numbers of PCs sold. Recyclers are subsidized by RMF in accordance with the collected amount of PCs. This subsidy is covered by the payment of the fee. Based on the above foundation, the PC recycling system is established. Under this system, the municipalities can get revenue by delivering discarded PCs collected from consumers.

3. Basic Model

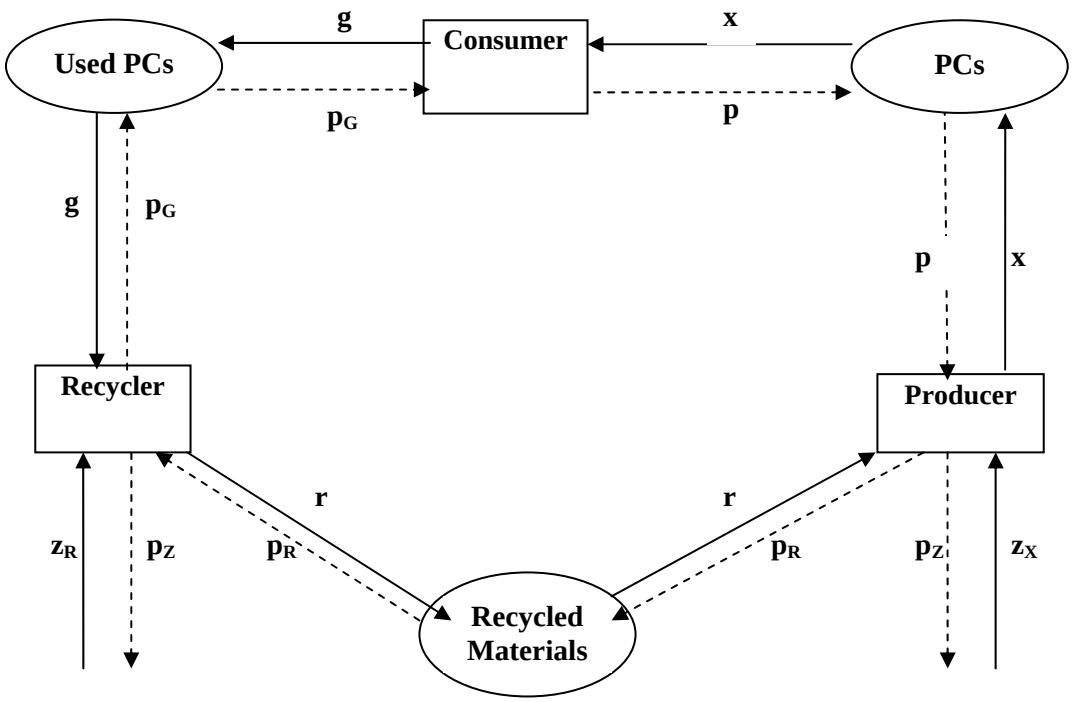
In this section, we build a basic model to make a policy evaluation of both systems. First we explain basic assumptions for our model and define social welfare in this economy. Next we show the economic equilibrium conditions under both systems.

3.1. Basic Assumptions and Social Welfare

We presuppose an economy constituted of three markets; PCs, used PCs, and recycled materials[2]. All markets are assumed to be perfectly competitive. Figure 1 expresses the basic behavior of each economic actor in this economy.

[2] In general, the term “used PCs” is employed as the meaning of PCs traded at second hand markets. However we use the term “used PCs” as the meaning of PCs which the consumers use up and throw away as useless.

Figure 1: Basic Behavior of Each Economic Actor



First the producers produce the PCs x using recycled materials r and a composite of other inputs z_X (e.g., labor and capital). We denote the price of the PCs by p, the price of recycled materials by p_R, and the price of the composite inputs by p_Z. The consumers buy the PCs and hand over the used PCs denoted by g to the recyclers. When the consumers hand over the used PCs to the recyclers, they can take the price of the used PCs p_G from the recyclers. Moreover the recyclers produce recyclable materials using the used PCs and a composite of other inputs z_R. We assume the representative actor for all the economic actors and represent the behavior of each actor mathematically.

Firstly the producer's production function is given by $x = X(r, z_X)$ and its property is $X_i < 0, X_{ii} < 0 \ (i = r, z)$. Then the cost minimization problem can be stated as follows.

$$\min \ \ \bar{p}_Z z_X + p_R r \ \ s.t \ \ x = X(r, z_X) \qquad (1)$$

We can get the conditions for cost minimization and derive the optimal amount of each input denoted by $r(x), z_X(x)$. Using these conditional factor demands, the cost function for the producer can be represented by

$$C(x) \equiv \bar{p}_Z z_X(x) + p_R r(x) \qquad (2)$$

assuming that its property is $C'(\equiv dC/dx) > 0, C''(\equiv d^2C/dx^2) > 0$. Using this cost function, we can write the producer's profit as

$$\pi = px - C(x) \qquad (3)$$

Secondly we assume that the consumer is the actor to get the net benefit defined by

$$V = U(x, g) + \overline{m} - px + p_G g \tag{4}$$

where $U(x, g)$ is a utility function derived from the purchase of the PCs and the delivery of used PCs. It is assumed that its properties are $U_x > 0, U_{xx} < 0, U_g < 0, U_{gg} < 0$. That is, the marginal utility for the PCs is positive and decreasing, but the marginal utility for the used PCs is negative and decreasing since the delivery of used PCs to the recyclers generates opportunity costs (e.g. additional labor to transport the used PCs). $\overline{m}$ is an income level and a constant. The third term is the payment from the purchase of the PCs. The fourth term is the receipt from handling of the used PCs. Moreover the amount of used PCs is given by

$$g = \overline{\alpha} x \tag{5}$$

Let $\overline{\alpha}$ be the rate at which the consumer delivers used PCs to the recycler and a constant. We suppose that consumers practice illegal dumping of used PCs. The amount of used PCs dumped illegally is represented by

$$g_I = (1 - \overline{\alpha}) x \tag{6}$$

The recyclers produce the recyclable materials using the used PCs and a composite of other inputs. Then we assume that the relationship between the used PCs and composite inputs is a perfect complement, which is written[3]

$$r = R(z_R) = \overline{\beta}_R g \tag{7}$$

where the first equation states the relationship between the amount of recycled material and the composite inputs. Its property is $R' > 0, R'' < 0$. Solving the function with respect to z_R, we can get $z_R(r)$. The second equation represents the relationship between the amount of recycled material and the used PCs. $\overline{\beta}_R$ denotes the proportion of recycled materials which can be produced per unit of the used PCs and is assumed to be a constant. After the production process of recycled materials, the remaining substances generated are to be disposed of in landfills. Then the amount of the residual disposed of legally in landfills is given by

$$b = \overline{\beta}_B g \tag{8}$$

where $\overline{\beta}_B$ is the rate which the recyclers treat the residual properly in landfills. Thus the amount of the residual disposed of illegally in landfills or mountain areas is represented by

$$b_I = (1 - \overline{\beta}_R - \overline{\beta}_B) g = (1 - \overline{\beta}) g \tag{9}$$

where $\overline{\beta} \equiv \overline{\beta}_R + \overline{\beta}_B$. Finally we can state the recycler's profit as follows

[3] This specification about the relationship between used PCs and composite inputs is based on Eichner (2005).

$$\Pi = p_R r - \bar{p}_Z z_R(r) - \bar{p}_B b - p_G g \tag{10}$$

where the first term is the revenue by selling recycled materials, the second term is the payment of the composite inputs, the third term is the payment for legal disposal of the residual in landfills, and the fourth term is the expenses to collect the used PCs from the consumers.

We assume that social welfare in this economy is defined as the social surplus and written

$$SS \equiv CS + PS + RS - E(g_I, b_I) \tag{11}$$

where CS is the consumer surplus given by

$$CS \equiv U(x, g) - px + p_G g \tag{12}$$

The producer surplus is denoted by $PS \equiv \pi$ and the recycler surplus is represented by $RS \equiv \Pi$. Moreover $E(g_I, b_I)$ describes the environmental damage or social costs of illegal dumping or disposal by consumers and recyclers and is assumed to be characterized as

$$E(g_I, b_I) \equiv E_G(g_I) + E_B(b_I) \tag{13}$$

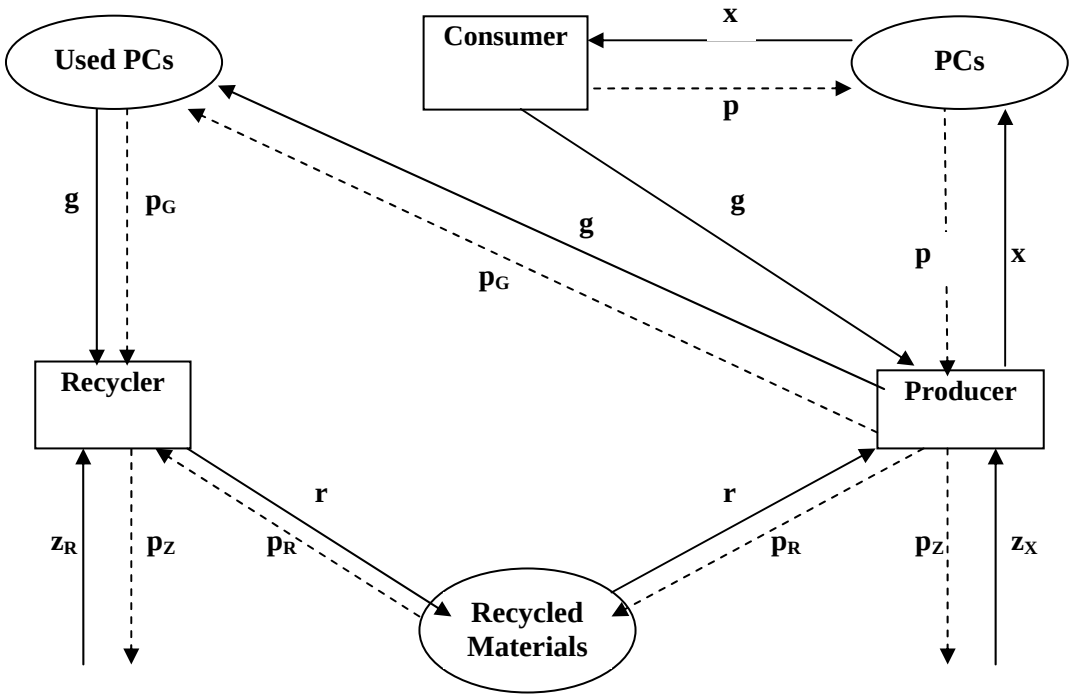
where its property is $E_i' > 0, E_i'' > 0 (i = G, B)$. Therefore we can derive social welfare as follows.

$$SS = U(x, g) - \bar{p}_Z(z_X(x) + z_R(r)) - \bar{p}_B b - E_G(g_I) - E_B(b_I) \tag{14}$$

3.2. Economic Equilibrium under Japanese System

Next we show the economic equilibrium conditions under Japan's PC recycling system. Figure 2 indicates the behavior of each actor under the Japanese system.

Figure 2: Behavior of Each Actor in Japan's PC Recycling System



Under Japan's system, the producers have to take back used PCs from the consumers in the event that the consumers require the producers to collect the used PCs. Then the producers can add the transport, recycling, and landfill costs to the price of the PCs. On the other hand, the recyclers do the recycling of used PCs and can take the charges for recycling and landfill from the producers.

Therefore the producer's profit, the consumer's net benefit, and the recycler's profit are expressed respectively by

$$\pi^J = (p+q)x - C(x) - p_G g \tag{15}$$

$$V^J = U(x,g) + \overline{m} - (p+q)x \tag{16}$$

$$\Pi^J = p_R r - \overline{p}_Z z_R(r) - \overline{p}_B b + p_G g \tag{17}$$

First the conditions of maximization of the producer's profit is given by

$$\pi_x^J = (p+q) - C'(x) - p_G \overline{\alpha} = 0 \tag{18}$$

Next we get the conditions of maximization of the consumer's net benefit as follows

$$V_x^J = U_x + U_g \overline{\alpha} - (p+q) = 0 \tag{19}$$

Lastly the profit maximization conditions for the recycler is shown by

$$\Pi_g^J = p_R \overline{\beta}_R - \overline{p}_Z z_R' \overline{\beta}_R - \overline{p}_B \overline{\beta}_B + p_G = 0 \tag{20}$$

Combining these maximization conditions yields the following equation.

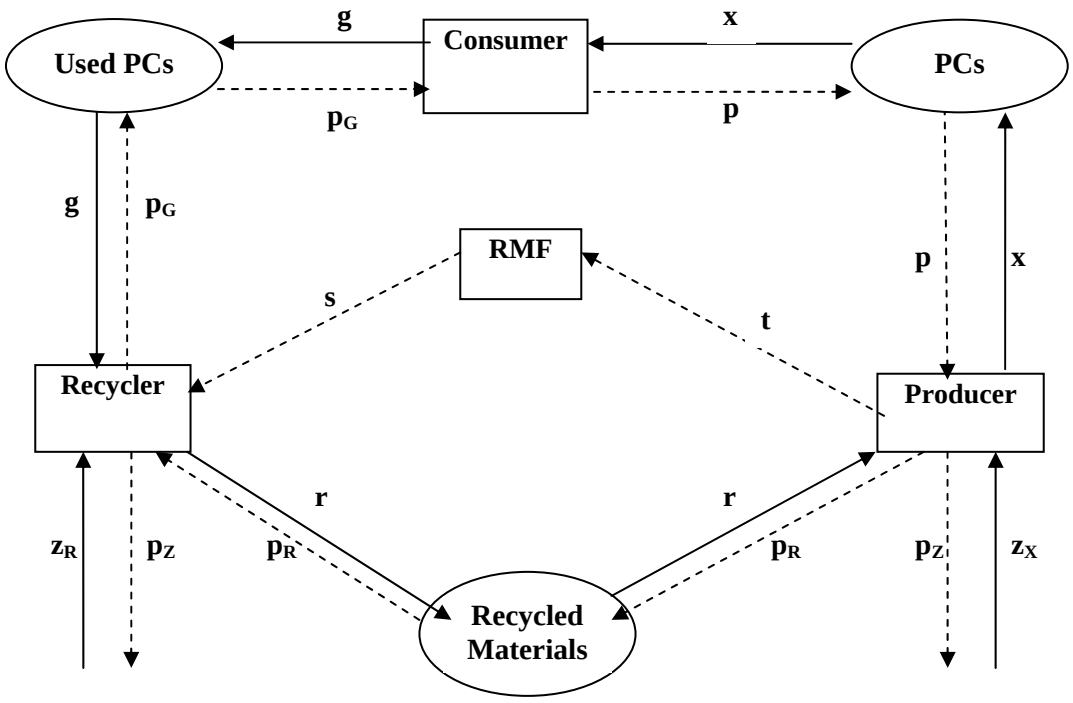
$$U_x + U_g \overline{\alpha} - \overline{p}_Z (z_X' + z_R' \overline{\beta}_R \overline{\alpha}) - \overline{p}_B \overline{\beta}_B \overline{\alpha} = 0 \tag{21}$$

where $r(x) = \overline{\beta}_R \overline{\alpha} x$ from the equilibrium conditions of the recycling market. This equation shows the economic equilibrium conditions under the Japanese system.

3.3. Economic Equilibrium under Taiwanese System

Thirdly we show the economic equilibrium conditions under Taiwan's PC recycling system. Figure 3 indicates the behavior of each actor in the Taiwanese system.

Figure 3: Behavior of Each Actor in Taiwan's PC Recycling System



Under the Taiwanese system, the RMF plays an important role. The RMF offers subsidies to recyclers in accordance with the amount of used PCs collected and levies the product fee on producers according to the numbers of PCs sold.

Therefore the producer's profit, the consumer's net benefit, and the recycler's profit are expressed respectively by[4]

$$\pi^T = px - C(x) - tx \tag{22}$$

$$V^T = U(x, g) + \overline{m} - px + p_G g \tag{23}$$

$$\Pi^T = p_R r - \overline{p}_Z z_R(r) - \overline{p}_B b - p_G g + sg \tag{24}$$

First the conditions of maximization of the producer's profit is given by

[4] The specification of the producers and recyclers is the same as Wen (2006). Although she built the model constituted by producers and recyclers, we built the model including consumers.

$$\pi_x^T = p - C'(x) - t = 0 \tag{25}$$

Next we get the conditions of maximization of the consumer's net benefit as follows

$$V_x^T = U_x + U_g\overline{\alpha} - p + p_G = 0 \tag{26}$$

Lastly the profit maximization condition for the recycler is shown by

$$\Pi_g^T = p_R\overline{\beta}_R - \overline{p}_Z z'_R\overline{\beta}_R - \overline{p}_B\overline{\beta}_B - p_G + s = 0 \tag{27}$$

Combining these maximization conditions yields the following equation.

$$U_x + U_g\overline{\alpha} - \overline{p}_Z(z'_X + z'_R\overline{\beta}_R\overline{\alpha}) - \overline{p}_B\overline{\beta}_B\overline{\alpha} - t + s\overline{\alpha} = 0 \tag{28}$$

where $r(x) = \overline{\beta}_R\overline{\alpha}x$ from the equilibrium conditions of the recycling market. This equation shows the economic equilibrium conditions under the Taiwanese system.

4. Policy Evaluation of Japanese and Taiwanese Systems

In this section, we evaluate recycling policy for PCs in Japan and Taiwan and consider some additional policies for the present PC recycling system in both countries.

To begin with, we apply the maximization of social welfare as a standard to judge the PC recycling systems in both countries. Differentiating the social welfare denoted by equation (14) with respect to x, we can represent the influence of the change of amount of PCs on social welfare as follows.

$$SS_x \equiv U_x + U_g\overline{\alpha} - \overline{p}_Z(z'_X + z'_R\overline{\beta}_R\overline{\alpha}) - \overline{p}_B\overline{\beta}_B\overline{\alpha} - E'_G(1-\overline{\alpha}) - E'_B(1-\overline{\beta})\overline{\alpha} \tag{29}$$

Then we can check whether the social welfare in economic equilibrium under each system can be maximized using this equation with the economic equilibrium conditions under each system.

4.1. Policy Evaluation of Japanese System

Firstly we want to know whether social welfare is maximized under the Japanese system. Substituting the economic equilibrium conditions under the Japanese system denoted by equation (21) into equation (29), we can show the influence of the change of amount of PCs under the Japanese system on social welfare as follows.

$$SS_x \equiv -E'_G(1-\overline{\alpha}) - E'_B(1-\overline{\beta})\overline{\alpha} < 0 \tag{30}$$

This equation indicates the effect of the change of PCs on social welfare is a negative. In other words, social welfare under the Japanese system cannot be maximized.

Let us examine this result in more detail. Under the Japanese system, physical responsibility for taking back and recycling used PCs lies with the producers. However the range of their responsibility

is restricted to cases in which consumers require the producers to take back the used PCs. As a consequence, the public authority performs the collection and disposal of used PCs illegally dumped by consumers or recyclers. As long as the resulting social costs are not reflected by the behavior of the producer, we can maximize the social welfare under the Japanese system.

4.2. Policy Evaluation of Taiwanese System

In similar fashion, we can show the influence of the change of PCs under the Taiwanese system on social welfare as follows.

$$SS_x \equiv t - s\bar{\alpha} - E'_G(1-\bar{\alpha}) - E'_B(1-\bar{\beta})\bar{\alpha} \tag{31}$$

This equation shows that there is room to maximize social welfare under the Taiwanese system. However we should notice that social welfare cannot always be maximized under the present system.

We can interpret this point in the following way. Under the Taiwanese system, the fee is charged to producers and the subsidy is paid to recyclers. According to Wen (2006), these policy instruments are interpreted as a policy to internalize the social costs. Her idea is based on the discussion about the optimal policy instruments defined as the deposit-refund system by Dinan (1993), Palmer and Walls (1997), and Fullerton and Wolverton (2000). They presume that two policy instruments are utilized independently to internalize social costs and demonstrate as a result that optimal policy instruments are the deposit-refund system. On the other hand, under the Taiwanese system, the RMF has to adjust the balance between the revenue of the fee from producers and the payment of the subsidy to recyclers[5]. In other words, the behavior of the RMF is restricted within the equilibrium of this balance. Then we can represent the conditions imposed on the RMF as follows.

$$tx = s\bar{\alpha}x \tag{32}$$

That is $t = s\bar{\alpha}$. Therefore regardless of the discussion of optimal policy instruments, we can get the following equation.

$$SS_x \equiv -E'_G(1-\bar{\alpha}) - E'_B(1-\bar{\beta})\bar{\alpha} < 0 \tag{31'}$$

We cannot maximize social welfare under the Taiwanese system.

[5] For the management method of the fee and subsidy, see Fan et al. (2005) and Wen (2004) in detail.

4.2. Consideration of an Additional Policy under Japanese and Taiwanese systems

As mentioned above, we confirm that social welfare cannot be maximized under each system. Thereupon we examine some additional policy to maximize social welfare under each system.

Let us begin with the Japanese system. We discussed earlier that physical responsibility for taking back and recycling used PCs lies with the producers and its range is restricted to cases in which consumers require the producers to take back used PCs under the Japanese system. To widen the range of physical responsibility to that of collection and recycling of used PCs illegally dumped is one of the better modifications. As a result, we can maximize social welfare under a modified Japanese system.

Next we examine an additional policy under the Taiwanese system. In the Taiwanese system, two policy instruments are subject to the behavior of the RMF. If the RMF is free to decide the level of the fee and subsidy, then we can get optimal policy instruments to internalize social costs as follows.

$$t^* = E'_G(1-\overline{\alpha}) > 0, s^* = -E'_B(1-\overline{\beta})/\overline{\alpha} < 0 \qquad (33)$$

Note that the fee is a positive level but the subsidy is a negative level. In other words, we can maximize social welfare under the Taiwanese system on condition that two policy instruments cannot constitute the deposit-refund system.

5. Concluding Remarks

So far we have outlined the present condition of the PC recycling system in Japan and Taiwan, evaluated the recycling policy from the viewpoint of the maximization of social welfare, and considered some additional policy under each system. Our analysis shows two main results as follows.

1. The social welfare can not be maximized under Japan system.
2. There is possibility that the social welfare is maximized under Taiwan system depending on the behavior of the RMF.

In conclusion, we should note implications of this study. Each country applies its own distinctive policy instruments. However each country faces common issues (e.g. illegal dumping and shortage of landfills). We need to study various policies in each country and compare the effects of the policies on waste problems. As a result, we can find more effective policy to deal with the problems.

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