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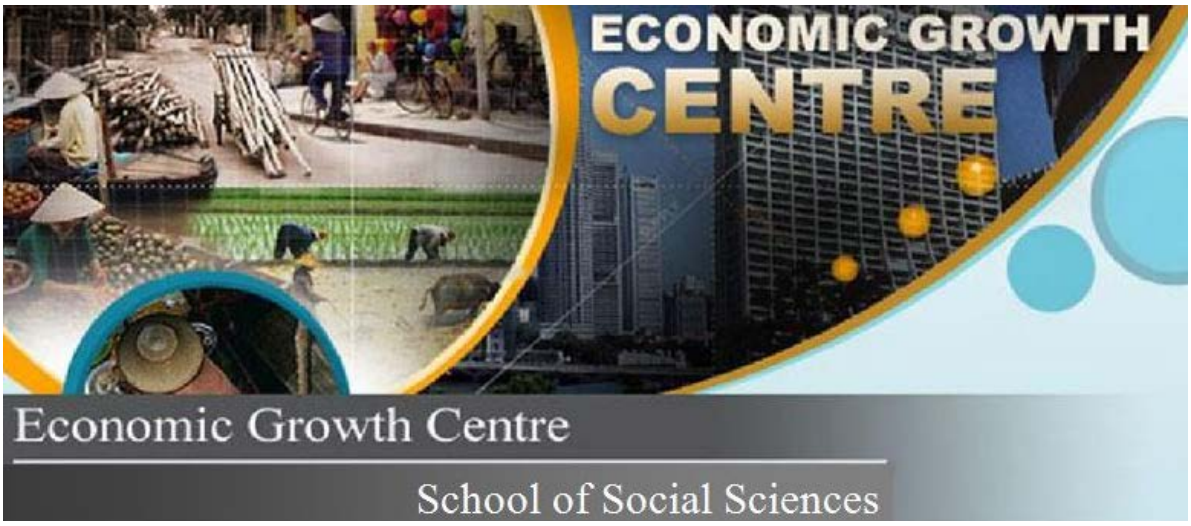

Privatization of solid waste collection firm

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Abstract

In this paper, we explore the optimal degree of the privatization of solid waste collection service. We show that the privatization of the collector decreases the investment to the selection capacity for the separated collection, the household's effort to separate the waste and the amount of the separated collection, while it increases the unseparated waste. Also, partial privatization is the optimum. The optimal level of privatization is inversely dependent on the disposal fee and the marginal environmental damage cost.

Keywords: Solid waste management; Privatization

JEL classification: L33, Q53, R11

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1. Introduction

Solid waste management in many countries has been facing serious problems such as cost inefficiencies, high financial burden, low satisfaction among households, scarcity of disposal capacity, and failure to collect sorted solid waste. In response to these challenges, the privatization of waste management services, including the collection of discarded products, sorting of recyclable components and materials, and incineration and/or landfilling of non-recycling parts, has increased since the 1980s.

Especially, the privatization of solid waste collection activities aims at saving costs, operating efficiently in waste collection and lowering financial risks for budget-stretched municipalities. However, the empirical literature does not find a significant link between privatization and cost savings (Bel and Mur, 2009; Bolaane and Isaac, 2015). Factors that might weaken cost savings have been shown to include the lack of competition and transaction costs (Dijkgraaf and Gradus, 2007).[1] Then, it is not clear empirically that the privatization of waste collection services improve social welfare.

In this paper, using the simple model, we consider whether the privatization of waste management collection firm is beneficial or not, from the social welfare viewpoint. By adopting Reggiani and Silvestri (2017) which model the municipal solid waste industry and Matsumura (1998) which considers the optimal level of privatization, we explore the effects of privatization and the optimal extent of privatization. We show that the partial privatization improves welfare. Further, the privatization reduces the investment of the available selection capacity for separated collection, the household's effort for separating waste, and the quantity of separated collection, while it increases environmental damage. The optimal level of privatization is inversely dependent on the disposal fee and

[1] For a review of empirical studies on the privatization of solid waste services, see Bel and Warner (2008).

the marginal environmental damage cost.

The problem on whether the public firm should be privatized has been of great interest to many theoretical economists.[2] They focus on the mixed oligopoly between public and private firms, and the objective of the public firm is assumed to maximize social welfare. Essentially, the establishment of the public firm is to correct market failure. However, in reality, production of the public firm tends to be inefficient and generates environmental pollution, which is a typically negative externality. In the recent years, by using the mixed oligopoly models, the interplay between privatization and environmental policy has received attention in the literature.[3] Literature on mixed oligopoly applies well to aviation, electricity, postal service, shipbuilding, and steel industries. Since such markets are relatively large, several firms, either public or private, can survive. On the other hand, since waste management services are isolated in each region and regulated due to public interest, the markets are monopolistic regardless of privatization. As far as we know, this is the first theoretical paper about the relationship between the privatization of waste management firms and the environment.

The rest of the paper is organized as follows. In section 2, we present the model. Section 3 derives the results. In section 4, we present the concluding remarks.

2. Basic set-up

We establish a model similar to that of Reggiani and Silvestri (2017). An economy is composed of households, one monopolistic collector, one monopolistic

[2]De Fraja and Delbono (1989) and Matsumura (1998), who are the pioneering theoretical studies of privatization, find that full or partial privatization improves welfare.

[3]Beladi and Chao (2006), Kato (2006), Ohori (2004, 2006, 2012), Naito and Ogawa (2009), Wang and Wang (2009) and Xu and Lee (2015) focus on environmental policies in the mixed market. For the empirical literature of public ownership's impact on environmental performance, see Clo et al. (2016).

disposer and one social planner.

Households are identical, and we normalize the number of the households in the region as unity. The representative household must eliminate all waste to dispose.[4] As with Reggiani and Silvestri (2017), for analytical simplicity, the household discards the amount of the waste which is normalized to the unity. The collector charges the disposal fee p for unseparated waste to the household according to the Pay-As-You-Throw principle. However, the price regulation is imposed on the disposal fee to avoid welfare loss stemming from natural monopoly, which means that the disposal fee is comparatively low and exogenously determined. To avoid the burden of the disposal fee, the household will exert effort e to separate recyclable from undifferentiated waste. The household can discard the recyclable separated collection r at no charge. The utility is described by

$$U = u - pg - e, \tag{1}$$

where $g(= 1 - r)$ is the unseparated waste and u is as given.

The collector's operation is to pick up waste from the household, to deliver that to collective waste disposal facilities (e.g. incinerator, landfill or sewage treatment plant) and to sell the separated collection to the recycling market. On the other hand, the disposer disposes the unseparated solid waste under the treatment process, which is located in the other suburban area far from the region in which the consumers and the collector exist. The delivery of the waste by the collector involves the transportation cost t, which is assumed to be proportional to the distance.

The privatized waste management firms provide the services by using the facilities that already exist, such as incinerator and landfill site. Since the construction cost of the facilities is sunk, it deters potential entrants. In many

[4] We assume that there is no illegal dumping.

local governments, the collectors have been permitted to run monopolistically. Therefore, it is assumed that the monopolization of the collector and the disposer is maintained even if the privatization is introduced. The collector equips the facilities for the household to separate waste, such as the installation sites for sorted waste and the guidance to raise awareness for waste separation. Thus, the collector sets the selection capacity k for the waste collection by incurring the quadratic cost. The enlargement in the selection capacity k as well as the household's effort e will increase the quantity of the separated collection r. Following Reggiani and Silvestri (2017), we assume that the waste separation is conducted under the Cobb-Douglas technology as follows:

$$r = e^{\frac{1}{2}} k^{\frac{1}{2}}. \tag{2}$$

The collector absorbs the unit cost a to collect the unseparated waste when it receives the unseparated waste. The unit price for recyclable separated collection f is exogenously set as a waste policy. The collector can make a profit by selling the separated collection to the recycling market. Therefore, the profit function (of the fully privatized collector) is given by

$$\pi^c = (p - a - t)g + fr - k^2. \tag{3}$$

The disposer charges a per unit to be disposed. Then, the disposer's profit is $\pi^d = ag$. a is assumed to be as given because the regulation is set to keep down the monopolistic price.

Social welfare W consists of the household's utility U, the collector's profit π^c, the disposer's profit π^d and the disutility from the unseparated waste $D(g)$:

$$W = U + \pi^c + \pi^d - D(g). \tag{4}$$

For simplicity, the disutility from the unseparated waste is assumed to be linear: $D(g) = \delta g$, where $\delta(> 0)$ denotes the marginal environmental damage cost. Activities of waste management lead to externalities that are produced at the collection, transport, and disposal stages. These externalities are affected by treatment processes, geografic location of the facilities, and the age of site. Landfilling generally involves environmental damage caused by greenhouse gas and contaminated grandwater. Incineration is associated mostly with externalities like air pollutants (NO_x, SO_x, dioxins, ash, etc.). Therefore, it is assumed that the marginal environmental damage cost is higher than or equals the marginal disposal cost for unseparated waste: $\delta \geq a$.

In accordance with Matsumura (1998), the collector's objective function is given by

$$\Pi^c = \alpha\pi^c + (1-\alpha)(U + \pi^c - D(g)), \tag{5}$$

where $\alpha \in [0, 1]$ denotes the proportion of the firm's shares that are held by the private owners. When $\alpha = 0$ (the perfect nationalization), the collector maximizes the sum of the household's utility and its own profit minus the disutility from the unseparated waste, and it is a pure profit-maximizer when $\alpha = 1$ (the perfect privatization). In other words, α is the level of privatization.

Note that the disposer is located in the different area far from the area in which the collector and the household exist. When the collector is publicly owned by the municipality in which the collector runs, the disposer is not the municipality's concern. That is why the disposer's profit is not included by (5).

The timing of the game is as follows. First, the social planner chooses the level of privatization α. Second, the collector sets the selection capacity k for separated collection. Finally, the household puts effort e into separating waste. This game is solved by using backward induction. It is also a game of complete information.

3. Analyses

We first consider the effort choice of the household for the separated collection. Given (2) and $g = 1 - r$, the household sets the extent of effort in order to maximize utility (1). The first-order condition of (1) with e yields the following optimal choice of effort:

$$e^* = \frac{p^2 k}{4}. \tag{6}$$

From (6), we have the optimal recyclable separated collection and unseparated waste, respectively:

$$r^* = \frac{pk}{2}, \quad \text{and} \tag{7}$$

$$g^* = 1 - \frac{pk}{2}. \tag{8}$$

(6), (7) and (8) imply that the selection capacity k set by the collector and the disposal fee p increase the household's effort for separated collection and the amount of separated collection, while those decrease the amount of unseparated waste. These results are intuitive and the same as Reggiani and Silvestri (2017).

Next, we derive the optimal selection capacity installed by the collector. Differentiating the collector's objective function (5) with respect to the selection capacity k, the first-order condition yields

$$k^* = \frac{p}{8}\left\{-p + 2(a + f + \delta + t) - \alpha(p + 2\delta)\right\}. \tag{9}$$

Now, we discuss the comparative static effects. See Appendix. From (6) - (9), it is easy to see that an increases in the transportation cost increases the selection capacity ($\partial k^*/\partial t > 0$), the household's effort ($\partial e^*/\partial t > 0$), and the recyclable separated collection ($\partial r^*/\partial t > 0$), whereas it decreases the unseparated waste

($\partial g^*/\partial t < 0$). Also, the effects of the unit price f for separated collection and the the unit cost a to collect the unseparated waste are similar with that of the transportation cost.

The effects of the marginal environmental damage cost are as follows. With an increase in the marginal environmental damage cost (speaking contrarily, a lax in the environmental regulation), the selection capacity, the household's effort and the separated collection increases ($\partial k^*/\partial \delta \geq 0$, $\partial e^*/\partial \delta \geq 0$ and $\partial r^*/\partial \delta \geq 0$), and the unseparated waste decreases ($\partial g^*/\partial \delta \leq 0$).

The derivatives of the capacity for the separated collection, the household's effort to separate the waste, the quantity of the separated collection, and the unseparated waste with respect to the level of privatization α can be seen as

$$\begin{aligned} \frac{\partial k^*}{\partial \alpha} &= -\frac{p(p+2\delta)}{8} < 0, \quad \frac{\partial e^*}{\partial \alpha} = -\frac{p^3(p+2\delta)}{32} < 0, \\ \frac{\partial r^*}{\partial \alpha} &= -\frac{p^2(p+2\delta)}{16} < 0, \quad \text{and} \quad \frac{\partial g^*}{\partial \alpha} = \frac{p^2(p+2\delta)}{16} > 0. \end{aligned} \tag{10}$$

From (6), (7), (8) and (10), we have the following proposition.

Proposition 1. *The privatization of the collector decreases the selection capacity for the separated collection, the household's effort to separate the waste and the amount of the separated collection, while it increases the unseparated waste.*

Proposition 1 implies that the privatization causes the environmental damage. However, from (3) and (10), we can check that the effects of privatization on the amount of unseparated waste and the selection capacity increase the collector's profit. In addition, the privatization increases the disposer's profit and the decrease in the household's effort by the privatization affects positively the utility. Therefore, it can be considered that the introduction of privatization

could not be always detrimental to social welfare.

In order to check that, we address the optimal level of privatization. Differentiating social welfare (4) with respect to the level of privatization α, we have

$$\frac{dW}{d\alpha} = \frac{\partial W}{\partial \alpha} + \left(\frac{fp}{2} - 2k - \frac{p^2}{4} + \frac{tp}{2} + \frac{\delta p}{2} \right) \frac{\partial k^*}{\partial \alpha}. \tag{11}$$

From (9), (10), (11) and the assumption ($\delta \geq a$), the first-order condition yields the optimal level of privatization

$$\alpha^* = \frac{2a}{p + 2\delta} \quad \in (0, 1). \tag{12}$$

From (12), we obtain the following proposition.

Proposition 2. *When the social planner controls the level of privatization of the collector, partial privatization is the optimum. The optimal level of privatization increases with the marginal disposal cost for unseparated waste and decreases with the marginal environmental damage cost and the disposal fee levied on the household.*

4. Concluding remarks

In this paper, we explore the optimal degree of the privatization of solid waste collection service. We show that the privatization of the collector decreases the available capacity for the separated collection, the household's effort to separate the waste and the amount of the separated collection, while it increases the unseparated waste. Also, partial privatization is the optimum. The optimal level of privatization is inversely dependent on the disposal fee imposed on the household and the marginal environmental damage cost.

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Appendix: The comparative statics of the selection capacity

The derivatives of k^*, e^*, r^* and g^* with respect to a, f and t respectively can be seen as

$$\frac{\partial k^*}{\partial a} = \frac{\partial k^*}{\partial f} = \frac{\partial k^*}{\partial t} = \frac{p}{4} > 0, \quad \frac{\partial e^*}{\partial a} = \frac{\partial e^*}{\partial f} = \frac{\partial e^*}{\partial t} = \frac{p^3}{16} > 0,$$
$$\frac{\partial r^*}{\partial a} = \frac{\partial r^*}{\partial f} = \frac{\partial r^*}{\partial t} = \frac{p^2}{8} > 0, \quad \text{and} \quad \frac{\partial g^*}{\partial a} = \frac{\partial g^*}{\partial f} = \frac{\partial g^*}{\partial t} = -\frac{p^2}{8} < 0$$

The derivatives of k^*, e^*, r^* and g^* with respect to δ respectively can be seen as

$$\frac{\partial k^*}{\partial \delta} = \frac{p}{4}(1-\alpha) \geq 0, \quad \frac{\partial e^*}{\partial \delta} = \frac{p^3}{16}(1-\alpha) \geq 0,$$
$$\frac{\partial r^*}{\partial \delta} = \frac{p^2}{8}(1-\alpha) \geq 0, \quad \text{and} \quad \frac{\partial g^*}{\partial \delta} = -\frac{p^2}{8}(1-\alpha) \leq 0$$

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