DISCUSSION PAPER SERIES

Discussion paper No. 186

Hold-up Problems in Contracting Out Waste Collection Services

Hiroaki Ino
(School of Economics, Kwansei Gakuin University)
Norimichi Matsueda
(School of Economics, Kwansei Gakuin University)
Jun'ichi Miki
(Faculty of Humanities and Social Sciences, Tohoku University of Community Service and Science)

May 2022

SCHOOL OF ECONOMICS

KWANSEI GAKUIN UNIVERSITY

1-155 Uegahara Ichiban-cho
Nishinomiya 662-8501, Japan

Hold-up Problems in Contracting Out Waste Collection Services*

Hiroaki Ino† Norimichi Matsueda‡ Jun'ichi Miki§

Abstract

Using the newly-available official data on the disposal of household solid waste, we estimate that there is generally an inverse relationship between the contracting-out rate and the contract price, but this inverse relationship levels out as the degree of contracting-out increases and the contract price even goes up eventually as the contracting rate approaches 100%. Then, we construct a simple bargaining model between municipal governments and private firms and identify how the bargaining equilibrium differs from an outcome where municipal governments can make take-it-or-leave-it offers to private enterprises. Particularly, we focus on the effects of municipalities' concerns of getting held up by private firms in contract-price negotiations. We also conduct a simple simulation analysis and demonstrate that such concerns can indeed lead to a U-shaped relationship between the contracting-out rate and the contract price across different municipalities.

Keywords: bargaining, contracting-out, contract price, hold-up, waste collection

JEL Codes: H42, L33

*The authors thank useful comments by the participants of a workshop at Tohoku University of Community Service and Science. Funding: This work has been supported by the Research Promotional Grant from the North East Think Tank of Japan. The usual disclaimer applies.

†School of Economics, Kwansei Gakuin University, 1-1-155 Uegahara, Nishinomiya, Hyogo, 662-8501, Japan; ino@kwansei.ac.jp

‡School of Economics, Kwansei Gakuin University, 1-1-155 Uegahara, Nishinomiya, Hyogo, 662-8501, Japan; nmatsued@kwansei.ac.jp

§Faculty of Humanities and Social Sciences, Tohoku University of Community Service and Science, 3-5-1 Iimoriyama, Sakata, Yamagata, 998-8580, Japan; j_miki@koeki-u.ac.jp

1 Introduction

It is common in developed nations that local authorities are legally responsible for the collection and disposal of household waste. Since around the 1980's, the contracting-out of household waste collection services to private firms has been widely promoted. In the case of Japan, contracting-out was encouraged primarily to ease the burden of municipal governments, which were sometimes financially troubled, by reducing the operating expenditure of waste collection services in general. This trend was further strengthened during the 90's when Japan experienced a prolonged recession and also when the privatization and contracting-out of "blue-collar" public services, including waste collection and disposal services, became even more politically fashionable among many developed countries.

Although there exist a number of empirical studies that identify significant cost savings from contracting out municipal waste collection services to private contractors,[1] few studies analytically examine what actually determines the political decision-makers' choice between private and public firms (Ohlsson 2003). One interesting feature of their decision-makings is that contracting-out is not necessarily an all-or-nothing deal, as we will see below for the case of household waste collection services in Japan. That is, it is often the case that a local government contracts out a certain portion of services to private firms but still keeps its own public operation unit despite the overwhelming empirical evidences that contracting-out would results in significant cost reductions for municipal governments.

In their recent study, Matsueda and Miki (2020) report that, based on their own survey in Japan, there was generally an inverse relationship between the contracting-out rate and the contract price, but this inverse relationship levels out as the degree of contracting-out increases and the contract price even goes up eventually as the contracting rate approaches 100%. In this paper, we conduct a simple regression analysis and check

[1] Based on the observations of 340 public and private firms in the US, Stevens (1978) indicated a cost decrease of 7 to 30% due to the contracting-out. For a sample of 205 Canadian cities, McDavid (1985) reported that public collection was 41% more expensive than private collection. Domberger et al. (1986) estimated the cost savings of 22% for contracting out household refuse collection in the UK. Reeves and Barrow (2000) showed that there is an enormous cost saving opportunity of around 45% for Ireland. Dijkgraaf and Gradus (2003) identified the cost savings of approximately 15 to 20% for the Netherlands.

the validity of this observation with more recent and comprehensive publicly-available data.

As a main objective of this study, then, we investigate into this U-shaped relationship by constructing a simple bargaining model between municipal governments and private enterprises. In particular, we focus on the municipalities' hold-up concerns. Most household wastes need to be hauled away within a fairly short time-frame, usually weekly or twice weekly, due to public health and sanitation concerns. Once a municipal government fully contracts out its waste collection services to private firms and stops investing in its internal unit, it could create an environment where a private firm is able to make a better case for a higher contract price by shifting the balance of bargaining positions in favor of a private firm. In particular, a private firm could threaten to go on a strike unless the contract price is raised. Such an issue would become more serious when a local government loses some pertinent skills and information in conducting waste collection services in a fairly efficient manner within a particular district.

As we demonstrate analytically below in a bargaining equilibrium, an important consequence of this hold-up concern is that, by anticipating the potential problem, a local government might decide to keep a larger portion of waste collecting operation internally than its simple expenditure-minimization would justify. Indeed, we can see in the data below that there are many municipalities that choose quite high proportions of contracting-out, but still retain a certain share of internal provision of waste collection services. The hold-up possibility that they could potentially face is one probable rationale for cutting down on the rate of contracting-out for municipalities.[2]

Such a hold-up situation would be more likely to pose a serious problem with a fewer number of potential contractors in a market, because then market forces could not completely wipe out the effect of even a false claim and also because firms are easier to collude to raise a tender price. Domberger and Jensen (1997) write, "[c]ontracting out is likely to be more (less) successful whenever the availability of competitive supply in the market, both actual or potential, is large (small)". In the following analysis, we suppose

[2]This is a completely different kind of hold up situation that has been discussed in the literature. Domberger and Jensen (1997) mentioned that the public ownership of the assets, such as specialized vehicles, and the existence of "relation-specific investments" that are sunk expenditures by the contractor results in under-investment, following a more general argument by Hart (1995).

that the competitiveness of a contracting market is reflected in the relative magnitudes of bargaining powers between a municipality and a potential contractor.

In the next section we report our empirical finding on the relationship between the rate of contracting-out and the contracting price. In the following section, we set up a simple analytical model and examine its implications in order to gain insights into how the contracting-out decision by a municipal government is affected by the hold-up concerns. We then conduct a simple simulation analysis to illustrate how a U-shaped relationship emerges between the rate of contracting-out and the contract price across different municipalities. The final section concludes the paper.

2 Empirical Finding

The most comprehensive data source concerning the waste collection services in Japan is an annual official survey published by the Ministry of the Environment,[3] and we resort to this data source in this study. Especially, we are interested in the relationship between the extent of the contracting-out and the contract price for household solid waste. In their survey, unfortunately, the contract price for the waste from households and that from private enterprises are not distinguishable although they report the rates of contracting-out for household solid waste alone. Therefore, we have assumed that the contract prices for these differenct types of waste are equivalent and a contracting-price is obtained by deviding the total payment to contractors by the volume of the total waste contracted.[4]

The data are plotted in Figure 1, excluding the ones with zero percent of contracting-out as we have no contract price for those municipalities.

[3]The data is available at `http://www.env.go.jp/recycle/waste_tech/ippan/index.html` (in Japanese).

[4]We also exclude one anormal case with an extremely high contracting-price.

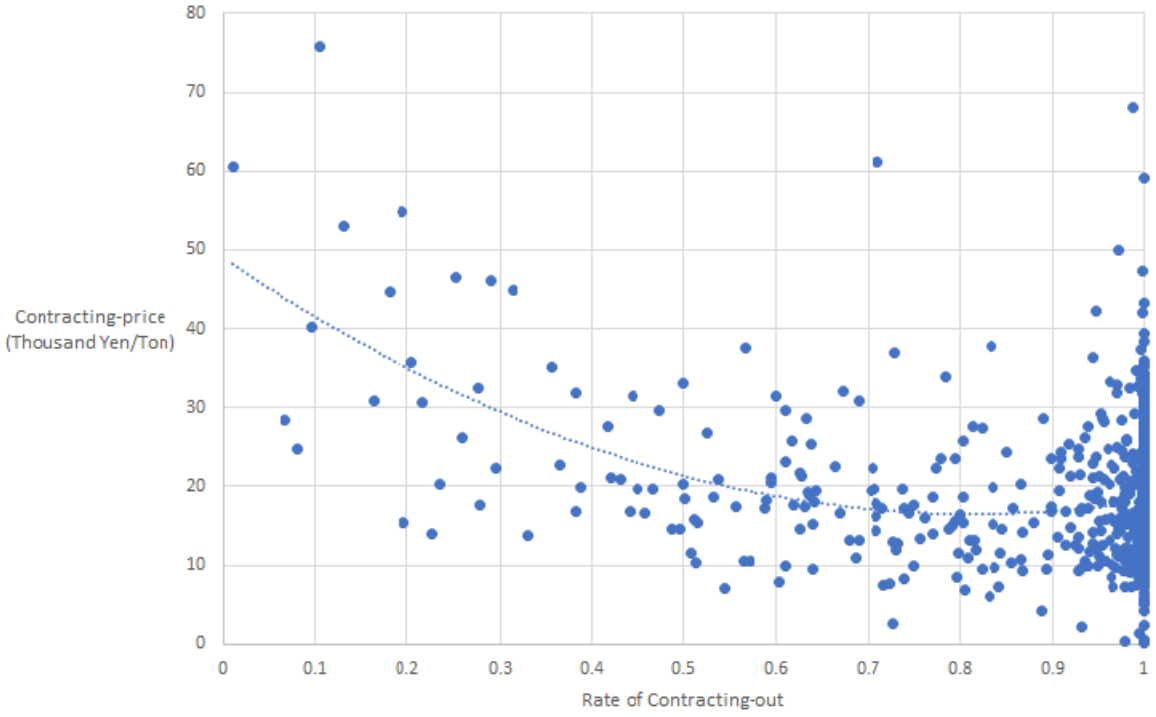

Figure 1: Contracting-out rates and contract prices in Japan

Source: Survey on Disposal of General Waste by the Ministry of the Environment

The curve shown in Figure 1 is the regression line, estimated by a quadratic equation with respect to the contracting rate (*rate*) with the contracting price (*price*) as a dependent variable. The estimation results based on 657 samples can be summarized as follows:

$$price = 49.03989 - 79.874 \times rate + 49.015513 \times rate^2,$$
$$(10.915) \quad (-5.234) \qquad (4.576)$$

where the numbers in the parentheses are associated t-values. The value of the adjusted R^2 is 0.142.

As we can see in Figure 1, in general there is an inverse relationship between the contracting-out rate and the contract price. Moreover, The solid quadratic regression line also indicates that this inverse relationship flattens as the contracting rate increases, and the contract price even moves up eventually as the contracting rate approaches 100%.

While Matsueda and Miki (2020) suggest several potential sources that could lead to the inverse relationship between the contracting-out rates and the contract prices, they did not discuss why the contract price levels out and even goes up as the rate becomes sufficiently close to 100%. Indeed, such a phenomenon has rarely been reported in previous empirical studies, much less investigated analytically. Those studies have mainly focused on the comparisons of the collection costs between fully-public and fully-contracted-out entities and, in our opinion, left some intriguing phenomena, such as this one, unexplored. In the next section, we present a theoretical hypothesis that can explain this inverted-U relationship, based on a barganing model between perfectly-rational local governments and private firms.

3 The Model

In this section, we set up a simple analytical model with a local government and a potential private contractor within a single district. The purpose of the model is to gain some insights into how household waste collection services are contracted out and, especially, how a contract price is related to the degree of contracting-out.

3.1 Basic Set-ups

Let us suppose that there are I municipalities in total and each municipality is indexed by $i \in \{1, \ldots, I\}$. Each municipality contains J districts within itself and a district is indexed by $j \in \{1, \ldots, J\}$.[5] We assume that there is a total waste amount of G_{ij} that needs to be collected in a district j of a municipality i, and G_{ij} is given exogenously.

A budget-conscious municipal government aims to minimize its total expenditure associated with collecting this amount of waste by choosing how much of G_{ij} is collected by a public enterprise and how much of it is contracted out to a private firm. We assume that there is a unique private firm in each district, mainly for the sake of simplicity, and discuss the implications of having multiple private firms which can potentially serve the same district later in the context of the "generalized" Nash bargaining solution.

[5] Alternatively, different districts can be interpreted as different types of household wastes, such as burnable, non-burnable and recyclable wastes.

We suppose that, in the absence of any investment (or effort) by the municipal government, the marginal cost of collecting waste through a public channel, which is denoted by b_{ij}, is greater than the marginal collection cost by a private enterprise, c_{ij}. However, the marginal cost of public waste collection service can be lowered through a deliberate investment by a municipal government. Such an investment reflects a government's efforts to keep its waste collection section operational and more efficient. Specifically, we assume that the following equation holds:

$$a_{ij} = b_{ij} - e_{ij}, \tag{1}$$

where e_{ij} is the level of investment by this particular municipal government i in each district j, and a_{ij} is the marginal cost of collecting waste by this public firm after the investment. Thus, a size of investment is measured in terms of its contribution to the resulting reduction in marginal collection cost.

We suppose that the cost of investment is given by the following quadratic form: $\frac{1}{2}\gamma_{ij}\left(e_{ij}\right)^2$. It seems reasonable that the value of γ_{ij} depends on the size of the waste, G_{ij}, since it would be more costly to decrease one unit of the marginal collection cost if the collection volume is larger, for instance, due possibly to a larger collection area or to an increase in the varieties of waste. Thus, we will rewrite γ_{ij} as $\gamma_{ij}(G_{ij})$ later, but, for the simplicity of notation, we suppress the function's argument for the time being. Furthermore, we assume that e_{ij} has no spillover effect to other districts.

The order of the interactions is as follows. First, each municipal government i chooses the contracting-out rate α_{ij} for each district j. Thus, $\alpha_{ij}G_{ij}$ amount of waste is collected by a public firm and $(1-\alpha_{ij})\,G_{ij}$ amount of waste is contracted out to a private firm in a district j of a municipality i. Next, the municipal government chooses the amount of investment, e_{ij}.[6] Finally, the contract price is determined through the negotiation between the municipal government and the private firm. Instead of modeling the negotiation process in a specific non-cooperative game-theoretic manner, we resort to the generalized Nash bargaining solution, following the now well-established works on incomplete

[6]It is also possible that a private sector makes an investment choice as well, but we do not model it for the sake of simplicity as it would not change the qualitative implications obtained below.

contracts (e.g., Hart 1995).

3.2 A Benchmark: No-bargaining Case

Before deriving the equilibrium outcome of the above sequential game that involves a bargaining, as a benchmark outcome, let us obtain the result where a municipal government can make a take-it-or-leave-it offer to a private firm. This is essentially the hypothetical case where the government can extract all the surplus from the contracting-out deal and does not have to deal with a potential hold-up issue at all.

3.2.1 The Second (Investment) Stage

For a given contracting-out rate, α_{ij}, let e_{ij}^O be the level of the municipal government's investment which minimizes the total expenditure associated with collecting the waste amount of G_{ij}, including the cost of investment as well as the payment to a private firm, which is simply its total collection cost in this case. Thus, e_{ij}^O solves the following minimization problem:

$$\min_{e_{ij}} \left(b_{ij} - e_{ij}\right)\left(1 - \alpha_{ij}\right) G_{ij} + c_{ij}\alpha_{ij}G_{ij} + \frac{1}{2}\gamma_{ij}\left(e_{ij}\right)^2, \tag{2}$$

whose first-order condition leads to

$$e_{ij}^O = \frac{\left(1 - \alpha_{ij}\right) G_{ij}}{\gamma_{ij}}. \tag{3}$$

3.2.2 The First (Contract) Stage

Given (3), the total-expenditure minimizing contracting-out rate, α_{ij}^O, solves the following problem:

$$\min_{\alpha_{ij}} \left(b_{ij} - e_{ij}^O\right)\left(1 - \alpha_{ij}\right) G_{ij} + c_{ij}\alpha_{ij}G_{ij} + \frac{1}{2}\gamma_{ij}\left(e_{ij}^O\right)^2. \tag{4}$$

In light of the envelope theorem, the first-order condition for (4) is given by

$$0 = -\left(b_{ij} - e_{ij}^O\right) G_{ij} + c_{ij}G_{ij} = -G_{ij}\left[\left(b_{ij} - c_{ij}\right) - \frac{\left(1 - \alpha_{ij}\right) G_{ij}}{\gamma_{ij}}\right], \tag{5}$$

which yields:

$$\alpha_{ij} = 1 - \frac{\gamma_{ij}\left(b_{ij} - c_{ij}\right)}{G_{ij}}. \tag{6}$$

Since $-\frac{G_{ij}^2}{\gamma_{ij}} < 0$, the second derivative of the objective function in (2) is negative, implying the function is a concave and quadratic function in α_{ij}. Invoking that γ_{ij} is actually a function of G_{ij}, or, $\gamma_{ij} = \gamma_{ij}(G_{ij})$, therefore, we can conclude

$$\alpha_{ij}^{O} = \begin{cases} 0 & if \quad \frac{\gamma_{ij}(G_{ij})}{G_{ij}}\left(b_{ij} - c_{ij}\right) \leq \frac{1}{2} \\ 1 & if \quad \frac{\gamma_{ij}(G_{ij})}{G_{ij}}\left(b_{ij} - c_{ij}\right) > \frac{1}{2} \end{cases}. \tag{7}$$

Note that the difference, $b_{ij} - c_{ij}$, measures how inefficient the public enterprise is in relation to the private firm before the investment and, if the difference is sufficiently large to allow the value of $\frac{\gamma_{ij}(G_{ij})}{G_{ij}}\left(b_{ij} - c_{ij}\right)$ to exceed $\frac{1}{2}$, the municipal government i can minimize the total expenditure by entirely contracting out the waste collection service in its district j. Otherwise, the expenditure-minimizing choice is to provide the collection services totally on its own.

From (7), we can easily see that an increase in the cost of investment adjusted for the scale of the waste, i.e., $\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$,[7] or in the *ex ante* difference between the marginal collection costs of the public and private sectors promotes the contracting-out, which are both quite intuitive.

3.3 The Bargaining Equilibrium

3.3.1 The Third (Bargaining) Stage

Given the levels of *ex post* marginal costs of collecting waste by the public and private enterprises, i.e., a_{ij} and c_{ij}, respectively, the total expenditure of collecting the waste G_{ij} to the municipal government is

$$a_{ij}\left(1 - \alpha_{ij}\right)G_{ij} + c_{ij}\alpha_{ij}G_{ij} = \left[a_{ij}\left(1 - \alpha_{ij}\right) + c_{ij}\alpha_{ij}\right]G_{ij}, \tag{8}$$

[7] If $\gamma_{ij}(G_{ij})$ is linear in G_{ij}, the size of the waste has no effect on the chosen contracting-rate in (7). On the other hand, if $\gamma_{ij}(G_{ij})$ is strictly convex (*resp.* concave), a larger waste size encourages (*resp.* discourages) the contracting-out decision by the municipal government.

if the contracting-out rate of α_{ij} is actually implemented. If all the waste collection is conducted publicly, the total cost is $a_{ij}G_{ij}$.

We suppose that the bargaining outcome is given by the generalized Nash bargaining solution. Let us assume that $a_{ij} > c_{ij}$ holds. Then, the sum of the payoffs of the local government and the private firm can be written as

$$f_{ij} + g_{ij} = -\left[a_{ij}\left(1-\alpha_{ij}\right) + c_{ij}\alpha_{ij}\right]G_{ij}, \tag{9}$$

where f_{ij} and g_{ij} are the respective payoffs of the private firm and the municipal government for this stage alone, only concerning this particular district. We suppose that the disagreement implies that the public sector must provide all the waste collection service for the district. In such a case, the government's payoff, i.e., g_{ij} is $-a_{ij}G_{ij}$, and the private firm's payoff, i.e, f_{ij}, becomes zero as it will not provide any service in this particular district.

With η $(0 \leq \eta \leq 1)$ denoting the bargaining power of the private firm and, consequently, $1-\eta$ the bargaining power of the municipal government, the respective parties' payoffs in the generalized Nash bargaining solution are the ones that solves the following problem:

$$\max_{f_{ij},g_{ij}} f_{ij}^{\eta}\left(g_{ij} + a_{ij}G_{ij}\right)^{1-\eta} \quad s.t.\ f_{ij} + g_{ij} = -\left[a_{ij}\left(1-\alpha_{ij}\right) + c_{ij}\alpha_{ij}\right]G_{ij}. \tag{10}$$

Solving the maximization problem above, we can obtain the private firm's payoff in the generalized Nash bargaining solution, denoted by f_{ij}^{*}, as

$$f_{ij}^{*} = \eta\left(a_{ij} - c_{ij}\right)\alpha_{ij}G_{ij}. \tag{11}$$

From (11), we can also derive the contract price in the generalized Nash bargaining solution as

$$\eta\left(a_{ij} - c_{ij}\right) + c_{ij} = \eta a_{ij} + \left(1-\eta\right)c_{ij}, \tag{12}$$

by taking into account the marginal cost of waste collection service by the private firm. It should be noted that, as η goes to zero, i.e., the bargaining power of the private firm

diminishes, the contract price approaches its own marginal cost of collection. When $\eta = 0$, it effectively coincides with the non-bargaining case analyzed in the previous subsection.

On the other hand, the government's payoff in the generalized Nash bargaining solution, denoted by g_{ij}^*, is

$$g_{ij}^* = -a_{ij}\left(1-\alpha_{ij}\right)G_{ij} - \left(\eta a_{ij} + \left(1-\eta\right)c_{ij}\right)\alpha_{ij}G_{ij}, \tag{13}$$

where the first term is the collection cost by the public enterprise and the second term is the payment made to the private firm, given the contract price above.

3.3.2 The Second (Investment) Stage

Taking into account the value of g_{ij}^* that is determined in the subsequent stage as in (13), the municipal government chooses the level of its investment e_{ij} that minimizes the total expenditure associated with collecting the waste of size G_{ij}. Hence, the government solves the following the problem:

$$\min_{e_{ij}} -g_{ij}^* + \frac{\gamma_{ij}}{2}e_{ij}^2 = \left(b_{ij}-e_{ij}\right)\left(1-\alpha_{ij}\right)G_{ij} + \left(\eta a_{ij} + \left(1-\eta\right)c_{ij}\right)\alpha_{ij}G_{ij} + \frac{\gamma_{ij}}{2}e_{ij}^2, \tag{14}$$

given the level of α_{ij} that has been determined in the preceding stage. Its first-order condition is

$$\left(1-\alpha_{ij}\right)G_{ij} + \eta\alpha_{ij}G_{ij} = \gamma_{ij}e_{ij}. \tag{15}$$

Here, the first term on the left hand side represents the effect of an increase in e_{ij} on its own collection cost and the second term is its effect on lowering the contracting-out price determined in the following bargaining stage by increasing the government's disagreement payoff. We can immediately see that an increase in α_{ij} lessens the former effect but it boosts the latter effect.

From (15), the government's equilibrium level of investment, e_{ij}^* , is given by

$$e_{ij}^* = \frac{1-\left(1-\eta\right)\alpha_{ij}}{\gamma_{ij}}G_{ij} \geq e_{ij}^O, \tag{16}$$

which indicates that the direct effect of an increase in α_{ij} on the public waste collec-

tion cost overwhelms its effect on the government disagreement payoff in total. When the contracting-out rate increases, the government responds by lowering its investment that reduces the public enterprise's collection cost, even if it recognizes that a smaller investment would worsen its bargaining position in the subsequent stage. Moreover, (16) implies that the equilibrium investment level is always larger than the no-bargaining investment level except for the case of no contracting-out whatsoever, i.e. $\alpha_{ij} = 0$ or for the case where the private firm has no bargaining power in the subsequent negotiation stage, i.e., $\eta = 0$.

Given (16), we need the following condition for having $a_{ij} > c_{ij}$:

$$b_{ij} - e^*_{ij} > c_{ij} \Leftrightarrow \alpha_{ij} > \frac{1}{1-\eta}\left[1 - \frac{\gamma_{ij}}{G_{ij}}\left(b_{ij} - c_{ij}\right)\right]. \tag{17}$$

The last condition may not be met when α_{ij} is sufficiently small. If that is indeed the case, the agreement between the government and the private firm will not be reached and all the waste must be collected by the public enterprise since it is more efficient than the private counterpart. As a result, the payoffs in the third stage alone will be $g_{ij} = -a_{ij}G_{ij}$ and $f_{ij} = 0$. In this case, the optimal investment by the government is given by the solution to the following problem:

$$\min_{e_{ij}} -g^*_{ij} + \frac{\gamma_{ij}}{2}e^2_{ij} = \left(b_{ij} - e_{ij}\right)G_{ij} + \frac{\gamma_{ij}}{2}e^2_{ij}, \tag{18}$$

which yields $e^*_{ij} = \frac{G_{ij}}{\gamma_{ij}} = e^O_{ij}$.

If the condition (17) is met, the contract price in the bargaining equilibrium is

$$\eta\left(b_{ij} - e^*_{ij}\right) + \left(1-\eta\right)c_{ij} = \left[\eta b_{ij} + \left(1-\eta\right)c_{ij} - \eta\frac{G_{ij}}{\gamma_{ij}}\right] + \frac{\eta\left(1-\eta\right)G_{ij}}{\gamma_{ij}}\alpha_{ij}. \tag{19}$$

Thus, the contract price increases as α_{ij} gets larger because an increase in the contracting-out rate aggravates the disagreement payoff of the municipal government, which will work against the government in the following bargaining stage. This is the hold-up issue that a municipality must face in our particular context.

3.3.3 The First (Contract) Stage

In this initial stage, the municipal government chooses the level of the contracting-out rate, α_{ij}, so as to minimize its total expenditure, including the cost of investment in the second stage. Therefore, it solves the following problem:

$$\min_{\alpha_{ij}} \left(b_{ij} - e^*_{ij}\right)\left(1-\alpha_{ij}\right)G_{ij} + \left[\eta\left(b_{ij} - e^*_{ij}\right) + \left(1-\eta\right)c_{ij}\right]\alpha_{ij}G_{ij} + \frac{\gamma_{ij}}{2}\left(e^*_{ij}\right)^2. \tag{20}$$

Let us, for the moment, suppose that the condition (17) holds for such a level of α_{ij}. In light of the envelope theorem again and combination with (16), the first-order condition for (20) is given by

$$\begin{aligned} 0 &= -\left(b_{ij} - e^*_{ij}\right)G_{ij} + \left[\eta\left(b_{ij} - e^*_{ij}\right) + \left(1-\eta\right)c_{ij}\right]G_{ij} \\ &= -\left(1-\eta\right)\left(b_{ij} - \tfrac{1-(1-\eta)\alpha_{ij}}{\gamma_{ij}}G_{ij}\right)G_{ij} + \left(1-\eta\right)c_{ij}G_{ij}. \end{aligned} \tag{21}$$

Solving (21) for α_{ij} yields

$$\alpha_{ij} = \frac{1}{1-\eta}\left[1 - \frac{\gamma_{ij}\left(b_{ij} - c_{ij}\right)}{G_{ij}}\right], \tag{22}$$

which exactly coincides with the threshold of whether the agreement between the municipal government and the private firm will be reached or not in (17). Since the second derivative of the objective function in (20) is $-\frac{(1-\eta)^2 G_{ij}^2}{\gamma_{ij}} < 0$, it is a concave and quadratic function in α_{ij}, and, therefore, the value of the objective function monotonically decreases as α_{ij} goes up from its value in (22).

If α_{ij} in (22) exceeds one-half, the government will collect all the waste through the public enterprise, i.e., $\alpha_{ij} = 0$, and the optimal investment becomes $e^*_{ij} = \frac{G_{ij}}{\gamma_{ij}}$. On the other hand, if α_{ij} in (22) is smaller than one-half, the optimal contracting-rate should be one. Invoking $\gamma_{ij} = \gamma_{ij}(G_{ij})$, once again, we can conclude that the optimal contracting-out rate, α^*_{ij}, which the municipal government should choose, is given by

$$\alpha^*_{ij} = \begin{cases} 0 & if \quad \frac{\gamma_{ij}(G_{ij})}{G_{ij}}\left(b_{ij} - c_{ij}\right) \leq \frac{1}{2} + \frac{\eta}{2} \\ 1 & if \quad \frac{\gamma_{ij}(G_{ij})}{G_{ij}}\left(b_{ij} - c_{ij}\right) > \frac{1}{2} + \frac{\eta}{2} \end{cases}. \tag{23}$$

which indicates that the choice of α^*_{ij} by the municipal government is distorted downwards

in comparison with (7) which minimizes the total expenditure of waste collection without any bargaining. In the bargaining equilibrium, however, the municipal government tends to over-invest in the second stage in anticipation of the bargaining over the contract price in the subsequent stage, and this makes the contracting-out to the private enterprise a less attractive option for the municipal government. In summary, we can state the following:

Proposition 1. *As long as a private firm has a positive bargaining power, it is always the case that the contracting-out rate in the bargaining equilibrium is smaller than the expenditure-minimizing contracting-out rate in the absence of any bargaining power on the side of the private firm.*

We can also note that an increase in the cost of investment adjusted for the scale of the waste, i.e., $\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$, or in the *ex ante* difference between the marginal collection costs of the public and private sectors, $b_{ij} - c_{ij}$, promotes the contracting-out, just as in the non-bargaining case.

4 Simulation

In this section, we present a simple simulation result which illustrates how a U-shaped relationship arises between the rate of contracting-out and the contract price across different municipalities.

As we have identified in the previous section, for a given distribution of bargaining powers, there are two main factors which influence the municipal government's decision on whether to contract out or not waste collection services in a certain district. They are the cost of investment adjusted for the scale of the waste (or, the degree of investment efficiency), represented by $\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$, and the *ex ante* difference between the marginal collection costs of the public and private sectors, $b_{ij} - c_{ij}$.

In the following simulation analysis, there are in total eighteen municipalities, each of which contains four districts of the same size, and we assign different values of $\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$ and $b_{ij} - c_{ij}$ to respective districts. For simplicity, we fix the level of the parameter η at one half, thus endowing the equal bargaining powers to a municipal government and to a private firm in each district. The two tables in Appendix A summarize the particular

values assigned to the eighteen municipalities. The first eight municipalities contain districts with different degrees of investment efficiency and the same *ex ante* difference between the marginal collection costs by public and private enterprises, whereas the next ten municipalities contain districts with the same degree of investment efficiency but varying *ex ante* cost differences within respective municipalities. The tables also show the resulting rates of contracting and average contract prices across districts within respective municipalities in the bargaining equilibrium.

By plotting the data in a similar fashion to Figure 1 and regressing them to a quadratic function, we obtain the following U-shaped regression curve between the contracting-out rates and the contract prices across mnicipalities:

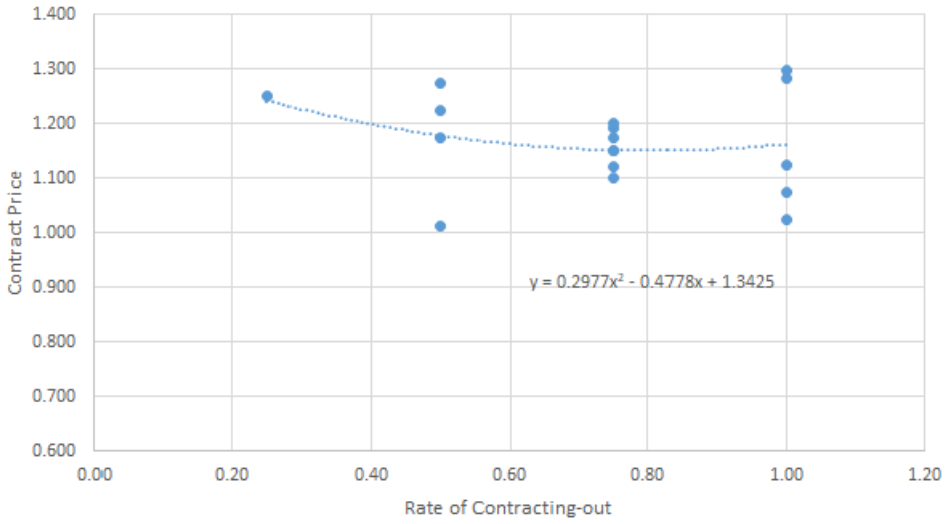

Figure 2: A simulation result

In fact, the equilibrium results obtained for the first eight municipalities gives a upward-sloping regression line, while the next ten municipalities produces a downward-sloping regression line. In combination, these two conflicting trends give rise to a U-shaped relationship observed in Figure 2. Thus, we argue that the bargaing model and municipalities' concerns for getting held-up examined in the previous section can indeed yield a phenomena that was observed in Figure 1.

5 Concluding Remarks

By examining a sequential game model of contracting-out waste collection services, which also involves a bargaining over the contract price between the concerned parties, we analytically show that, due to hold-up concerns, a municipal government tends to over-invest in its own cost reduction and this leads to a smaller degree of contracting-out chosen by local government. We also illustrate, through utilizing a simple simulation exercise, that these considerations, in turn, can give rise to an U-shaped relationship between the contracting-out ratio and the contract price of waste collection services across multiple municipalities with different characteristics.

Despite such a theoretical possibility and, moreover, increasing interest in contracting out household waste collection services over time, this U-shaped relationship has seldom attracted the attentions of researchers so far. The foremost importance should be given to further empirical investigations, and the relationship between the contracting-out rate and the contract price need to be scrutinized with more detailed data and especially by using data from different regions or countries.

References

[1] Dijkgraaf, E. and R. Gradus (2003). Cost Savings of Contracting Out Refuse Collection. *Empirica*, **30**, pp. 149-161.

[2] Domberger, S., S. Meadowcroft and D. Thompson (1986). Competitive Tendering and Efficiency: the Case of Refuse Collection. *Fiscal Studies*, **7**, pp. 69-87.

[3] Domberger, S. and P. Jansen (1997). Contracting Out by the Public Sector: Theory, Evidence and Prospects. *Oxford Journal of Public Policy*, **13**, pp. 67-78.

[4] Hart, O. (1995). *Firms, Contracts and Financial Structure*. Oxford University Press.

[5] Matsueda, N. and Miki, J. (2020), Contracting-out of Household Waste Collection Services in Japan. *Singapore Economic Review*, **65**, pp. 179-192.

[6] McDavid, J. (1985). The Canadian Experience with Privatizing Residential Solid Waste Collection Services. *Public Administration Review*, **45**, pp. 602-608.

[7] Ohlsson, H. (2003). Ownership and Production Costs: Choosing between Public Production and Contracting-Out in the Case of Swedish Refuse Collection. *Fiscal Studies*, **24**, pp. 451-476.

[8] Reeves, E. and M. Barrow (2000). The Impact of Contracting Out on the Costs of Refuse Collection Services: The Case of Ireland. *Economic and Social Review*, **31**, pp. 129-150.

[9] Stevens, B. (1978). Scale, Market Structure, and the Cost of Refuse Collection. *Review of Economics and Statistics*, **60**, pp. 438-448

Appendix A: Simulation Data

i	j	$\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$	b_{ij}	c_{ij}	contracting-out rate in i	average contract price in i
1	1	0.7	2.0	1.4	0.50	0.968
1	2	0.7	2.0	1.1		
1	3	0.7	2.0	0.8		
1	4	0.7	2.0	0.5		
2	1	0.8	2.0	1.4	0.50	1.013
2	2	0.8	2.0	1.1		
2	3	0.8	2.0	0.8		
2	4	0.8	2.0	0.5		
3	1	0.9	2.0	1.4	0.75	1.122
3	2	0.9	2.0	1.1		
3	3	0.9	2.0	0.8		
3	4	0.9	2.0	0.5		
4	1	1.0	2.0	1.4	0.75	1.150
4	2	1.0	2.0	1.1		
4	3	1.0	2.0	0.8		
4	4	1.0	2.0	0.5		
5	1	1.1	2.0	1.4	0.75	1.173
5	2	1.1	2.0	1.1		
5	3	1.1	2.0	0.8		
5	4	1.1	2.0	0.5		
6	1	1.2	2.0	1.4	0.75	1.192
6	2	1.2	2.0	1.1		
6	3	1.2	2.0	0.8		
6	4	1.2	2.0	0.5		
7	1	1.3	2.0	1.4	1.00	1.283
7	2	1.3	2.0	1.1		
7	3	1.3	2.0	0.8		
7	4	1.3	2.0	0.5		
8	1	1.4	2.0	1.4	1.00	1.296
8	2	1.4	2.0	1.1		
8	3	1.4	2.0	0.8		
8	4	1.4	2.0	0.5		

Table 1: Eight municipalities with different degrees of investment efficiency

i	j	$\frac{\gamma_{ij}(G_{ij})}{G_{ij}}$	b_{ij}	c_{ij}	contracting-out rate in i	average contract price in i
9	1	1.0	2.0	1.9	0.25	1.250
9	2	1.0	2.0	1.6		
9	3	1.0	2.0	1.3		
9	4	1.0	2.0	1.0		
10	1	1.0	2.0	1.8	0.50	1.275
10	2	1.0	2.0	1.5		
10	3	1.0	2.0	1.2		
10	4	1.0	2.0	0.9		
11	1	1.0	2.0	1.7	0.50	1.225
11	2	1.0	2.0	1.4		
11	3	1.0	2.0	1.1		
11	4	1.0	2.0	0.8		
12	1	1.0	2.0	1.6	0.50	1.175
12	2	1.0	2.0	1.3		
12	3	1.0	2.0	1.0		
12	4	1.0	2.0	0.7		
13	1	1.0	2.0	1.5	0.75	1.200
13	2	1.0	2.0	1.2		
13	3	1.0	2.0	0.9		
13	4	1.0	2.0	0.6		
14	1	1.0	2.0	1.4	0.75	1.150
14	2	1.0	2.0	1.1		
14	3	1.0	2.0	0.8		
14	4	1.0	2.0	0.5		
15	1	1.0	2.0	1.3	0.75	1.100
15	2	1.0	2.0	1.0		
15	3	1.0	2.0	0.7		
15	4	1.0	2.0	0.4		
16	1	1.0	2.0	1.2	1.00	1.125
16	2	1.0	2.0	0.9		
16	3	1.0	2.0	0.6		
16	4	1.0	2.0	0.3		
17	1	1.0	2.0	1.1	1.00	1.075
17	2	1.0	2.0	0.8		
17	3	1.0	2.0	0.5		
17	4	1.0	2.0	0.2		
18	1	1.0	2.0	1.0	1.00	1.025
18	2	1.0	2.0	0.7		
18	3	1.0	2.0	0.4		
18	4	1.0	2.0	0.1		

Table 2: Ten municipalities with various *ex ante* differences in marginal collection costs