

An Effect of Governance Structures in Duopoly: Is Privatization Preferable?*

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Abstract

When government can control public firms through a complete contract even when they are privatized, privatization is a varied governance structure of public firms. From the viewpoint of social welfare, privatization of public firms is always preferable in monopoly industries when an agency cost for government is reduced by privatization. But it is not always preferable in mixed duopoly industries since it leads to overinvestment by privatized firms and underinvestment by private firms. When a bureaucrat who is risk-neutral but protected by limited liabilities manages the public firm, the investment level of the firm depends on the reservation utility of the bureaucrat. There exists an interval of reservation utility value for which privatization is undesirable from the viewpoint of social welfare.

Keywords: Contract, Limited Liability, Privatization, Nationalization, Investment, Duopoly

1 Introduction

Privatization of public firms¹ is thought as a way to improve the efficiency of supplying public goods and services and then is one of a major problem discussed in the real political economy in many countries, especially in Japan.² However, since a number of public firms compete with several private firms in an identical markets (called as mixed oligopoly market), whether privatizing a public firm or not also affects the management of private firms. If privatized firms act more aggressively, decisions by private firms are distorted and profits of them seem to be reduced. Then we should decide whether privatizing the firm or not from the viewpoint of social welfare.

Previous studies related to this problem can be divided three classes; concerning mixed oligopoly, corporate governance, and markets and contracts. There are many literatures analyzing mixed oligopoly markets. Most literatures analyze the ex-post

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¹We use the terminology 'public firms' meaning enterprises owned by either central or local governments.

²Privatization of postal services, consisting of package delivery, banking, and insurance services, in Japan is one of a major political issue in the last Lower House election in 2005.

allocation under quantity or price setting competitions (Merrill and Schneider (1966), Harris and Wiens (1980), Beato and Mas-Colell (1984), Cremer, Marchand, and Thisse (1989), and so on). Moreover, a number of literatures analyze the impact of privatization of public firm in mixed oligopoly industry (De Fraja and Delbono (1989), Fershtman (1990), Matsumura (1998), Matsumura and Matsushima (2003), and so on).³ Poyago-Theotoky (1998) also analyzes ex-ante innovative investment. But these literatures do not analyze any agency problems.

Literatures concerning corporate governance analyze the incentive and efficiency of ex-ante investment with a contracting theory. Sappington and Stiglitz (1987) provide a basic theorem that privatization has no effect on efficiency in an ideal world and give three sources of distortion: (i) imperfect rent acquisition, (ii) contracting costs and limitation, and (iii) problems in implementing contracts. Therefore, literatures analyzing privatization in this class use a type of incomplete contract. Schmidt (1996a)⁴ introduce incentive problems into a model with innovative investment and production (a hidden action problem at the stage of investment and a hidden information problem at the stage of production). He shows that privatization makes the decision on investment more efficient but distorts the decision on production. In this literature, he supposes that state contingent contracts are not feasible at the initial period. Our model is mainly based on his models but is critically different from his because we suppose such contracts to be feasible. Alternatively, we introduce a private competitor with which governments cannot contract. Other literatures in this class are, for example, Laffont and Tirole (1991) and Shapiro and Willig (1990).⁵

Fershtman and Judd (1987) is an early literature concerning markets and contracts. They present a model using contracts as a tool of strategic commitment in a quantitative competition. Barros (1995) introduces this structure into a model of mixed duopoly market and shows the difference of incentive schemes between public and private firms.⁶ These literatures above consider the ex-post allocations only. Schmidt (1997) is a literature considering both ex-post allocation and ex-ante investment. He shows that an increase in competition affects the incentive of innovative investment by two ways. One is a 'threat-of-liquidation effect', which implies that an increase in competition increases the effort level because it leads to a reduction of profit and liquidation of the business when the manager fails in the innovation. The other is 'value-of-a-cost-reduction effect', which implies that an increase in competition reduces marginal benefit of innovation. Although he analyzes a relation between market structures and incentives of innovative investment, he does not consider an interaction of investments among firms and the existence of public firms.⁷

We analyze the effect of privatization on not only ex-post allocations but also ex-ante incentives of uncertain innovative investments in a mixed duopoly industry. Moreover, we compare the expected social welfare under privatization to that under nation-

³See, for example, Nett (1993) for a survey of mixed oligopoly literatures.

⁴See also Schmidt (1996b).

⁵See Section 6 of Schmidt (1996a).

⁶A recent literature similar to this literature is Nishimori and Ogawa (2005). They extend Barros (1995) to a two period model and show that public firm prefers a short-term contract while private firm prefers a long-term contract.

⁷For a survey on this class of literatures, see Chapter 13 in Bolton and Dewatripont (2004) for example.

alization.

The results shows that privatization leads to certain degree of overinvestment by privatized firms and underinvestment by private firms from the viewpoint of social welfare, and the investment level of nationalized firm (a firm kept to be owned by the government) is less than or equal to that of privatized firm. On the other hand, privatization does not affect the allocation. It follows that privatization is not always preferable from the viewpoint of social welfare. Moreover, we show that the difference between privatization and nationalization is dependent of the reservation utility of bureaucrat, who is risk neutral but protected by limited liability. When it is sufficiently high, the limited liability does not affect the investment levels and then nationalization is indifferent to privatization. When the reservation utility is sufficiently low by contraries, the limited liability may affect the investment levels so much that privatization improves the expected social welfare. And there exists an interval of the value of reservation utility for which nationalization is preferable to privatization from the viewpoint of social welfare.

The rest of this article is organized as follows: In Section 2, we formulates the model. Section 3 presents a benchmark case of public monopoly. In Section 4, we analyze the effects of governance structures (nationalization and privatization) on innovative investments and allocations in a duopoly market and compare the expected social welfares in each structures. Finally, we present concluding remarks in Section 5.

2 Model

Consider an industry with two firms producing a homogeneous good. One (firm 0) is owned by a government (G) and the other (firm 1) is owned by a private entrepreneur (P). The government has two possible ways to control the quantities produced by firm 0, q_0 . It can either nationalize the firm, that is, employ a bureaucrat (B) as a manager and control the quantities directly (*nationalization*), or privatize the firm, that is, sell out the firm to a potential entrant (commissioned entrepreneur (C)) and control the quantities through an incentive contract (*privatization*).⁸ On the contrary, the private entrepreneur manages her firm (firm 1) by herself.

Suppose all agents, G, P, B, and C, are risk neutral. Moreover, we suppose that B has no wealth but C has sufficient wealth to buy out the public firm. This assumption implies that B cannot buy out the public firm and G confronts a limited liability constraint in the case of nationalization.⁹ We do not model both the hiring and the selling out process explicitly. But we assume the existence of a competitive market for managers and the existence of sufficient number of potential entrants, which assures both contracts between G and B and between G and C are offered such that the expected utility of B and C equal their reservation values, \underline{w} and $\underline{\pi}$, respectively. The detailed

⁸Another way to control the firm is to employ C as the manager. We explain it in the next footnote.

⁹In general, we need to suppose that an agency cost for nationalized firm is more serious than that for private and privatized firms. We consider that limited liability is a possible source of agency cost. We could achieve similar conclusion with an assumption that bureaucrats are more risk-averse than entrepreneurs, alternatively. Assuming that all agents are risk-neutral and only bureaucrats have no wealth is just for simplicity.

structure of contracts is explained later in this section.¹⁰

Each firm confronts a market inverse demand function $P(Q)$, where $Q = q_0 + q_1$, and has a cost function $C_i(q_i | \theta_i)$ for $i = 0, 1$ respectively. In this function, θ_i is an endogenous factor denoting the fruits of an innovative investment. We assume θ_i has two possible values, θ_{ig} and θ_{ib} , and $0 < \theta_{ig} < \theta_{ib} < \bar{\theta}$ for each $i = 0, 1$. Moreover, for simplicity, we assume that the function $C_i(q_i | \theta_i)$ and the parameters θ_{ig} and θ_{ib} are common for each $i = 0, 1$, that is, the cost function is $C(q_i | \theta_i)$ and the parameters are θ_g and θ_b for each firm. Finally we assume the followings:

Assumption 1. $\frac{dP}{dQ} < 0$

Assumption 2. (i) $\frac{\partial C}{\partial q} > 0$, and $\frac{\partial^2 C}{\partial q^2} > 0$ for all q , (ii) $C'(q | \theta_g) < C'(q | \theta_b)$ for all q .

Assumption 1 indicates a normal inverse demand function such that the market price decreases with the total supply of the product. Assumption 2 (i) implies that the total cost and the marginal cost are increasing. These aspects assure positive productions by both firms. Assumption 2 (ii) implies that θ represents a parameter increasing the marginal costs.

The manager of each firm, either B or C for firm 0 and P for firm 1, has an opportunity to choose an unobservable action e_i , $e_i \in [0, \bar{e}]$, before he produces the good. This action reduces the expected costs of production by affecting the probability distribution over the possible value of θ_i . That is, after this action, nature draws $\theta_i = \theta_g$ with probability $v(e_i)$ and $\theta_i = \theta_b$ with probability $1 - v(e_i)$ for each $i = 0, 1$.¹¹ We can consider this action e_i as the level of an innovative investment (or effort). The more he invests the more likely he enjoys the low cost operation. The action e_i is measured in units of disutility caused to him. We impose an assumptions on the function $v(\cdot)$ as follows:

Assumption 3. For all $e \in [0, \bar{e}]$, $v(e)$ is three-times differentiable and satisfying the followings: (i) $v_e(e) \geq 0$ and $v_{ee}(e) < 0$, (ii) $v(0) = 0$ and $v(\bar{e}) = 1$, and (iii) $v_e(0) = +\infty$ and $v_e(\bar{e}) = 0$.

Assumption 3 (i) implies that this investment (or effort) is innovative, that is, increases the probability of drawing lower value of θ , but marginal productivity of this investment is decreasing. Assumption 3 (ii) is imposed since $v(\cdot)$ is probability. Assumption 3 (iii) assures an interior solution with respect to the investment level.

Now, we present the timing of actions and informational structure explicitly. There are three time periods. At period 0, G decides the way to control the firm 0, that is,

¹⁰If G could employ C as the manager of firm 0 alternatively, G did not confront the limited liability constraint. Moreover, nationalization and privatization were indifferent. This result can be confirmed shortly by using the following analysis. However, we focus on the case in which G cannot employ C as the manager of firm 0 from now on. One rationale of this assumption is an inflexible employment of bureaucrat. Governments tend to keep the employment of bureaucrats as long as the size of government is unchanged. Then the governments employ the manager of public firms from 'inside labor market', that is, from existing bureaucrats instead of employing from an outside labor market. This tendency could be taken into account but is not out of the scope of our analysis.

¹¹For simplicity, we again suppose the function $v(\cdot)$ is a common function.

whether nationalization or privatization. In this period, every technology described above is common knowledge. At the beginning of period 1, G contracts with the manager of firm 0 (B or C), ex-ante transfer defined by the contract is fulfilled, and the manager of firm 0 decides his effort level immediately. At the same time, P decides his effort level without observing the contract between G and the manager of firm 0.¹² At the end of this time period, the state of the world, which corresponds to the set of θ_0 and θ_1 , is realized. It is known to all the owners and the managers but is not known to G if privatized.¹³ At the beginning of period 2, both firms produce the good and the quantities of both firms are commonly observed. Finally, at the end of this period, ex-post transfer defined by the contract is fulfilled.

Suppose complete contracts contingent on the quantities can be written in period 1. We analyze the contracts deciding ex-ante lump-sum transfers z_0 from C to G and menus consisting of an ex-post transfers and a quantities, that is, (w_s, q_{0s}) between G and B and (S_{is}, q_{is}) between G and C, where s denotes the state of the world.¹⁴ Given these contracts, the payoff for G, P, B, and C in a certain state s are described as follows:

$$V_s^G = \begin{cases} CS_s + \pi_{0s} - w_s & \text{if nationalized} \\ CS_s + z_0 - S_{0s} & \text{if privatized,} \end{cases} \quad (1)$$

$$V_s^P = \pi_{1s} - e_1, \quad (2)$$

$$V_s^B = \begin{cases} w_s - e_0 & \text{if nationalized} \\ 0 & \text{if privatized,} \end{cases} \quad (3)$$

$$V_s^C = \begin{cases} 0 & \text{if nationalized} \\ \pi_{0s} - e_0 - z_0 + S_{0s} & \text{if privatized.} \end{cases} \quad (4)$$

In these equations, CS_s and π_{is} denote consumer surplus and firm i 's profit, respectively, conditional on an equilibrium quantity set (q_{0s}, q_{1s}) when the state is s .

Note that we suppose G cannot contract with P. In general, when complete contracts between governments and private firms, or sophisticated regulations, are feasible, most of problems derived from market structures can be resolved. Then the literatures concerning market structures often ignore such contracts and we also rule them out in this literature. If we introduced contracts between G and P in our framework, we could obtain a trivial conclusion that first best outcome is achieved when any agency problem does not affect the contracts.

¹²If the contract between G and the manager of firm 0 could be accessed by P, it affected the decision of P concerning the effort level. Such informational structures would produce more complicated problems, for example, timing of investment, using of contract as a commitment device, and so on.

¹³This information structure implies that any players in the industry can access the information about the state of the world but outsiders cannot. It may seem to be peculiar that the government cannot access the information that the competitor can access. However, this assumption is not essential in this complete contracting setting. In equilibrium, the information is observed without any costs through chosen menus. Then we can introduce the same outcome more simply even when supposing that G can always observe the state of the world.

¹⁴ s is in $\{gg, gb, bg, bb\}$, where, for example, gb denotes the state with $\theta_0 = \theta_g$ (good) and $\theta_1 = \theta_b$ (bad).

Now the social welfare can be described as follows:

$$W_s = Y_s + \pi_{1s} - e_0 - e_1, \quad (5)$$

where

$$Y_s \equiv CS_s + \pi_{0s}. \quad (6)$$

Y_s denotes a gross joint benefit for G and firm 0's manager derived from production. G is concerned with Y_s but is not concerned with π_1 when G cannot contract with P. This is a source of distortion with respect to effort levels.¹⁵

3 A Benchmark — Public Monopoly Case

First, we analyze public monopoly case as a benchmark. In this case, social welfare is equal to the sum of G's payoff and either B's or C's payoff. Then first best outcome can be achieved when an appropriate contract is feasible. In this case, the state space is $\{g, b\}$

3.1 First Best

Define that the first best outcome is the set of quantities conditional on the state $\{q_{0s}\}_{s \in \{g, b\}}$ and effort level e_0 maximizing the expected social welfare. The maximization problem is described as follows:

$$\max_{e_0, \{q_{0s}\}_{s \in \{g, b\}}} E[W] = v(e_0)W(e_0, q_{0g} | \theta_g) + (1 - v(e_0))W(e_0, q_{0b} | \theta_b), \quad (7)$$

where

$$W(e_0, q_0 | \theta_s) = Y(q_0 | \theta_s) - e_0. \quad (8)$$

Then the first best outcome is

$$\begin{cases} q_{0g}^* = \arg \max_{q_{0g}} Y(q_{0g} | \theta_g) \\ q_{0b}^* = \arg \max_{q_{0b}} Y(q_{0b} | \theta_b) \\ e_0^* \text{ s.t. } v_e(e_0^*) (Y(q_{0g}^* | \theta_g) - Y(q_{0b}^* | \theta_b)) = 1. \end{cases} \quad (9)$$

Note that the quantities q_{0s} in both states are not dependent of the effort level e_0 since the gross benefit of production Y_s is not affected by the effort level. First best effort level is such a level that the marginal gross benefit of effort equals to the marginal cost of it. Following from Assumption 3, It is interior value, that is, $e_0^* \in (0, \bar{e})$.

¹⁵Most literatures analyzing mixed oligopoly industries suppose that governments maximize the social welfare, and present that the existence of public firm makes some problems even when the government is the most benevolent. On the contrary, we suppose that government maximizes the sum of consumer surplus and own revenue in stead of the social welfare, and present that, in some cases, nationalization is more preferable than privatization from the viewpoint of social welfare in some cases even when the government is less benevolent.

3.2 Nationalization

When G decides to nationalize the firm, G employs B as a manager of firm 0 and controls the management through the contract $(\{w_s\}_{s \in \{g,b\}}, \{q_{0s}\}_{s \in \{g,b\}})$ as mentioned before. Since G can observe the state of the world s (or cost parameter θ_0) and the quantity q_{0s} , G can enforce this type of state-contingent contract. The maximization problem is as follows:

$$\begin{aligned} \max_{e_0, \{q_{0s}\}_{s \in \{g,b\}}, \{w_s\}_{s \in \{g,b\}}} \quad & E[V^G] = v(e_0)V^G(q_{0g}, w_g | \theta_g) + (1 - v(e_0))V^G(q_{0b}, w_b | \theta_b) \\ \text{s.t.} \quad & v(e_0)w_g + (1 - v(e_0))w_b - e_0 \geq \underline{w} \\ & v_e(e_0)(w_g - w_b) = 1 \\ & w_g \geq 0, \quad w_b \geq 0, \end{aligned}$$

where

$$V^G(q_0, w | \theta_s) = Y(q_0 | \theta_s) - w. \quad (10)$$

Three constraints are participation constraint, incentive compatible constraint, and limited liability constraints, respectively.

Since the government's payoff V^G is not affected by the effort level, G decides the quantity to maximize V^G in each state. Then the optimal quantities are as follows:

$$\begin{cases} q_{0g}^n = \arg \max_{q_{0g}} Y(q_{0g} | \theta_g) = q_{0g}^* \\ q_{0b}^n = \arg \max_{q_{0b}} Y(q_{0b} | \theta_b) = q_{0b}^* \end{cases} \quad (11)$$

G can induce B to undertake the first best action (production) since both the ex-ante information (cost parameter) and the ex-post outcome (quantity) in each state are common knowledge at period 2.

Next, we analyze the optimal effort level under nationalization. Substituting q_{0s} ($s = g, b$) into the maximization problem, we can rewrite it as follows:

$$\begin{aligned} \max_{e_0, \{w_s\}_{s \in \{g,b\}}} \quad & v(e_0)(Y_g^* - w_g) + (1 - v(e_0))(Y_b^* - w_b) \\ \text{s.t.} \quad & v(e_0)w_g + (1 - v(e_0))w_b - e_0 \geq \underline{w} \\ & v_e(e_0)(w_g - w_b) = 1 \\ & w_g \geq 0, \quad w_b \geq 0, \end{aligned}$$

where $Y_s^* = Y(q_{0s}^* | \theta_s)$ in each state. Solving this problem (See Appendix A), we have the following inequality with respect to the optimal effort level under nationalization, e_0^n :

$$e_0^n \leq e_0^*. \quad (12)$$

When the limited liability constraint $w_b \geq 0$ is not binding, G can induce B to input the first best effort level and keep the participation constraint just binding. However, when the limited liability constraint is binding, it is too costly for G to enforce the first best effort level in general. Then the nationalization probably raises an underinvestment problem under some kind of technological structures and/or parameters.

3.3 Privatization

Given the informational structure described in the previous section, G confronts an asymmetric information problem with respect to the cost parameters under privatization. That is, although C knows the cost parameter θ at the beginning of period 2, G cannot observe it. G must draw out the information by contracting a menu consisting of pairs of quantity and ex-post transfer (q_{0s}, S_s) for both states. G must also decide the price of the firm z_0 to increase the payoff as much as possible. Then the contract is $(z_0, \{(q_{0s}, S_s)\}_{s \in \{g, b\}})$ in this case. The maximization problem is written as follows:

$$\begin{aligned} \max_{e_0, z_0, \{q_{0s}\}, \{S_s\}} & v(e_0)V^G(q_{0g}, z_0, S_g) + (1 - v(e_0))V^G(q_{0b}, z_0, S_b) \\ \text{s.t.} & v(e_0)V^C(e_0, q_{0g}, z_0, S_g | \theta_g) + (1 - v(e_0))V^C(e_0, q_{0b}, z_0, S_b | \theta_b) \geq \underline{\pi} \\ & v_e(e_0) (V^C(e_0, q_{0g}, z_0, S_g | \theta_g) - V^C(e_0, q_{0b}, z_0, S_b | \theta_b)) = 1 \\ & \pi_0^p(q_{0s} | s) + S_s \geq \tilde{\pi}_s \quad \forall s \\ & \pi_0^p(q_{0s} | s) + S_s \geq \pi_0^p(q_{0u} | s) + S_u \quad \forall s, u \in \{g, b\}, s \neq u, \end{aligned}$$

where

$$V^G(q_{0s}, z_0, S_s) = CS(q_{0s}) + z_0 - S_s$$

and

$$V^C(e_0, q_{0s}, z_0, S_s | \theta_s) = \pi_0(q_{0s} | \theta_s) - e_0 - z_0 + S_s.$$

The first inequality is the participation constraint at the beginning of period 1, implying that the expected payoff for C exceeds his reservation utility. The second equation is the incentive compatible constraint with respect to the effort level at the beginning of period 1.¹⁶ The third inequalities are the individual rationality constraints at the beginning of period 2, where $\tilde{\pi}_s$ denotes monopoly profit in the state s and which imply that C prefers to execute the contract, that is, to produce q_{0s} and to receive S_s , rather than to withdraw it in both states. The fourth inequalities are the incentive compatible constraints with respect to the quantities C produces at period 2. These constraints ensure that C voluntarily tells the truthful state through producing the quantity designed for it.

We should solve this problem to introduce the optimal quantities and effort level. However, following from Sappington and Stiglitz (1987), we can shortly introduce an optimal contract (quantities, selling out price, and ex-post transfers) and effort level as follows:

$$\begin{aligned} \text{Quantities : } & \begin{cases} q_{0g}^p = q_{0g}^* \\ q_{0b}^p = q_{0b}^* \end{cases} \\ \text{Selling out Price : } & z_0 = v(e_0^*)Y_g^* + (1 - v(e_0^*))Y_b^* - e_0^* - \underline{\pi} \\ \text{Ex-post transfers : } & \begin{cases} S_g = CS(q_{0g}^* | \theta_g) \\ S_b = CS(q_{0b}^* | \theta_b) \end{cases} \\ \text{Effort level : } & e_0^p = e_0^*. \end{aligned}$$

¹⁶This constraint is held with equality following from Assumption 3.

The quantities under privatization are equal to the first best quantities in both states although the information is asymmetric. This is because G can use the ex-post transfers to internalize the consumer surplus into the C's objective without any costs since we suppose C is risk neutral. Moreover, given the quantities are the first best level in both state, G can induce C to undertake the first best effort level without any costs following from risk-neutrality. The sell out price (ex-ante transfer) works as a device for G to absorb all the rent.

3.4 Which Is Preferable?

Following from the preceding results, we have the following proposition concerning 'which is preferable'.

Proposition 1. *In monopoly industries, (i) privatization is always preferable from the viewpoint of expected social welfare, $E^n[W^n] \leq E^p[W^p]$, and (ii) privatization is adopted if $E^*[W^*] - \underline{\pi} \geq E^n[W^n] - \underline{w}$.*

Proof. (i) Summing up the preceding results, we have $q_{0j}^n = q_{0j}^p = q_{0j}^*$ for each $s = g, b$ and $e_0^n \leq e_0^p = e_0^*$, where upper subscripts represent nationalization, privatization, and first best, respectively. Then we have $E^n[W^n] \leq E^p[W^p] = E^*[W^*]$, where $E^n[W^n]$, for example, denotes the expected social welfare with the optimal quantities and effort level under nationalization. (ii) G prefers privatization to nationalization if and only if $E^n[V^{Gn}] \leq E^p[V^{Gp}]$. This can be reduced as $E^n[W^n] - E^n[V^B] \leq E^p[W^p] - E^p[V^C]$. In this inequality, $E^n[V^B] \geq \underline{w}$ since B's participation constraint may not be binding. On the contrary, $E^p[V^C] = \underline{\pi}$ since G can absorb all the rent from C by using z_0 . Then G prefers privatization when $E^*[W^*] - \underline{\pi} \geq E^n[W^n] - \underline{w}$. Q.E.D.

The existence of limited liability under nationalization distorts the effort level and reduces the expected social welfare. Then privatization is always preferable from the viewpoint of expected social welfare. However, G does not always adopt privatization since G is interested in only a part of the expected social welfare.

This proposition implies two aspects with respect to the government's decision. First, it may be preferable for G to adopt privatization even when the reservation utility of C is larger than that of B, that is, $\underline{\pi} > \underline{w}$. One of the major rationale of privatization is to reduce G's expected payment. However, when agency costs under nationalization is large, privatization which increases G's expected payment may be preferable for G. Second, that said, G may adopt nationalization when the expected payment under privatization is much larger than that under nationalization, that is, $\underline{\pi} \gg \underline{w}$. However, this decision is not preferable from the viewpoint of expected social welfare.

4 Solution with a Private Firm

Now, we analyze the case with a private firm. In case of the public monopoly analyzed in the previous section, there exist no conflicts between welfare maximization and G's problem under both nationalization and privatization. However, in mixed duopoly

cases, G's problem loses touch with welfare maximization in general since there is a private firm as a third party. This divergence poses new problems on the effort levels of both managers.

4.1 Solution without Agency Problem

We introduce a benchmark solution without any agency problems, where G can enforce the manager of firm 0 to engage any effort levels and any production quantities without paying rent. First, we analyze the decision of G and P with respect to the quantities. Since G and P know the state in which they live at period 2, they decide their quantities to maximize their objectives in the state. Note that G can commit her quantities in each state at the beginning of period 1 by contracting with her manager although actual production is taken place at period 2. Therefore, if G can disclose the contract with her manager at period 1 and P cannot commit her quantities at period 1, G can act as a Stackelberg leader. If else, G and P compete within a Cournot setting.¹⁷ We are not interested in which types of competitions are taken place. We define a certain type of competitive-equilibrium quantity set as (q_{0s}^c, q_{1s}^c) for $s \in \{gg, gb, bg, bb\}$, where gb , for example, represents the state in which $\theta_0 = \theta_g$ and $\theta_1 = \theta_g$. Substituting these quantities, the objectives in each state are described as follows:

$$W_s^c = W^c(\theta_k, \theta_l) \quad (13)$$

$$Y_s^c = Y^c(\theta_k, \theta_l) \quad (14)$$

$$\pi_{1s}^c = \pi_1^c(\theta_k, \theta_l), \quad (15)$$

when $\theta_0 = \theta_k, \theta_1 = \theta_l$, and $s = kl$.

Assumption 4. The objectives in each state satisfy the followings:

- (i) $W_{gb}^c - W_{bb}^c > W_{gg}^c - W_{bg}^c > 0$ and $W_{bg}^c - W_{bb}^c > W_{gg}^c - W_{gb}^c > 0$
- (ii) $Y_{gb}^c - Y_{bb}^c > Y_{gg}^c - Y_{bg}^c > 0$
- (iii) $\pi_{1bg}^c - \pi_{1bb}^c > \pi_{1gg}^c - \pi_{1gb}^c > 0$.

One aspect Assumption 4 (ii) and (iii) imply is that the gross benefits for both G and P increase as her cost parameters improve.¹⁸ The other is that the increases in their benefits are larger when the parameter of the counter party is bad. When the counter party is in bad state, the innovation generates much benefit following from cost advantage. On the contrary, it generates little because of harder competition when the counter party is in good state. Assumption 4 (i) implies that, from the viewpoint of social welfare, the innovation of both firms is beneficial, but the increase in the social welfare following from one firm's innovation is larger when the other is in bad

¹⁷We implicitly assume that the market structure supposed in this paper has a unique (and stable) equilibrium with respect to quantities in both competition structures. Assuming $P(Q) = a - Q$ and $C(q | \theta) = \frac{1}{2}\theta q^2$ for example. Then the unique equilibrium quantity set in Stackelberg competition is $(q_0^{st}, q_1^{st}) = \left(\frac{(2+\theta_1)^2 - 1}{(1+\theta_0)(2+\theta_1)^2 - 1} a, \frac{a - q_0^{st}}{2+\theta_1} \right)$ and that in Cournot competition is $(q_0^{co}, q_1^{co}) = \left(\frac{a}{1+\theta_0}, \frac{a - q_0^{co}}{2+\theta_1} \right)$.

¹⁸ Y_s denotes the gross joint benefit for G and her manager to be precise. However, in case of first best environment, G is not concerned with CS_s and π_{0s} separately but is only concerned with Y_s .

state. This is because that the innovation leads to an increase in total supply and a production substitution. Assumption 4 is satisfied when we specify the market structure as $P(Q) = a - Q$, $C(q | \theta) = \frac{1}{2}\theta q^2$, and $0 < \theta_g < \theta_b < 2$, for example.

Now the expected payoffs for G and P at the beginning of date 1 are as follows:

$$E[Y^c] - e_0 = v(e_0)[v(e_1)Y_{gg}^c + (1 - v(e_1))Y_{gb}^c] \\ + (1 - v(e_0))[v(e_1)Y_{bg}^c + (1 - v(e_1))Y_{bb}^c] - e_0 \quad (16)$$

$$E[\pi_1^c] - e_1 = v(e_1)[v(e_0)\pi_{1gg}^c + (1 - v(e_0))\pi_{1bg}^c] \\ + (1 - v(e_1))[v(e_0)\pi_{1gb}^c + (1 - v(e_0))\pi_{1bb}^c] - e_1. \quad (17)$$

Since G and P decide their effort level simultaneously, then the first order conditions for optimization are the following equations:

$$v_e(e_0) [v(e_1) (Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1)) (Y_{gb}^c - Y_{bb}^c)] = 1 \quad (18)$$

$$v_e(e_1) [v(e_0) (\pi_{1gg}^c - \pi_{1gb}^c) + (1 - v(e_0)) (\pi_{1bg}^c - \pi_{1bb}^c)] = 1. \quad (19)$$

Define the response functions $R_0^c(e_1)$ and $R_1^c(e_0)$ derived from (18) and (19) respectively.

On the other hand, the expected social welfare is

$$E[W^c] = v(e_0)[v(e_1)W_{gg}^c + (1 - v(e_1))W_{gb}^c] \\ + (1 - v(e_0))[v(e_1)W_{bg}^c + (1 - v(e_1))W_{bb}^c]. \quad (20)$$

The first order conditions for welfare maximizing are the following equations:

$$v_e(e_0) [v(e_1) (W_{gg}^c - W_{bg}^c) + (1 - v(e_1)) (W_{gb}^c - W_{bb}^c)] = 1 \quad (21)$$

$$v_e(e_1) [v(e_0) (W_{1gg}^c - W_{1gb}^c) + (1 - v(e_0)) (W_{1bg}^c - W_{1bb}^c)] = 1. \quad (22)$$

Define the response functions $R_0^{**}(e_1)$ and $R_1^{**}(e_0)$ derived from (21) and (22) respectively.

Assumption 5. There exist a unique competitive equilibrium, (e_0^c, e_1^c) , which satisfies two response functions, $e_0 = R_0^c(e_1)$ and $e_1 = R_1^c(e_0)$, and a unique welfare-maximizing equilibrium, (e_0^{**}, e_1^{**}) , which satisfies two response functions, $e_0 = R_0^{**}(e_1)$ and $e_1 = R_1^{**}(e_0)$.

Assumption 4 always assures that the derivatives of response function are negative, that is, the decisions of investment level are strategic substitute. Moreover, the investment levels, e_i , are less sensitive to the other's levels, e_j , that is, $\frac{dR_i^c}{de_j} > -1$ and $\frac{dR_i^{**}}{de_j} > -1$, for sufficiently positive value of the other's level, e_j , following from Assumption 3. In addition, we have both $0 < R_i^c(1) < R_i^c(0) < \bar{e}$ and $0 < R_i^{**}(1) < R_i^{**}(0) < \bar{e}$ for $i = 0, 1$. Therefore this assumption is plausible.¹⁹

Finally, we compare the two effort sets (e_0^c, e_1^c) and (e_0^{**}, e_1^{**}) . We pose another assumption as follows:

¹⁹See also Figure 1.

Assumption 6. The objectives Y_s^c and π_{1s}^c in each state satisfy the followings:
(i) $Y_{gg}^c > Y_{gb}^c$ and $Y_{bg}^c > Y_{bb}^c$ (ii) $\pi_{1gg}^c < \pi_{bg}^c$ and $\pi_{gb}^c < \pi_{bb}^c$.

Assumption 6 (ii) implies that the production substitution following from a cost reduction by firm 0 decreases the payoff for P. This is a plausible assumption. On the other hand, Assumption 6 (i) implies that, although the production substitution following from a cost reduction by firm 1 probably reduces the profit of firm 0, it increases the payoff for G since it increases the consumer surplus. This assumption is critical for our results. Whether this properties in Assumption 6 (ii) is held or not is depending on the market structure, but the specified market structure mentioned before²⁰, for example, satisfies these properties.

Lemma 1. $R_0^c(e_1) > R_0^{**}(e_1)$ for all e_1 and $R_1^c(e_0) < R_1^{**}(e_0)$ for all e_0 .

Proof. See Appendix B.

Proposition 2. *G induces an overinvestment and P decides an underinvestment under the competitive decision making compared to the levels under welfare maximizing decision making, that is, $e_0^c > e_0^{**}$ and $e_1^c < e_1^{**}$.*

Proof. See Appendix B.

We can explain this outcome as follows: The expected social welfare is described as

$$E[W] = E[Y] + E[\pi_1] - e_0 - e_1. \quad (23)$$

Increasing in e_0 increases G's benefit $E[Y]$ but decreases P's benefit $E[\pi_1]$. On the contrary, increasing in e_1 increases P's benefit $E[\pi_1]$ and also increases G's benefit $E[Y]$. Since G and P are not interested in the other's benefit under competitive decision, G has an incentive to induce her manager to engage higher effort and P has an incentive to engage lower effort compared to those under welfare-maximizing decision for any level of rival's effort respectively. Then the overinvestment of firm 0 and the underinvestment of firm 1 are taken place in equilibrium.

The relation between the competitive effort set e^c and the welfare-maximizing effort set e^{**} is described in Figure 1. The response curve of firm 0 under the competitive decision, L_0^c , is on the right side of that under the welfare-maximizing decision, L_0^{**} . On the contrary, the response curve of firm 1 under the competitive decision, L_1^c , is on the downside of that under the welfare-maximizing decision, L_1^{**} . Given the stability constraints, e^c is located in the lower-right area.

4.2 Nationalization

The quantity sets of both firms under nationalization \mathbf{q}_s^n are equal to the competitive quantity sets $\mathbf{q}_s^c = \mathbf{q}_s^{**}$ since the information structure is identical to that explained the previous subsection. Given these quantity sets in each state, G decides the wage levels conditional on the states to control the effort level of B, and P decides her effort level.

²⁰ $P(Q) = a - Q$ and $C(q | \theta) = \frac{1}{2}\theta q^2$.

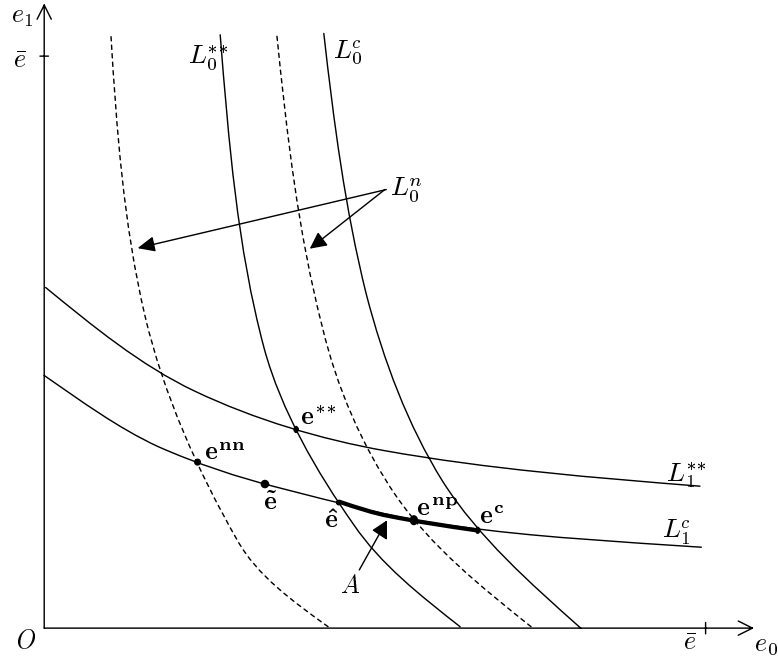


Figure 1: L_i^{**} , L_i^c , and L_i^n denote the response curves of firm i under welfare maximizing, competition without agency problem, and nationalization, respectively, and e^{**} and e^c denote the equilibrium effort sets under welfare maximizing and competition without agency problem, respectively. Furthermore, the bold segment on L_1^c denotes the set A in the proof of Proposition 5 and \tilde{e} denotes the effort set equivalent to e^c defined in Appendix C. When L_0^n is shifted a little from L_0^c , the equilibrium effort set is such one, e^{np} , in A . On the contrary, when L_0^n is sufficiently shifted from L_0^c , the equilibrium effort set is such one like e^{nn} , which is not preferable to e^c .

P's problem is to maximize (17) under a given effort level of B. Then the first order condition for P's problem is (19). On the other hand, G's problem is revised as follows:

$$\begin{aligned} & \max_{e_0, \{w_s\}} E[Y - w] \\ \text{s.t. } & E[w] - e_0 \geq \underline{w} \\ & v_e(e_0) [v(e_1)(w_{gg} - w_{bg}) + (1 - v(e_1))(w_{gb} - w_{bb})] = 1 \\ & w_s \geq 0 \quad \forall s \in \{gg, gb, bg, bb\}. \end{aligned}$$

The first constraint represents B's participation constraint. The second represents B' incentive compatible constraint described as a first order condition. The last is a set of B's limited liability constraints. Following from the first order conditions for this problem, We have a following condition on the effort levels:

$$v_e(e_0) [v(e_1) (Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1)) (Y_{gb}^c - Y_{bb}^c)] = 1 - \gamma \frac{v_{ee}(e_0)}{v_e(e_0)}. \quad (24)$$

Note that γ is a nonnegative coefficient denoting a Lagrangean multiplier for the incentive compatible constraint and the fraction $\frac{v_{ee}(e_0)}{v_e(e_0)}$ is a negative value following from Assumption 3. Moreover, γ is strictly positive when two limited liability constraints are binding.²¹

Lemma 2. *There exists a threshold of the reservation utility \hat{w} such that $\gamma > 0$ for all $\underline{w} < \hat{w}$.*

Proof. See Appendix C.

G must design some degree of differences of wage between wages for good outcome and those for bad outcome, that is, between w_{gl} and w_{bl} for each $l = g, b$, to draw B's incentive of effort. When the reservation utility is sufficiently high, G must pay a higher wage in each state for B to participate the management of firm 0. Then the limited liability constraints are not binding. On the contrary, when the reservation utility is low, several number of limited liability constraints are binding. In this case, the effort level under no agency problem is too costly to be induced and then the incentive compatible constraint is binding.

Define $R_0^n(e_1)$ and $R_1^n(e_0)$ as response functions of B and P under nationalization respectively and e^n as a set of effort levels. Then we have the followings.

Lemma 3. $R_0^n(e_1) \leq R_0^c(e_1)$ for all e_1 and $R_1^n(e_0) = R_1^c(e_0)$ for all e_0 .

Proof. Obvious following from (18), (19), and (24). Q.E.D.

Proposition 3. *The existence of limited liability for bureaucrats reduces the investment of public firms and instead increases that of public firms, that is, $e_0^n \leq e_0^c$ and $e_1^n \geq e_1^c$.*

Proof. Obvious following from Lemma 3. Q.E.D.

²¹We have a detailed explanation of the solution for G's problem in Appendix C.

When the limited liability constraints are binding, G induces B to engage less effort for any effort level of P. On the other hand, P's incentive structure is not changed. Then firm 0's investment level is lower and firm 1's investment level is higher than those under no agency problem respectively. When the limited liability constraints are not binding, G's incentive structure is also unchanged and then the set of effort levels is identical. This relation is described in Figure 1. The response curve of firm 0 under nationalization, L_0^n , is on the left side (or on the identical location) of that under no agency problem, L_0^c . On the other hand, the response curves of firm 1 under nationalization, L_1^n , and under no agency problem, L_1^c , are identical. Then the intersection of firm 0's and firm 1's response curves under nationalization, denoted as e^n , is located on the upper-left side of the intersection of two response curves under no agency problem, e^c .

4.3 Privatization

When G privatizes firm 0, she confronts the asymmetric information problem with the respect to the cost parameters, or the state of the world, at period 2 similar to the monopoly case. She decides the contract $(z_0, \{(q_{0s}, S_{0s})\}_{s \in \{gg, gb, bg, bb\}})$ to draw out the information and to absorb production rent. Given a certain type of competition structure discussed in 4.1, firm 0's profit and the consumer surplus in state s can be written as $\pi_0^p(q_0 | s)$ and $CS^p(q_0 | s)$ respectively.²² Then G's objective function is

$$v(e_0) \left[v(e_1) V_{gg}^{Gp} + (1 - v(e_1)) V_{gb}^{Gp} \right] + (1 - v(e_0)) \left[v(e_1) V_{bg}^{Gp} + (1 - v(e_1)) V_{bb}^{Gp} \right], \quad (25)$$

where $V_s^{Gp} = CS^p(q_{0s} | s) - S_{0s} + z_0$. Similar to the monopoly case, the contract must satisfy the following constraints:

$$v(e_0) \left[v(e_1) V_{gg}^{Cp} + (1 - v(e_1)) V_{gb}^{Cp} \right] + (1 - v(e_0)) \left[v(e_1) V_{bg}^{Cp} + (1 - v(e_1)) V_{bb}^{Cp} \right] \geq \bar{\pi} \quad (26)$$

$$v_e(e_0) \left[v(e_1) \left(V_{gg}^{Cp} - V_{bg}^{Cp} \right) + (1 - v(e_1)) \left(V_{gb}^{Cp} - V_{bb}^{Cp} \right) \right] = 1 \quad (27)$$

$$\pi_0^p(q_{0s} | s) + S_{0s} \geq \tilde{\pi}_{0s} \quad \forall s \quad (28)$$

$$\pi_0^p(q_{0s} | s) + S_{0s} \geq \pi_0^p(q_{0u} | s) + S_{0u} \quad \forall s, u \in \{gg, gb, bg, bb\}, s \neq u, \quad (29)$$

where $V_s^{Cp} = \pi_0^p(q_{0s} | s) + S_{0s} - z_0 - e_0$. These constraints represent participation constraint at period 1, incentive compatible constraint at period 1, individual rationality constraints at date 2, and incentive compatible constraints at period 2, respectively. G's problem is to maximize (25) under (26), (27), (28), (29), and a given e_1 . Note $\tilde{\pi}_{0s}$ in (28) represents a deviation utility, which is implied as a payoff under a certain type of private competition.

²²The decision on q_1 by P under the competitive structure is already taken into account in these forms.

Although G's problem is very complicated form, following from Sappington and Stiglitz (1987) again, we can conclude that $S_{0s} = CS^p(q_{0s} | s)$ in each state. This transfer structure draws out a truth-telling with respect to the state and then realizes the quantity set \mathbf{q}^c in each state. Given these transfer structure and quantity set, the solution of G's problem satisfies (18) and

$$z_0 = E[Y] - e_0 - \underline{\pi}. \quad (30)$$

On the other hand, the first order condition for P's problem is (19). We define the response functions as $R_0^p(e_1)$ and $R_1^p(e_0)$ respectively and then have the followings:

Lemma 4. $R_0^p(e_1) = R_0^c(e_1)$ and $R_1^p(e_0) = R_1^c(e_0)$.

Proof. Obvious since both $R_0^p(e_1)$ and $R_0^c(e_1)$ are derived from (18) and both $R_1^p(e_0)$ and $R_1^c(e_0)$ are derived from (19). Q.E.D.

Proposition 4. *The effort levels under privatization is identical to those under no agency problem, that is, $\mathbf{e}^p = \mathbf{e}^c$.*

Proof. Obvious following from Lemma 4. Q.E.D.

Following from Sappington and Stiglitz (1987), the existence of asymmetric information under privatization has no effect on the decisions of privatized firm when the commissioned entrepreneur is risk neutral and has sufficient wealth. This property is held even under a competition with private firms, that is, both the ex-ante investment levels and the production levels are not distorted.

4.4 Which Is Preferable?

Now we compare the outcomes under nationalization and privatization. The quantity sets are identical in any states, that is, $\mathbf{q}_s^n = \mathbf{q}_s^p$ for all $s \in \{gg, gb, bg, bb\}$. On the contrary, the effort sets are differentiated as $e_0^n \leq e_0^p$ and $e_1^n \geq e_1^p$, where equalities are held when the limited liability constraints are not binding. Then we have the major result.

Proposition 5. *In duopoly industries, (i) nationalization is probably preferable from the viewpoint of expected social welfare, $E^n[W^n] \geq E^p[W^p]$, but (ii) privatization is adopted if $E^n[Y^c] - \underline{w} < E^p[Y^c] - \underline{\pi}$.*

Proof. (i) Define $\hat{\mathbf{e}}$ such that $\hat{e}_0 = R_0^{**}(\hat{e}_1)$ and $\hat{e}_1 = R_1^c(\hat{e}_0)$. And define $A = \{\mathbf{e} | e_1 = R_1^c(e_0), \hat{e}_0 \leq e_0 < e_0^c\}$. Since $\frac{dR_1^c}{de_0} < 0$, $e_1^c < e_1 \leq \hat{e}_1$ for all \mathbf{e} in A . For any \mathbf{e}'' such that $e_0'' \geq R_0^{**}(e_1'')$ and $e_1'' \leq R_1^{**}(e_0'')$, the expected social welfare is decreasing in e_0 and increasing in e_1 since $R_i^{**}(\cdot)$ represents the optimal response for each i . Then the expected social welfare under $\mathbf{e} \in A$ is larger than that under $\mathbf{e}^c = \mathbf{e}^p$. Depending on the value of γ , \mathbf{e}^n is contained in A . It follows that we have $E^n[W^n] \geq E^p[W^p]$ in some cases. (ii) Similar to the proof of Proposition 1 (ii). Q.E.D.

Figure 1 describes the relations among the effort sets. e^c is located in the lower-right of e^{**} . Moreover, e^p is identical to e^c , and e^n is located in the upper-left of e^c on the curve L_1^c . When the shift of the firm O 's response curve under nationalization, L_0^n , from that under no agency problem, L_0^c , is relatively little, e^n is located in the interval between \hat{e} and e^c , that is, in the set A . In this case, e^n is preferable from the viewpoint of expected social welfare since the effort set closes in the second best one, e^{**} , roughly spoken.

Under competitive market, the governments would like to induce her agent to engage higher investment (or effort level) than the second best level. However, the existence of limited liability under nationalization reduces the incentive of investment. Then nationalization is preferable from the viewpoint of expected social welfare when this reduction of incentive is relatively small.

Now we present a comparative statics with respect to the reservation utility of B , \underline{w} . As we show in 4.2, the investment level under nationalization depends on \underline{w} .

Proposition 6. *From the viewpoint of social welfare, nationalization and privatization are indifferent when \underline{w} is sufficiently high. On the contrary, when \underline{w} is extremely low, nationalization may lead to so serious underinvestment that privatization is preferable. Moreover, there exists an interval of \underline{w} for which nationalization is preferable.*

Proof. See Appendix C.

Q.E.D.

For $\underline{w} \geq \hat{w}$, where \hat{w} is the threshold value defined in Lemma 2, L_0^n and L_0^c are identical. Then nationalization and privatization are indifferent. For $\underline{w} < \hat{w}$, L_0^n shifts to the left as \underline{w} decreases, which increases the expected social welfare at first but decreases it later on. Therefore, privatization is preferable only when \underline{w} is sufficiently low.²³

The reservation utility can be interpreted as a parameter of an agent's ability, which does not affect the outcome of the firm managed by him now, since it represent a maximum value that he can gain if he works in outside opportunities. Then we can present an interpretation of this proposition as follows: When a bureaucrat who is going to manage the public firm has high ability, privatization does not improve the social welfare, in other words, nationalization and privatization is indifferent. When the bureaucrat has an intermediate value of ability, nationalization is rather preferable to privatization. Thus privatization is preferable to nationalization only when the ability of the bureaucrat is sufficiently low. More interestingly, the social welfare under nationalization is decreasing in the ability for an interval of the value since a decrease in ability reduces the public firm's investment, which makes it approach the welfare-maximizing level for the interval of the value. It follows that assigning the bureaucrat with highest ability to the manager of public firm in mixed market is probably suboptimal.

²³More precisely, L_0^n stops shifting at a location for $\underline{w} \leq \check{w}$, where \check{w} is the threshold value that the participation constraint is never binding for $\underline{w} \leq \check{w}$. Then privatization is never preferable for any \underline{w} in some cases. See Appendix C.

5 Conclusion

We analyze the effect of privatization on both ex-post allocations and ex-ante incentives of uncertain innovative investments in a mixed duopoly industry. Moreover, we compare the expected social welfare under privatization to that under nationalization. Either nationalizing or privatizing a firm can be considered as a difference of governance structures, since government can control the firm through sophisticated contracts.

The results shows that privatization leads to an overinvestment of privatized firm and an underinvestment of private firm from the viewpoint of social welfare and the investment level of nationalized firm (the firm kept to be owned by the government) is less than or equal to that of privatized firm. Then the difference of governance structures affects the incentive of innovative investment. On the other hand, the difference of governance structures does not affect the outcome of competition in the production stage. We show that privatization is not always preferable from the viewpoint of social welfare. In addition, we show that the difference of governance structure depends on the reservation utility of bureaucrat, who is risk neutral but protected by limited liability. When it is sufficiently high, the limited liability does not affect the investment levels and then the outcomes of different governance structures are identical. When the reservation utility is sufficiently low by contraries, the limited liability may affect the investment levels so much that privatization improves the expected social welfare. There exists an interval of the value of reservation utility for which nationalization is preferable to privatization from the viewpoint of social welfare.

Appendix

A Solution under Nationalization — monopoly Case

Lagrangean of the government problem is defined as

$$L = v(e_0)(Y_g^* - w_g) + (1 - v(e_0))(Y_b^* - w_b) + \lambda [v(e_0)w_g + (1 - v(e_0))w_b - e_0 - \underline{w}] + \gamma [v_e(e_0)(w_g - w_b) - 1]. \quad (31)$$

First order conditions are the followings:

$$(1 - \lambda)v(e_0) - \gamma v_e(e_0) \geq 0 \quad (32)$$

$$(1 - \lambda)(1 - v(e_0)) + \gamma v_e(e_0) \geq 0 \quad (33)$$

$$v_e(e_0) [(Y_g^* - w_g) - (Y_b^* - w_b)] + \lambda [v_e(e_0)(w_g - w_b) - 1] + \gamma v_{ee}(e_0)(w_g - w_b) = 0 \quad (34)$$

$$\lambda [v(e_0)w_g + (1 - v(e_0))w_b - e_0 - \underline{w}] = 0 \quad (35)$$

$$v_e(e_0)(w_g - w_b) - 1 = 0. \quad (36)$$

Substituting (36) into (34), we have the following equation:

$$v_e(e_0)(Y_g^* - Y_b^*) = 1 - \gamma \frac{v_{ee}(e_0)}{v_e(e_0)}. \quad (37)$$

When the limited liability constraints are not binding, both (32) and (33) are held with equality, which leads to $\lambda = 1$ and $\gamma = 0$. Then we have $v_e(e_0)(Y_g^* - Y_b^*) = 1$ and $v(e_0)w_g + (1 - v(e_0))w_b - e_0 = \underline{w}$, which implies that G can induce B the first best effort level and absorb whole rent. However, when the limited liability constraint with respect to w_b is binding, γ is ordinarily positive. It follows that $e_0^n < e_0^*$ since $\frac{v_{ee}(e_0)}{v_e(e_0)} < 0$. We have a more precise analysis in Appendix C.

B Proof of Lemma 1 and Proposition 2

B.1 Proof of Lemma 1

Proof. Following from (18) and (21), we have the following equations:

$$v_e(R_0^c(e_1)) [v(e_1)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1))(Y_{gb}^c - Y_{bb}^c)] = 1 \quad (38)$$

$$v_e(R_0^{**}(e_1)) [v(e_1)(W_{gg}^c - W_{bg}^c) + (1 - v(e_1))(W_{gb}^c - W_{bb}^c)] = 1. \quad (39)$$

Since we have

$$(W_{gg}^c - W_{bg}^c) - (Y_{gg}^c - Y_{bg}^c) = (\pi_{1gg}^c - \pi_{1bg}^c) < 0 \quad (40)$$

and

$$(W_{gb}^c - W_{bb}^c) - (Y_{gb}^c - Y_{bb}^c) = (\pi_{1gb}^c - \pi_{1bb}^c) < 0, \quad (41)$$

then we have $v_e(R_0^c(e_1)) < v_e(R_0^{**}(e_1))$, which is reduced as $R_0^c(e_1) > R_0^{**}(e_1)$.

On the contrary, following from (19) and (22), we have $v_e(R_1^c(e_0)) > v_e(R_1^{**}(e_0))$. Then we have $R_1^c(e_0) < R_1^{**}(e_0)$. Q.E.D.

B.2 Proof of Proposition 2

Proof. Following from Lemma 1 and Assumption 5. See also Figure 1. Q.E.D.

C Solution under Nationalization and Comparison — duopoly Case

C.1 Solution under Nationalization

Given e_1 , Lagrangean of the government problem in the duopoly case is defined as

$$L = E[Y^c - w] + \lambda(E[w] - e_0 - \underline{w}) + \gamma [v_e(e_0)\{v(e_1)(w_{gg} - w_{bg}) + (1 - v(e_1))(w_{gb} - w_{bb})\} - 1], \quad (42)$$

Where $\lambda \geq 0$ and $\gamma \geq 0$. First order conditions are reduced as follows:

$$(1 - \lambda)v(e_0) - \gamma v_e(e_0) \geq 0 \quad (43)$$

$$(1 - \lambda)(1 - v(e_0)) + \gamma v_e(e_0) \geq 0 \quad (44)$$

$$v_e(e_0) [v(e_1)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1))(Y_{gb}^c - Y_{bb}^c)] = 1 - \gamma \frac{v_{ee}(e_0)}{v_e(e_0)} \quad (45)$$

$$\lambda [E[w] - e_0 - \underline{w}] = 0 \quad (46)$$

$$v_e(e_0) \{v(e_1)(w_{gg} - w_{bg}) + (1 - v(e_1))(w_{gb} - w_{bb})\} - 1 = 0, \quad (47)$$

where (45) is derived from $\frac{\partial L}{\partial e_0} = 0$ and (47).

Suppose the limited liability constraints are not imposed, then (43) and (44) are held with equality, which implies $\lambda = 1$ and $\gamma = 0$. It follows that we have the following equations;

$$v_e(e_0) [v(e_1)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1))(Y_{gb}^c - Y_{bb}^c)] = 1, \quad (48)$$

$$E^c[w] - e_0^c - \underline{w} = 0, \quad (49)$$

$$v_e(e_0^c) \{v(e_1^c)(w_{gg} - w_{bg}) + (1 - v(e_1^c))(w_{gb} - w_{bb})\} = 1. \quad (50)$$

Reducing w_{gb} and w_{bb} and increasing w_{gg} and w_{bg} heighten the incentive of investment. Then distortion derived from limited liabilities takes place if and only if the incentive is insufficient for such a wage set that satisfies both (49) and $w_{gb} = w_{bb} = 0$, that is,

$$v(e_1^c)w_{gg} + (1 - v(e_1^c))w_{bg} < v(e_1)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1))(Y_{gb}^c - Y_{bb}^c) \quad (51)$$

$$v(e_0^c) [v(e_1^c)w_{gg} + (1 - v(e_1^c))w_{gb}] = e_0^c + \underline{w}. \quad (52)$$

These conditions can be reduced as

$$v(e_1^c)Y_{bg}^c + (1 - v(e_1^c))Y_{bb}^c < E^c[Y^c] - e_0^c - \underline{w}. \quad (53)$$

Define \hat{w} satisfying (53) with equality. Then, for all $\underline{w} < \hat{w}$, two limited liability constraints are binding, which implies $\gamma > 0$ (Lemma 2). Note that we have $w_{bg}^c = w_{bb}^c = 0$, $\lambda = 1$, and $\gamma = 0$ when \underline{w} is just equal to \hat{w} . Note also \hat{w} is strictly positive. If else we have

$$v(e_1^c)Y_{bg}^c + (1 - v(e_1^c))Y_{bb}^c \geq E^c[Y^c] - e_0^c. \quad (54)$$

following from (53). In this inequality, the left-hand side is equal to the expected social welfare when B engages no effort. Then this inequality contradicts the fact that $e_0^c > 0$ is the optimal response to e_1^c .

For $\underline{w} < \hat{w}$, optimal wage contract $\{w_s\}$ and effort levels (e_0^n, e_1^n) satisfy following conditions:

$$(1 - \lambda)v(e_0^n) - \gamma v_e(e_0^n) = 0 \quad (55)$$

$$v_e(e_0^n) [v(e_1^n)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1^n))(Y_{gb}^c - Y_{bb}^c)] = 1 - \gamma \frac{v_{ee}(e_0^n)}{v_e(e_0^n)} \quad (56)$$

$$\lambda [v(e_0^n) \{v(e_1^n)w_{gg}^n + (1 - v(e_1^n))w_{gb}^n\} - e_0^n - \underline{w}] = 0 \quad (57)$$

$$v_e(e_0^n) \{v(e_1^n)w_{gg}^n + (1 - v(e_1^n))w_{gb}^n\} - 1 = 0 \quad (58)$$

$$w_{bg}^n = w_{bb}^n = 0. \quad (59)$$

These conditions are reduced as follows:

$$v_e(e_0^n) [v(e_1^n)(Y_{gg}^c - Y_{bg}^c) + (1 - v(e_1^n))(Y_{gb}^c - Y_{bb}^c)] = 1 - (1 - \lambda) \frac{v(e_0^n)v_{ee}(e_0^n)}{[v_e(e_0^n)]^2} \quad (60)$$

$$\lambda \left[\frac{v(e_0^n)}{v_e(e_0^n)} - e_0^n - \underline{w} \right] = 0 \quad (61)$$

Define $f : [0, \infty) \rightarrow [0, \bar{e}]$ satisfying $\frac{v(f(\underline{w}))}{v_e(f(\underline{w}))} - f(\underline{w}) - \underline{w} = 0$. $f(\cdot)$ represents a correspondence from reservation utility \underline{w} to effort level e_0 satisfying the participation condition with equality. Note that $f(\cdot)$ is a monotonously increasing function and $f(\hat{w}) = e_0^c$.

Define $(\check{e}_0, \check{e}_1)$ and \check{w} satisfying the followings:

$$v_e(\check{e}_0) [v(\check{e}_1)(Y_{gg}^c - Y_{bg}^c) + (1 - v(\check{e}_1))(Y_{gb}^c - Y_{bb}^c)] = 1 - \frac{v(\check{e}_0)v_{ee}(\check{e}_0)}{[v_e(\check{e}_0)]^2} \quad (62)$$

$$v_e(\check{e}_1) [v(\check{e}_0)(\pi_{1gg}^c - \pi_{1gb}^c) + (1 - v(\check{e}_0))(\pi_{1bg}^c - \pi_{1bb}^c)] = 1 \quad (63)$$

$$f(\check{w}) = \check{e}_0. \quad (64)$$

The pair of (62) and (62) implies that $(\check{e}_0, \check{e}_0)$ is the equilibrium effort set when $\lambda = 0$, and (64) implies that \check{w} is a level of reservation utility such that the participation constraint is held with equality under the effort set $(\check{e}_0, \check{e}_1)$. \check{w} represents a value of reservation utility for which the participation constraint is not binding but holds just with equality.

Since $f' > 0$ and $\check{e}_0 < e_0^c$, we have $\check{w} < \hat{w}$. Then the investment level can be written as

$$e_0^n = \begin{cases} \check{e}_0 & \forall \underline{w} \in [0, \check{w}) \\ f(\underline{w}) & \forall \underline{w} \in [\check{w}, \hat{w}) \\ e_0^c & \forall \underline{w} \in [\hat{w}, +\infty). \end{cases} \quad (65)$$

$f(\underline{w})$ represents such an effort level that both the incentive compatible constraint and the participation constraint are binding. On the other hand, \check{e}_0 is such an effort level that the participation constraint is not binding although the incentive compatible constraint is binding. The relation between the reservation utility and the effort level is described in Figure 2.

C.2 Comparison

Define \tilde{e} as an effort set satisfying $\tilde{e}_1 = R_1^c(\tilde{e}_0)$ for which the expected social welfare equals to that under privatization. Although \tilde{e} may not be unique, we suppose it is unique for simplicity of explanation. In other words, we suppose that there exists a threshold \tilde{e} satisfying $\tilde{e}_1 = R_1^c(\tilde{e}_0)$ such that

$$\begin{cases} E[W^c | e'] \leq E^c[W^c] & \forall e'_0 \in [0, \tilde{e}_0] \\ E[W^c | e'] \geq E^c[W^c] & \forall e'_0 \in [\tilde{e}_0, e_0^c] \end{cases} \quad (66)$$

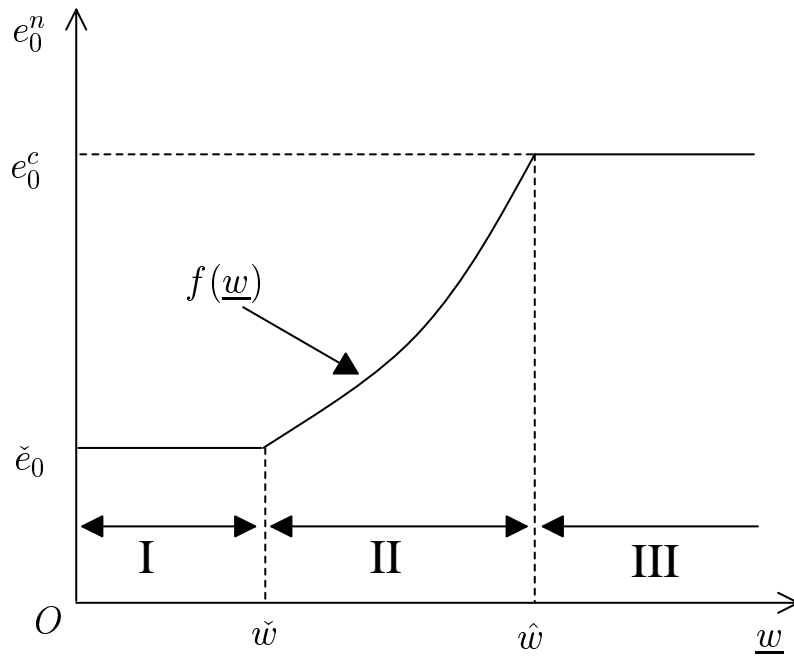


Figure 2: The figure describes the relation between the reservation utility and the effort level. The limited liability constraints are not binding in the interval III and are binding in both I and II. The interval II represents the interval of reservation utility in which the participation constraints are binding, that is, $\lambda > 0$. The interval I represents an interval in which the participation constraint is not binding, $\lambda = 0$.

for e' satisfying $e'_1 = R_1^c(e'_0)$. Then the comparison from the viewpoint of social welfare is as follows:

- Case: $\tilde{e}_0 \in [0, \check{e}_0)$:
Nationalization is preferable for $\underline{w} \in [0, \hat{w})$ and is indifferent to privatization for $\underline{w} \in [\hat{w}, +\infty)$.
- Case: $\tilde{e}_0 \in [\check{e}_0, e_0^c)$:
Nationalization is preferable for $\underline{w} \in (\tilde{w}, \hat{w})$ and is indifferent to privatization for $\underline{w} \in [\hat{w}, +\infty) \cup \{\tilde{w}\}$. On the contrary, privatization is preferable for $\underline{w} \in [0, \tilde{w})$.

The results show that the difference of governance structure depends on the reservation utility of bureaucrat, who is risk neutral but protected by limited liability. When it is sufficiently high, the limited liability does not affect the investment levels and then the outcomes of different governance structures are identical. When it is sufficiently low by contraries, the limited liability affects the investment levels so much that privatization improves the expected social welfare. And there exists an interval of the value of reservation utility for which nationalization is preferable to privatization from the viewpoint of social welfare.

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