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Abstract

We reexamine the results in Gil Molto et al. (2011) and compare the welfare effect of privatization policy in an R&D competition between a mixed duopoly and a private duopoly with an R&D subsidy. We show that an R&D subsidy with privatization policy is beneficial for society unless the spillovers rate is sufficiently low. Otherwise, public R&D leadership in a mixed market is socially superior.

JEL Classifications: L13; L32; H21

Keywords: Privatization; R&D subsidy; R&D spillovers; R&D leadership;

1. Introduction

Privatization and liberalization policies prompted policymakers to reconstruct their actions with respect to encouraging competition, enhancing innovations and stimulating R&D performances. A significant number of studies have concluded that R&D spillovers are critical to assess the welfare effect of governmental intervention.[1] Due to its important features associated with policy implications on innovation and competition activities, the works on the relations between privatization and R&D policies have become popular.

Recent studies have suggested that the conventional presumption about the desirability and efficiency of privatization can be overturned when the R&D spillovers are included. For instance, Gil Molto et al. (2011) examined the welfare effect of privatization policy in a mixed and a private duopoly market with or without the use of subsidies to R&D, and showed that privatization of the public firm reduces R&D activities and welfare irrespective of R&D spillovers. Further, Gil Molto (2018) extended

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[1] For recent works, see Gil Molto (2018), Kesavayuth et al. (2018), Lee and Muminov (2017) and works cited therein.

to the oligopolistic competition market and showed that privatization of the public firm can reduce the welfare when the number of competing private firms is not sufficiently large.[2]

However, these analyses compared an asymmetric regulatory environment wherein the government is able to use the combination of two polices between direct ownership control over the public firm and an indirect R&D subsidy in a mixed market, while only an indirect R&D subsidy is available in a private market. Therefore, if the government can provide an R&D subsidy in a mixed duopoly as well, it is highly likely to improve the welfare under full ownership over the public firm. Then, a sequential question is that if the government is only able to use one of two policy options because of political reasons[3], when should the government privatize the public firm?

This study considers alternative policy situation that allows us to anticipate whether the public firm is likely to be privatized in the situation where only a single policy option is available. In specific, we reexamine the equilibrium of firm's R&D competition in Gil Molto et al. (2011) with different scenarios and investigate the welfare effect of privatization policy between a mixed duopoly without an R&D subsidy and a private duopoly with an R&D subsidy. In the presence of R&D spillovers, we also allow public R&D leadership game in a mixed duopoly market and show that public firm can increase welfare with lower rate of spillovers while higher rate of spillovers induces the government to privatize the public firm and subsidize the R&D investments. Our findings highlight the significance of R&D spillovers with respect to liberalization and innovation policies under different structure of organizations.[4]

2. The Model

Our model follows Gil-Molto et al. (2011) with a simple duopoly market setting consisting of two firms, firms 0 (either private or public firm) and 1 (private firm), which produce homogeneous goods. Let the

[2] As extensive works, Kesavayuth and Zikos (2013) examined the relative welfare effects of an R&D and an output subsidy in a mixed duopoly while Lee et al. (2017) considered partial privatization and showed that government has a higher incentive to privatize the public firm under the output subsidy than the R&D subsidy. Further, Zikos (2007) and Lee and Tomaru (2017) investigated the policy mix of R&D and output subsidies in a mixed oligopoly, and found that the privatization policy does not influence welfare consequences although R&D stage is introduced

[3] For example, if the government undergoes public deficit and budget with state-owned enterprises, it might have an option to sell them and then publicly finance the privatized firms with increased subsidies or reduced taxes.

[4] The EU R&D policies have promoted different forms of research joint ventures and joint research agreements for encouraging higher returns from appropriative R&D performances under the proactive program of the research Framework Programmes (FPs) in 1984 and the Research, Innovation, and Science Policy Experts (RISE) in 2014.

inverse demand function be $P = a - Q$, where P is the market price, $Q = q_0 + q_1$ is the market output, and q_i is the output of firm $i = 0,1$, respectively.

We assume that firms face identical costs functions and marginal costs are increasing. Moreover, firms invest in cost-reducing R&D with spillovers, i.e., as well as its own R&D, a firm can benefit from its competitor's R&D via spillovers of $\beta \in [0,1]$. In specific, firm i's cost function is given by:

$$C(q_i, x_i, x_j) = (c - x_i - \beta x_j)q_i + q_i^2 \quad \text{and} \quad \Gamma(x_i) = x_i^2, \quad i,j = 0,1 \; and \; i \neq j. \tag{1}$$

where $a > c > 0$ and x_i denotes the amount of R&D investment for firm i, which exhibits decreasing returns to scale, i.e., the firm has to spend x_i^2 to implement cost-reducing R&D, x_i. We also consider that each firm might receive an R&D subsidy, sx_i, where s denotes the per-unit subsidy rate of R&D output.

Then, the profit function of the firm is:

$$\pi_i = (a - q_i - q_j)q_i - (c - x_i - \beta x_j)q_i - q_i^2 - x_i^2 + s\,x_i, \quad for \;\; i,j = 0,1 \; and \; i \neq j. \tag{2}$$

The private firm maximizes profit, while the public firm maximizes social welfare defined as the sum of consumer surplus, $CS = Q^2/2$, and both firms' profits minus total expenditures of R&D subsidies, if exist:

$$W = CS + \pi_0 + \pi_1 - s(x_0 + x_1). \tag{3}$$

Note that the subsidies are financed from taxpayers in a lump sum manner, so that they cancel out when aggregating. We assume that the government determines the subsidy rate to maximize the social welfare.

We compare two distinct models of private and mixed duopolies in which firm 0 is either a private firm or a public firm while firm 1 is a private firm in both cases. We assume that an R&D subsidy is only provided in a private market and both firms play Cournot competition in R&D and output stages.

The timing in the model is as follows. In stage one, the government commits to the level of an R&D subsidy if it is a private market while its level is zero if it is a mixed market.[5] In stage two, firms choose their R&D investments simultaneously. In stage three, firms compete in the product market by setting quantities simultaneously. The game is solved by backward induction to obtain its subgame perfect equilibrium.

[5] This asymmetry allows us to anticipate whether the public firm is likely to be privatized in this game. Then, if the government can provide an R&D subsidy in a mixed duopoly, as shown in Gil Molto (2011), it can always improve the welfare under the two regulatory instruments with full ownership of the public firm and an R&D subsidy.

3. The Analysis and comparison

We first consider a private duopoly with an R&D subsidy. The equilibrium outcomes come from Gil Molto et al. (2011) in Table 4. In specific, we have the following results:

Lemma 1. In a private duopoly with an R&D subsidy, the equilibrium outcomes are:

(i) R&D subsidy rate: $s^P = \frac{2(a-c)(1+11\beta)}{66-9\beta(2+\beta)}$,

(ii) R&D investments: $x_i^P = \frac{3(a-c)(1+\beta)}{22-3\beta(2+\beta)}$, $i = 0,1$.

(iii) Output levels: $q_i^P = \frac{5(a-c)}{22-3\beta(2+\beta)}$, $i = 0,1$.

(iv) The profit of the private firm: $\pi_i^P = \frac{(a-c)^2(43+\beta(6+13\beta))}{(22-3\beta(2+\beta))^2}$, $i = 0,1$.

(v) Social welfare: $W^P = \frac{6(a-c)^2}{22-3\beta(2+\beta)}$.

where superscript *P* denotes the R&D subsidy in a **P**rivate duopoly. Note that not only the R&D subsidy rate but the R&D investments and outputs are increasing in the spillovers.

We also consider a mixed duopoly without an R&D subsidy. The equilibrium outcomes come from Gil-Molto et al. (2011) in Table 1. In specific, we have the following results:

Lemma 2. In a mixed duopoly without an R&D subsidy, the equilibrium outcomes are:

(i) R&D investments: $x_0^M = \frac{(a-c)(25+2\beta(18-8\beta))}{167+2\beta(1-\beta)(25-\beta)}$, $x_1^M = \frac{2(a-c)(9-\beta^2))}{167+2\beta(1-\beta)(25-\beta)}$

(ii) Output levels: $q_0^M = \frac{(a-c)(53-\beta(31-18\beta))}{167+2\beta(1-\beta)(25-\beta)}$, $q_1^M = \frac{11(a-c)(3+\beta)}{167+2\beta(1-\beta)(25-\beta)}$

(iii) The profit of the private firm: $\pi_1^M = \frac{2(a-c)^2(3+\beta)^2(103+2(6-\beta)\beta)}{(167+2(25-\beta)(1-\beta)\beta)^2}$

(iv) Social welfare: $W^M = \frac{(a-c)^2(7736+\beta(6550-\beta(2495+2\beta(864-239\beta))))}{(167+2(25-\beta)(1-\beta)\beta)^2}$

where superscript *M* denotes the R&D subsidy in a **M**ixed duopoly. Note that $x_0^M > x_1^M$ and $q_0^M > q_1^M$. Thus, the public firm takes more R&D investments and produce more outputs. Note also that public firm's R&D and both firms' outputs are increasing in the spillovers rate while that of private firm is only increasing for a high rate of spillovers, i.e,. $\frac{\partial x_1^M}{\partial \beta} \gtrless 0$ if $\beta \gtrless 0.879$.

Then, we compare the two scenarios:

Lemma 3. Comparing the equilibrium outcomes between private and mixed markets,

(i) $x_0^P \gtreqless x_0^M$ if $\beta \gtreqless 0.384$ while $x_1^P > x_1^M$ and $X^P > X^M$ for any $\beta \in [0,1]$

(ii) $q_0^P < q_0^M$ and $q_1^P > q_1^M$ for any $\beta \in [0,1]$ while $Q^P \gtreqless Q^M$ if $\beta \lesseqgtr 0.647$

(iii) $\pi_1^P > \pi_1^M$ for any $\beta \in [0,1]$

Lemma 3 (i) provides the effect of R&D subsidy policy along with privatization on the equilibrium outcomes. It states that with privatization policy, the private firm's R&D increases while that of the public firm depends on the spillovers rate. In particular, the privatized (public) firm increases R&D only when the spillovers rate is high. That is, the incentive effect of an R&D subsidy works for a higher spillovers. However, total industry R&D investments increase after privatization.

Lemma 3(ii) indicates privatization effect that the privatized firm becomes a profit-oriented firm and behaves less aggressively by reducing its output. As the outputs are strategic substitutes, it increases the output of the competitive private firm irrespective the rate of spillover. That is, output substitution effect occurs. However, total industry output increases after privatization only when the spillovers rate is low. It also implies that consumer surplus increases when the government implements R&D subsidy policy with privatization policy for a lower spillovers rate.

Finally, Lemma 3(iii) states that privatization policy increases the profit of the private firm for any rate of spillover. Due to the output substitution effect between the two firms, the private firm can increase its output and profits as well.

Proposition 1. Comparing the welfare levels, $W^P \gtreqless W^M$ if $\beta \gtreqless 0.26405$.

In their findings in Proposition 6 and 9, respectively, Gil Molto et al. (2011) showed that privatization would result in a reduction in total surplus with or without subsidization. This is sharply contrast to our findings in Proposition 1. We show that social welfare in a private duopoly with an R&D subsidy can be higher than that in a mixed duopoly without subsidization unless the spillovers rate is sufficiently low. Therefore, the rate of spillovers is crucial to determine the welfare effect of privatization policy.

4. Public R&D leadership and policy discussion

In this section, we consider a sequential-move game in R&D choices under public firm's leadership in a mixed market, while keeping that both firms play Cournot competition in output stage.[6] This structural enhancement of the model allows us to anticipate whether the public firm is likely to play either a leader or a follower in making its R&D decision. Then, the public firm chooses its R&D first and then by observing this, the private firm acts as a follower in R&D choices. In the last stage, both firms compete with outputs simultaneously. We can solve the subgame perfect equilibrium of this game and then show that our findings in Proposition 1 is still robust in the public R&D leadership game in a mixed market.

Lemma 4. In a mixed duopoly with a public R&D leadership game, the equilibrium outcomes are:

(i) R&D investments: $x_0^{LM} = \frac{(a-c)(2551+3890\beta+764\beta^2-122\beta^3-84\beta^4+12\beta^5)}{17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6}$

$$x_1^{LM} = \frac{2(a-c)(927+126\beta-205\beta^2+92\beta^3-42\beta^4+6\beta^5)}{17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6}.$$

(ii) Output levels: $q_0^{LM} = \frac{(a-c)(5447+3863\beta-1562\beta^2-344\beta^3+54\beta^4)}{17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6}$

$$q_1^{LM} = \frac{11(a-c)(309+145\beta-20\beta^2+24\beta^3-6\beta^4)}{17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6}$$

(iii) The profit of the private firm: $\pi_1^{LM} = \frac{2(a-c)^2(103+12\beta-2\beta^2)(309+145\beta-20\beta^2+24\beta^3-6\beta^4)^2}{(17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6)^2}$

(iv) Social welfare: $W^{LM} = \frac{(a-c)^2(4768+3246\beta-835\beta^2-192\beta^3+24\beta^4)}{17189+7440\beta-5922\beta^2-236\beta^3-4\beta^4+72\beta^5-12\beta^6}$

where the superscript *LM* denotes the equilibrium with a public **L**eadership in a **M**ixed market. Note that $x_0^{LM} > x_1^{LM}$ and $q_0^{LM} > q_1^{LM}$. Note also that public firm's R&D and both firms' outputs are increasing in the spillovers rate while that of private firm is only increasing for a high rate of spillovers, i.e., $\frac{\partial x_1^{LM}}{\partial \beta} \gtrless 0$ if $\beta \gtrless 0.759$, but its threshold is lower than Cournot R&D competition in a mixed duopoly. Thus, public leadership can encourage the private firm's R&D for a higher rate of spillovers.

Lemma 5. Comparing equilibrium outcomes between private market and the public R&D leadership in a mixed market:

[6] Regarding the sequencing R&D decisions with Cournot competition in outputs, see Amir et al. (2000) in a private duopoly and Leal et al. (2020) in a mixed duopoly with corporate social responsibility.

(i) $x_0^P \gtreqless x_0^{LM}$ if $\beta \gtreqless 0.401$ while $x_1^P > x_1^{LM}$ and $X^P > X^{LM}$ for any $\beta \in [0,1]$

(ii) $q_0^P < q_0^{LM}$ and $q_1^P > q_1^{LM}$ for any $\beta \in [0,1]$ while $Q^P \gtreqless Q^{LM}$ if $\beta \lesseqgtr 0.665$

(iii) $\pi_1^P > \pi_1^{LM}$ for any $\beta \in [0,1]$

Lemma 5 provides the similar effect of R&D subsidy policy along with privatization on the equilibrium outcomes derived under Cournot R&D competition in Lemma 3. Only difference is that the threshold value for increasing the effect of privatization is higher. That is, (i) the incentive effect of an R&D subsidy after privatization works for more higher spillovers, while (ii) total industry output increases after privatization for less lower spillovers. Finally, (iii) due to the output substitution effect between the two firms, the private firm can increase its output and profits as well.

Proposition 2. Comparing the welfare levels, $W^P \gtreqless W^{LM}$ if $\beta \gtreqless 0.26407$.

Proposition 2 supports that social welfare in a private duopoly with an R&D subsidy can be higher than that in a mixed duopoly without subsidization unless the spillovers rate is sufficiently low. Note that the welfare under the public R&D leadership is always higher than that under the Cournot R&D competition in a mixed duopoly, i.e., $W^M < W^{LM}$ for any $\beta \in [0,1]$. Our findings suggest that nationalization is effective for increasing welfare as long as the spillovers rate is relatively low, while privatization is effective for maintaining higher welfare under the R&D subsidy subject to higher spillover rate.

5. Concluding Remarks

This study investigated whether the public firm is likely to be privatized and showed that the rate of spillovers play a key role to determine the welfare effect of privatization policy. We found that that social welfare in a private duopoly with an R&D subsidy can be higher than that in a mixed duopoly without subsidization unless the spillovers rate is sufficiently low. We also examined the public R&D leadership game in a mixed duopoly and confirmed that our findings are robust. Therefore, in the absence of an R&D subsidy, full ownership of public firm can increase welfare only with lower rate of spillovers, while higher rate of spillovers induces the government to privatize the public firm and subsidize the R&D

investments.[7]

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[7] This finding also supports recent R&D policies that the US and the UK enacted more liberal antitrust regulations for allowing joint research agreements and knowledge sharing contracts under the various research program. See Marinucci (2012), Gil Molto (2018) and Lee and Muminov (2019).