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**Privatization, Entry and Corporate Social Responsibility with Consumer
Cognition**

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Abstract: In this paper, we formulate a mixed triopoly with product differentiation and consumer cognition in which a welfare-maximizing public firm and CSR-concerned private firms conduct quantities competition. The government decides the optimal degree of privatization of public firm. We find that the privatization degree of public firm is closely related to product differentiation and consumer cognition. When private firm enters, whether CSR efforts are made or not, the degree of privatization will be higher. Furthermore, if the public firm is the leader of the industry, government's optimal choice of privatization is not to privatize. The total output level, consumer surplus and social welfare are lower than those of Cournot competitors.

Keywords: Privatization; Corporate Social Responsibility; Mixed Triopoly; Consumer Cognition

JEL Classifications: D43; L13; L21; L31; M14

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1. Introduction

State-owned firms in the world have been privatized to varying degrees since the 1980s, which has also formed a new mixed oligopolistic market includes public firms, private firms and privatized public firms. A large number of private firms have entered various industries. New private firms may pursue their own profits and weights different degree of corporate social responsibilities in objective function paying attention to consumers' rights and interests, thus forming different mixed oligopoly market patterns.

In the literature, an increasing number of studies on mixed oligopoly and policy implications have been emerging. De Fraja and Delbono (1989) first showed that the privatization of public firms might improve social welfare. But, Matsumura (1998) showed that partial privatization of public firms is the best strategy.¹ In mixed oligopoly market, public firms pursue the maximization of social welfare, while private firms not only maximize their profits, but also sometimes take consumer welfare into account. Goering (2007) introduced CSR into a mixed oligopoly, where private not-for-profit organizations (NPOs) maximizes an objective function that takes their own profits and consumer surplus into account. Kopel and Brand (2012) had extended this framework by endogenizing hiring decisions of socially responsible firms. To see how the adoption of CSR influences the privatization policy, Ouattara (2017) examined the impact of CSR on the level of privatization in a mixed duopoly consisting of one public firm and one CSR firm that could either be owned by domestic private investors or owned by foreign private investors. It showed that the government should decrease the degree of privatization if the level of CSR increases. Furthermore, if the CSR level is high enough, the optimal degree of privatization in an international mixed duopoly is higher than that obtained in a domestic mixed duopoly. Wang et al. (2018) studied a duopoly Cournot and Stackelberg competition, highlighting the fact that CSR has an influence on outputs and profits. Kim et al.

¹ In an open economy, Chao and Yu (2006) studied the effect of partial privatization degree on the optimal tariff, and Van Long and Stähler (2009) analyzed that the degree of privatization was influenced by the optimal trade policy instruments. Bárcena-Ruiz et al. (2020) considered partial privatization of state-holding firms when there are foreign-owned firms.

(2019) formulated a mixed triopoly, in which one public and two private firms that might engage in CSR activities produce homogenous products. They found that depending on CSR level and cost differences among firms, either nationalization or full privatization can be optimal. Besides, Dong and Wang (2019, 2021) studied the optimal privatization of state holding corporations and the presence of corporate social responsibility (CSR) and corporate profit taxation, respectively. Zhang and Wang (2022) built a homogenous mixed triopoly in which one public firm competes with two private firms: an established CSR firm and a profit-maximizing entrant that could either be domestic or foreign-owned. They found that with an increasing degree of CSR, the government might levy a higher tariff to restrict imports from the welfare viewpoint. Furthermore, a third firm entrant is going to increase welfare specially if the firm is domestic. Surprisingly, when the degree of CSR is in a certain range, privatization and tariff are always negatively correlated with CSR. Chen et al. (2022) recently emphasized how the consumer's cognition of the CSR activity of private firms influence privatization wave.

In this paper, we formulate a mixed triopoly with product differentiation and consumer cognition that in which a public firm and CSR-concerned private firms conduct quantities competition. We first find that the privatization degree of public firm is closely related to product differentiation and consumer cognition. When private firm enters, whether CSR efforts are made or not, the degree of privatization will be higher. Our result is in sharp contrast with the corner solution of Kim et al. (2019). Furthermore, when entering firm make CSR efforts, the optimal degree of privatization becomes even higher. Secondly, if the public firm is the leader of the industry, its optimal choice is not to privatize. The entry of private firm as follower because there are not able to reverse the leading position of the public firm. Although the privatization degree of the government is not to privatize, the existence of the third firm objectively strengthens the competition and other favorable factors, resulting in the outcome that total output level, consumer surplus and social welfare are equal to the scenario of non-privatization policy.

The remainder of this paper is organized as follows. Section 2 builds the basic

model of mixed duopoly with CSR and product differentiation. Section 3 analyzes the basic model without market entry. Section 4 examines a mixed oligopoly and two specific cases in that the third entrant firm determines whether to undertake CSR. Section 5 considers the degree of privatization when the public firm acts as a leader. Section 6 concludes the paper.

2. Basic Model

Consider that in an industry there are one public firm and CSR-concerned private firms, denoted by firm i ($i = 0, 1, 2$), produce differentiated products with a critical input. In line with Singh and Vives (1984), the representative consumers' preference is given by

$$U = aq_0 + \sum_{i=1}^n (a + \beta s_i) q_i - \frac{1}{2} (\sum_{j=0}^n q_i^2 + \sum_{i \neq j=0}^n 2\gamma q_i q_j) + m \quad (1)$$

where q_0 is public output, and q_i and q_j are the product of firm i and firm j . a is a positively constant and m is the composite goods. $\beta \in (0,1)$ represents consumers' CSR-cognition and s_i is the degree of CSR activity that firm i undertaking. $\gamma \in (0,1)$ measures the degree of product differentiation. If $\gamma = 1$, the two goods are perfect substitutes, and if $\gamma = 0$, the two goods are isolated. Hence, each firm faces the inverse product demand given by: $p_i = a - q_i - \sum_{j \neq i} \gamma q_j + \beta s_i$, where p_i is the product price of firm i . The total output level is denoted by $Q = \sum_{i=0}^n q_i$. In addition, we assume that firms have identical technology and the increasing cost function denoted by $c_i = \frac{q_i^2}{2}$.

The social welfare is given by:

$$SW = CS + \sum_{i=0}^n \pi_i \quad (2)$$

where $CS = \frac{1}{2} (\sum_{i=0}^n q_i^2 + \sum_{i \neq j=0}^n 2\gamma q_i q_j)$ represents consumer surplus and π_i is the profits of firm i . The profit functions of welfare-maximizing state-owned public firm and CSR-concerned private firm are given as: $\pi_0 = p_0 q_0 - c_0$ and $\pi_i = p_i q_i - c_i - k(\frac{s_i^2}{2})$. Firm i invests in CSR and costs $k(\frac{s_i^2}{2})$, where k indicates whether the firm makes CSR efforts. If $k = 0$ indicates that the firm does not make CSR efforts,

$k = 1$ indicates that the firm makes CSR efforts.

The payoff of public firm 0 is given by:

$$V_0 = \theta\pi_0 + (1 - \theta)SW \quad (3)$$

where $0 \leq \theta \leq 1$ represents the degree of privatization, determined by the welfare-maximizing benevolent government. $\theta = 1$ denotes the firm is completely privatized and its profit is maximized, $\theta = 0$ denotes firm 1 is nationalized and the social welfare is maximized, and $\theta \in (0,1)$ denotes partial privatization. The higher the value of θ , the higher the privatization degree. CSR-concerned private firm maximizes its own profit:

$$V_i = \pi_i \quad (4)$$

A three-stage game is now considered. At the stage 1, the government determines the optimal privatization degree θ to maximize social welfare. At the stage 2, the CSR-concerned private firm chooses the optimal investment in CSR. At the stage 3, all firms choose their product quantities to maximize their objective functions competing in Cournot fashion. We derive the subgame-perfect Nash equilibrium(SPNE) through backward induction.

3. Equilibrium Analysis without Entry

We first consider the case in which new private firm doesn't enter, $n = 1$. All firms choose their product quantities based on their objective functions. The public firm maximizes (3) with respect to q_0 and the CSR private firm maximizes (4) with respect to q_1 . Solving the first-order conditions $\left(\frac{\partial V_0}{\partial q_0} = 0 \text{ and } \frac{\partial V_1}{\partial q_1} = 0 \right)$, we obtain:

$$q_0 = \frac{a(3-\beta^2-\gamma)}{3(2+\theta)-\beta^2(2+\theta)-\gamma^2} \quad (5a)$$

$$q_1 = \frac{a(2-\gamma+\theta)}{3(2+\theta)-\beta^2(2+\theta)-\gamma^2} \quad (5b)$$

In the second stage, the CSR-concerned private firm maximizes its profit with respect to s_1 . Solving the first-order condition $\left(\frac{\partial V_1}{\partial s_1} = 0 \right)$, we obtain:

$$s_1 = \beta q_1 \quad (6)$$

After necessary calculations on the consumer surplus and firms' profits, we obtain the social welfare SW as a function of θ , β and γ as follow:

$$SW = \frac{a^2(2\beta^4(1+\theta) - \beta^2((16-4\gamma)(1+\theta) - \gamma^2 + \theta^2)) + 2(17(1+\theta) - 2\gamma^2 + \gamma^3 + 2\theta^2 - \gamma(8+7\theta))}{2((3-\beta^2)(2+\theta) - \gamma^2)^2} \quad (7)$$

In the first stage, the government maximizes (8) to determine the optimal privatization degree θ^* . Solving the first-order conditions $\left(\frac{\partial SW}{\partial \theta} = 0\right)$, we obtain:

$$\theta^* = \frac{(2-\gamma)\gamma}{9 + \beta^4 - \beta^2(6-\gamma) - 4\gamma} \quad (8)$$

where superscript '*' denotes the equilibrium result without entry. We have the following Lemma 1.

Lemma 1: *The privatization degree of public firm is related to product differentiation and consumer cognition. The higher the value of product differentiation and consumer cognition, the higher the privatization degree of public firm.*

Proof: See that:

$$\frac{\partial \theta^*}{\partial \gamma} = \frac{2(9-9\gamma+2\gamma^2) + 2\beta^4(1-\gamma) - \beta^2(12-12\gamma+\gamma^2)}{(9+\beta^4+\beta^2(-6+\gamma)-4\gamma)^2} > 0$$

$$\frac{\partial \theta^*}{\partial \beta} = \frac{2\beta\gamma(2-\gamma)(6-2\beta^2-\gamma)}{(9+\beta^4-\beta^2(6-\gamma)-4\gamma)^2} > 0$$

The reasoning is that the higher degree of product differentiation represents fiercer competition of the market that will lead the private firm to produce more and also will make the public firm more sensitive to the market and pursue more profit via privatization. By the similar reasoning, if the consumers acknowledge the private firm's CSR effort will then purchase more of the private firm's product and due to that public firm has the less burden to maximize the social welfare, the government will increase the degree of privatization.

The SPNE of the output level, profit, consumer surplus and social welfare are as follow:

$$q_0^* = \frac{a(9 + \beta^4 - \beta^2(6 - \gamma) - 4\gamma)}{18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2}$$

$$\begin{aligned}
q_1^* &= \frac{a(3 - \beta^2)(2 - \gamma)}{18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2} \\
Q^* &= \frac{a(15 + \beta^4 - 2\beta^2(4 - \gamma) - 7\gamma)}{18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2} \\
\pi_0^* &= \frac{a^2(9 + \beta^4 - \beta^2(6 - \gamma) - 4\gamma)(9 + \beta^4 - \beta^2(6 - \gamma) - 2\gamma^2)}{2(18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2)^2} \\
\pi_1^* &= \frac{a^2(3 - \beta^2)^3(2 - \gamma)^2}{2(18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2)^2} \\
CS^* &= \frac{a^2(117 + \beta^8 - 77\gamma^2 + 24\gamma^3 - 2\beta^6(6 + \gamma - \gamma^2) + 2\beta^4(29 + 6\gamma - 10\gamma^2 + \gamma^3) - 2\beta^2(66 + 9\gamma - 34\gamma^2 + 7\gamma^3))}{2(18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2)^2} \\
SW^* &= \frac{a^2(17 + \beta^4 - 2\beta^2(4 - \gamma) - 8\gamma)}{2(18 + 2\beta^4 - 4\gamma^2 - 12\beta^2 + \gamma^2\beta^2)}
\end{aligned}$$

4. Entry and Privatization

In this section, we consider the third private competitor entering the market, $n = 2$. This new firm may or may not make CSR efforts.

(i) *The entry firm is a profit-maximizing firm*

We first consider that the third private competitor doesn't make CSR efforts. The objective function of the firm is thus given as:

$$V_2 = \pi_2 = p_2 q_2 - c_2 \quad (9)$$

In the three stage, the public firm maximizes (3) with respect to q_0 , the CSR private firm maximizes (4) with respect to q_1 and the third private firm maximizes (9) with respect to q_2 . Solving the first-order conditions $\left(\frac{\partial V_0}{\partial q_0} = 0, \frac{\partial V_1}{\partial q_1} = 0 \text{ and } \frac{\partial V_2}{\partial q_2} = 0 \right)$, we obtain:

$$q_0 = \frac{a(3-\gamma)(3-\beta^2-\gamma)}{9(2+\theta)+2\gamma^3-\gamma^2(8+\theta)-\beta^2(6+3\theta-\gamma^2)} \quad (10a)$$

$$q_1 = \frac{a(2-\gamma+\theta)(3-\gamma)}{9(2+\theta)+2\gamma^3-\gamma^2(8+\theta)-\beta^2(6+3\theta-\gamma^2)} \quad (10b)$$

$$q_2 = \frac{a(2-\gamma+\theta)(3-\beta^2-\gamma)}{9(2+\theta)+2\gamma^3-\gamma^2(8+\theta)-\beta^2(6+3\theta-\gamma^2)} \quad (10c)$$

In the second stage, the private firm's optimal invests in CSR which is the same as (6). Similarly, after necessary calculations and we obtain the social welfare SW as a function of θ , β and γ as follow:

$$SW = \frac{a^2(2\beta^4(17-2\gamma^2+\gamma^3+17\theta+2\theta^2-\gamma(8+7\theta)) + \beta^2(3-\gamma)(80+7\gamma^3+80\theta+11\theta^2-\gamma^2(19+4\theta)-\gamma(28+24\theta-\theta^2)) + 2(3-\gamma)^2(25+3\gamma^3+25\theta+4\theta^2-3\gamma^2(3+\theta)-\gamma(6+4\theta-\theta^2)))}{2(9(2+\theta)+2\gamma^3-\gamma^2(8+\theta)-\beta^2(6+3\theta-\gamma^2))^2} \quad (11)$$

In the first stage, the government maximizes (11) to determine the optimal privatization degree θ^* . Solving the first-order conditions $\left(\frac{\partial SW^*}{\partial \theta} = 0\right)$, we obtain:

$$\theta^{N*} = \frac{(2(3-\gamma)^2+\beta^4-2\beta^2(3-\gamma))(2-\gamma)\gamma}{\beta^4(9-4\gamma)+(3-\gamma)^2(9-\gamma(2+\gamma))+\beta^2(3-\gamma)(18-\gamma(5+\gamma))} \quad (12)$$

where superscript ' N^* ' denotes the equilibrium result with entry. We have the following Lemma 2.

Lemma 2: *When the firm that does not make CSR efforts entering the market, the privatization degree of public firms is related to product differentiation and consumer cognition, and the privatization degree will be higher.*

Proof: See that

$$\begin{aligned} \frac{\partial \theta^{N*}}{\partial \gamma} &= \frac{4(3-\gamma)^5(3-2\gamma)-4\beta^2(3-\gamma)^4(9-7\gamma)+2\beta^8(9-9\gamma+2\gamma^2) + 2\beta^4(3-\gamma)^2(63-69\gamma+18\gamma^2-\gamma^3)-\beta^6(216-288\gamma+123\gamma^2-20\gamma^3+\gamma^4)}{(\beta^4(9-4\gamma)+(3-\gamma)^2(9-2\gamma-\gamma^2)-\beta^2(54-33\gamma+2\gamma^2+\gamma^3))^2} > 0 \\ \frac{\partial \theta^{N*}}{\partial \beta} &= \frac{2\beta(3-\gamma)^2(2-\gamma)\gamma(6(3-\gamma)^2-2\beta^2(3-\gamma)^2-\beta^4\gamma)}{(\beta^4(9-4\gamma)+(3-\gamma)^2(9-2\gamma-\gamma^2)-\beta^2(54-33\gamma+2\gamma^2+\gamma^3))^2} > 0 \\ \theta^* - \theta^{N*} &= \frac{(2-\gamma)\gamma}{9+\beta^4-\beta^2(6-\gamma)-4\gamma} - \frac{2(2-\gamma)\gamma(3-\gamma)^2+\beta^4-2\beta^2(3-\gamma)}{\beta^4(9-4\gamma)+(3-\gamma)^2(9-\gamma(2+\gamma))-\beta^2(3-\gamma)(18-\gamma(5+\gamma))} < 0 \end{aligned}$$

Of note, the degree of optimal privatization becomes higher when the market exhibits intensive competition.

The SPNE of the output level, profit, consumer surplus and social welfare under three firm competitions are as follow:

$$\begin{aligned} q_0^{N*} &= \frac{a(\beta^4(9-4\gamma) + (3-\gamma)^2(9-2\gamma-\gamma^2) - \beta^2(54-33\gamma+2\gamma^2+\gamma^3))}{H_1} \\ q_1^{N*} &= \frac{a(3-\gamma)(2-\gamma)(9-3\beta^2-\gamma^2)}{H_1} \\ q_2^{N*} &= \frac{a(3-\beta^2-\gamma)(2-\gamma)(9-3\beta^2-\gamma^2)}{H_1} \end{aligned}$$

$$Q^{N*} = \frac{a(\beta^4(15 - 7\gamma) + (3 - \gamma)^2(21 - 4\gamma - 3\gamma^2) - 2\beta^2(54 - 36\gamma + 3\gamma^2 + \gamma^3))}{H_1}$$

$$\pi_0^{N*} = \frac{a^2(\beta^4(9 - 4\gamma) + (3 - \gamma)^2(9 - 2\gamma - \gamma^2) - \beta^2(54 - 33\gamma + 2\gamma^2 + \gamma^3))}{2H_1^2}$$

$$\pi_0^{N*} = \frac{(\beta^4(9 - 2\gamma^2) + (3 - \gamma)^2(9 + 6\gamma - 5\gamma^2) - \beta^2(54 - 9\gamma - 18\gamma^2 + 5\gamma^3))}{2H_1^2}$$

$$\pi_1^{N*} = \frac{a^2(3 - \beta^2)(3 - \gamma)^2(2 - \gamma)^2(9 - 3\beta^2 - \gamma^2)^2}{2H_1^2}$$

$$\pi_2^{N*} = \frac{3a^2(2 - \gamma)^2(3 - \beta^2 - \gamma)^2(9 - 3\beta^2 - \gamma^2)^2}{2H_1^2}$$

CS^{N*}

$$\begin{aligned} & a^2(\beta^8(117 - 77\gamma^2 + 24\gamma^3) + 2\beta^4(3 - \gamma)^2(369 + 360\gamma - 414\gamma^2 + 8\gamma^3 + 30\gamma^4 + \gamma^5) \\ & - 2\beta^2(3 - \gamma)^3(270 + 345\gamma - 289\gamma^2 - 53\gamma^3 + 31\gamma^4 + 4\gamma^5) + \\ & (3 - \gamma)^4(153 + 228\gamma - 144\gamma^2 - 66\gamma^3 + 19\gamma^4 + 6\gamma^5) \\ & - 2\beta^6(702 + 153\gamma - 843\gamma^2 + 370\gamma^3 - 23\gamma^4 - 7\gamma^5)) \\ = & \frac{\hspace{10em}}{2H_1^2} \end{aligned}$$

SW^{N*}

$$= \frac{a^2(\beta^4(17 - 8\gamma) + (3 - \gamma)^2(25 - 6\gamma - 3\gamma^2) - 2\beta^2(60 - 41\gamma + 4\gamma^2 + \gamma^3))}{2H_1}$$

where $H_1 = 2(3 - \gamma)^2(9 + 6\gamma - 3\gamma^2 - \gamma^3) - \beta^2(108 - 45\gamma^2 + 8\gamma^3 + \gamma^4) + 2\beta^4(9 - 2\gamma^2)$, and $H_1 > 0$

(ii) *The entry firm is a CSR-concerned firm*

We then consider first that the third private competitor make CSR efforts. The objective function of the firm is thus given as:

$$V_2 = \pi_2 = p_2q_2 - c_2 - \frac{s_2^2}{2} \quad (13)$$

In the third stage, firms maximize (3), (4) and (13) with respect to q_0 , q_1 and q_2 . Solving the first-order conditions $\left(\frac{\partial V_0}{\partial q_0} = 0, \frac{\partial V_1}{\partial q_1} = 0 \quad \text{and} \quad \frac{\partial V_2}{\partial q_2} = 0 \right)$, we obtain:

$$q_0 = \frac{a(3 - \beta^2 - \gamma)}{6 + 2(1 - \gamma)\gamma + (3 + \gamma)\theta - \beta^2(2 + \theta)} \quad (14a)$$

$$q_1 = \frac{a(2 - \gamma + \theta)}{6 + 2(1 - \gamma)\gamma + (3 + \gamma)\theta - \beta^2(2 + \theta)} \quad (14b)$$

$$q_2 = \frac{a(2 - \gamma + \theta)}{6 + 2(1 - \gamma)\gamma + (3 + \gamma)\theta - \beta^2(2 + \theta)} \quad (14c)$$

In the second stage, the CSR-concerned private firms maximize its profit with

respect to s_1 and s_2 . Solving the first-order conditions $\left(\frac{\partial V_1}{\partial s_1} = 0 \text{ and } \frac{\partial V_2}{\partial s_2} = 0 \right)$, we obtain:

$$s_1 = \beta q_1 \quad (15a)$$

$$s_2 = \beta q_2 \quad (15b)$$

After necessary calculations, we obtain the social welfare SW as a function of θ , β and γ as follow:

$$SW = \frac{a^2(25+3\gamma^3+25\theta+4\theta^2+\beta^4(1+\theta)-3\gamma^2(3+\theta)) - \gamma(6+4\theta-\theta^2) - \beta^2((10-2\gamma)(1+\theta)-\gamma^2+\theta^2)}{(2\gamma^2-3(2+\theta)+\beta^2(2+\theta)-\gamma(2+\theta))^2} \quad (16)$$

In the first stage, the government maximizes (16) to determine the optimal privatization degree θ^* . Solving the first-order condition $\left(\frac{\partial SW^*}{\partial \theta} = 0 \right)$, we obtain:

$$\theta^{C*} = \frac{2(2-\gamma)\gamma}{(3-\beta^2)^2 - 2\gamma - \gamma^2} \quad (17)$$

where superscript ‘C *’ denotes the equilibrium result of one privatized public firm, and two CSR-concerned private firms. We have the following Lemma 3.

Lemma 3: *When CSR-concerned firm enters the market, the privatization degree of public firm is closely related to product differentiation and consumer cognition, and the privatization degree will be higher than that in Lemma 2.*

Proof: See that

$$\frac{\partial \theta^{C*}}{\partial \gamma} = \frac{4((9 - 6\beta^2 + \beta^4)(1 - \gamma) + 2\gamma^2)}{((3 - \beta^2)^2 - 2\gamma - \gamma^2)^2} > 0$$

$$\frac{\partial \theta^{C*}}{\partial \beta} = \frac{8\beta(3 - \beta^2)(2 - \gamma)\gamma}{((3 - \beta^2)^2 - 2\gamma - \gamma^2)^2} > 0$$

$$\theta^{N*} - \theta^{C*} = \frac{2(2-\gamma)\gamma(3-\gamma)^2 + \beta^4 - 2\beta^2(3-\gamma)}{\beta^4(9-4\gamma) + (3-\gamma)^2(9-\gamma(2+\gamma)) - \beta^2(3-\gamma)(18-\gamma(5+\gamma))} - \frac{2(2-\gamma)\gamma}{(3-\beta^2)^2 - 2\gamma - \gamma^2} < 0$$

We summarize the above Lemmas in the following Proposition 1.

Proposition 1: *The privatization degree of public firm is closely related to product*

differentiation and consumer cognition. When more private firms enter the market, the degree of privatization will be higher.

When there is product differentiation between public firm and private firm, the privatization degree of public firm is correlated with product differentiation. The smaller the product differentiation, the greater the degree of privatization of public firm. The greater the product differentiation is, the smaller the privatization degree of public firm becomes. That is, if there is a substitution relationship between the products of public firm and private firm, and the stronger the substitution relationship of products is, the higher the degree of privatization of public firm. Our result is in sharp contrast with the corner solution of Kim et al. (2019). Private firm make CSR efforts out of consideration for consumers' awareness. The stronger consumers' awareness of products is, the higher private firm pays for CSR, while public firm bears policy burden to maximize the social welfare, which has a certain positive correlation with consumers awareness. Therefore, the stronger consumers' awareness is, the higher the privatization degree of public firm is.

When a new firm enters, whether CSR efforts are made or not, the competition of products in the market will be intensified, and the privatization degree of public firm will be increased. Notice that when entering firm to make CSR efforts, the degree of privatization promotes will even be higher.

The SPNE of the output level, profit, consumer surplus and social welfare under three firm competitions are as follow:

$$\begin{aligned}
 q_0^{C*} &= \frac{a(9 - 6\beta^2 + \beta^4 - 2\gamma - \gamma^2)}{H_2} \\
 q_1^{C*} = q_2^{C*} &= \frac{a(2 - \gamma)(3 - \beta^2 + \gamma)}{H_2} \\
 Q^{C*} &= \frac{a(21 + \beta^4 - 2\beta^2(5 - \gamma) - 4\gamma - 3\gamma^2)}{H_2} \\
 \pi_0^{C*} &= \frac{a^2(9 - 6\beta^2 + \beta^4 + 6\gamma - 5\gamma^2)(9 - 6\beta^2 + \beta^4 - 2\gamma - \gamma^2)}{2H_2^2} \\
 \pi_1^{C*} = \pi_2^{C*} &= \frac{a^2(3 - \beta^2)(2 - \gamma)^2(3 - \beta^2 + \gamma)^2}{2H_2^2}
 \end{aligned}$$

$$CS^{C*} = \frac{a^2(153 + \beta^8 + 228\gamma - 144\gamma^2 - 66\gamma^3 + 19\gamma^4 + 6\gamma^5 - 4\beta^6(3 + 2\gamma - \gamma^2) + 2\beta^4(31 + 34\gamma - 18\gamma^2 - \gamma^3) - 4\beta^2(39 + 52\gamma - 31\gamma^2 - 6\gamma^3 + 2\gamma^4))}{2H_2^2}$$

$$SW^{C*} = \frac{a^2(25 + \beta^4 - 2\beta^2(5 - \gamma) - 6\gamma - 3\gamma^2)}{2H_2}$$

where $H_2 = 2(9 + \beta^4 + 6\gamma - 3\gamma^2 - \gamma^3 - \beta^2(6 + 2\gamma - \gamma^2))$, and $H_2 > 0$.

We have the following Proposition 2.

Proposition 2: *If $0 < \beta < 1$, $0 < \gamma < 1$, then $Q^* < Q^{N*} < Q^{C*}$, $CS^* < CS^{N*} < CS^{C*}$ and $SW^* < SW^{N*} < SW^{C*}$*

Considering consumer awareness and product differentiation concurrently, the total output level, consumer surplus and social welfare under entry restriction are the smallest. When entry of a private firm does not make CSR efforts, it will increase the total output level, consumer surplus and social welfare. When it makes CSR efforts, the total output level, consumer surplus and social welfare will be the largest. This is because the entry of private firms will promote competition and diversify product differences. Further, the entry of CSR firm will increase consumer welfare and social welfare, and the final output, consumer welfare and social welfare will also be increased. In short, the anti-entry regulation is hardly justified.

5. Stackelberg Leader in Oligopoly

If developing countries want to realize industrialization and modernization quickly and catch up with developed countries, it is necessary to develop the industrial priority development strategy with strategic change. However, it is difficult to maintain the huge transaction costs in the transitional economy. In some industries, public firms first enter the market as the leader and undertake huge policy burdens. We study the privatization degree of public firm as the industry leader.²

² Kopel (2021) showed that in a price-setting duopoly market with horizontally differentiated products, where firms can increase the willingness to pay of the consumers of their products by investing in socially responsible activities. It demonstrated that if the investment in CSR is perfectly specific to the CSR leader and does not spill over to the CSR follower, the CSR leader achieves higher profits. Hence, a first-mover advantage arises. Also see Hirose et al. (2016) who consider a model in which two firms

Wang and Mukherjee (2012) in a homogenous oligopoly showed that the entry of private profit-maximizing firms makes the consumers worse off compared to having a nationalized monopoly. Later entry of private firms increases the nationalized firm's profit, industry profit, and social welfare, at the expense of the consumers. In that paper, social-welfare maximizing public firm is the leader and no consideration of partial privatization. We consider the degree of privatization if privatized firm is a leader in a differentiated oligopoly with the consumer's cognition of CSR efforts. Our results echo what they called "undesirable competition" in mixed Stackelberg model.

When there is a public firm and a CSR private firm, CSR private firm decides its output level according to its own objective function and maximizes (4) with respect to q_1 . Solving the first-order condition $\left(\frac{\partial V_1}{\partial q_1} = 0\right)$, we obtain:

$$q_1 = \frac{a - q_0}{3 - \beta^2} \quad (18)$$

The public firm responds to the CSR private firm and decides its output level by maximizing (3) with respect to q_0 . Solving the first-order conditions $\left(\frac{\partial V_0}{\partial q_0} = 0\right)$, we find the output level of public and CSR firm,

$$q_0 = \frac{a(8 + \beta^4 - \beta^2(6 - \gamma) - 3\gamma + \theta)}{20 - 6\gamma - \beta^2(13 - 2\gamma + 5\theta) + 7\theta + \beta^4(2 + \theta)} \quad (19a)$$

$$q_1 = \frac{a(2(2 + \theta) - \gamma - \beta^2(1 + \theta))}{20 - 6\gamma - \beta^2(13 - 2\gamma + 5\theta) + 7\theta + \beta^4(2 + \theta)} \quad (19b)$$

We obtain the social welfare SW as a function of θ , β and γ as follow:

$$SW = \frac{a^2(-6\gamma^3 + 2\beta^8(1 + \theta) + 2\gamma^2(34 + 7\theta) + 32(10 + 7\theta + \theta^2) - 4\gamma(64 + 28\theta + \theta^2) - \beta^6(29 + 26\theta + \theta^2 - 2\gamma(3 + 2\theta)) + 2\beta^4(78 + 63\theta + 5\theta^2 + \gamma^2(3 + \theta) - 2\gamma(16 + 9\theta)) + \beta^2(2\gamma^3 - \gamma^2(41 + 10\theta) + 2\gamma(112 + 54\theta + \theta^2) - 16(23 + 17\theta + 2\theta^2)))}{2(20 - 6\gamma - \beta^2(13 - 2\gamma + 5\theta) + 7\theta + \beta^4(2 + \theta))^2} \quad (20)$$

In the first stage, the government maximizes (20) to determine the optimal privatization degree θ^* . Solving the first-order condition $\left(\frac{\partial SW^*}{\partial \theta} = 0\right)$, we obtain:

$$\theta^{S^*} = 0$$

where superscript 'S*' indicates the equilibrium result of Stackelberg competition.

choose whether to adopt environmental corporate social responsibility policies and then face Stackelberg competition under price competition. They showed that the first-mover has the advantage, which is in contrast to the second-mover advantage typically seen in standard price competition models.

We have the SPNE of the output level, profit, consumer surplus and social welfare as follow:

$$q_0^{S*} = \frac{a(8 + \beta^4 - \beta^2(6 - \gamma) - 3\gamma)}{20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma)}$$

$$q_1^{S*} = \frac{a(4 - \beta^2 - \gamma)}{20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma)}$$

$$Q^{S*} = \frac{a(4 - \beta^2)(3 - \beta^2 - \gamma)}{20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma)}$$

$$\pi_0^{S*} = \frac{a^2(8 + \beta^4 - \beta^2(6 - \gamma) - 3\gamma)(16 + \beta^4 - 11\gamma + 2\gamma^2 - \beta^2(8 - 3\gamma))}{2(20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma))^2}$$

$$\pi_1^{S*} = \frac{a^2(4 - \beta^2 - \gamma)(28 - 25\gamma + 6\gamma^2 + \beta^4(3 - 2\gamma) - \beta^2(19 - 15\gamma + 2\gamma^2))}{2(20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma))^2}$$

CS^{S*}

$$= \frac{a^2(80 - 12\beta^6 + \beta^8 + 8\gamma - 30\gamma^2 + 6\gamma^3 + \beta^4(53 + 2\gamma - 3\gamma^2) - 2\beta^2(52 + 5\gamma - 10\gamma^2 + \gamma^3))}{2(20 + 2\beta^4 - 6\gamma - \beta^2(13 - 2\gamma))^2}$$

$$SW^{S*} = \frac{a^2(4 - \beta^2 - \gamma)^2}{40 + 4\beta^4 - 12\gamma - \beta^2(26 - 4\gamma)}$$

Through similar calculation, we get that when the third private firm enters, regardless of making CSR efforts or not, and if the public firm is the leader, the optimal choice of privatization is not privatize, $\theta = 0$. After simplification, we get the output level, profit, consumer surplus and social welfare when the third private competitor does and doesn't make CSR efforts as follow:

(i) when the third private competitor doesn't make CSR efforts, the subscript ' NS^* ' in the following refers to the equilibrium result of Stackelberg competition without CSR.

$$q_0^{NS*} = \frac{a(\beta^4(9 - 4\gamma) + (3 - \gamma)^2(9 - \gamma(2 + \gamma)) - \beta^2(3 - \gamma)(18 - \gamma(5 + \gamma)))}{H_1}$$

$$q_1^{NS*} = \frac{a(3 - \gamma)(2 - \gamma)(9 - 3\beta^2 - \gamma^2)}{H_1}$$

$$q_2^{NS*} = \frac{a(3 - \beta^2 - \gamma)(2 - \gamma)(9 - 3\beta^2 - \gamma^2)}{H_1}$$

$$Q^{NS*} = \frac{a(\beta^4(15 - 7\gamma) + (3 - \gamma)^2(21 - 4\gamma - 3\gamma^2) - 2\beta^2(54 - 36\gamma + 3\gamma^2 + \gamma^3))}{H_1}$$

$$\pi_0^{NS*} = \frac{a^2(\beta^4(9 - 4\gamma) + (3 - \gamma)^2(9 - 2\gamma - \gamma^2) - \beta^2(54 - 33\gamma + 2\gamma^2 + \gamma^3))}{2H_1^2}$$

$$\pi_0^{NS*} = \frac{(\beta^4(9 - 2\gamma^2) + (3 - \gamma)^2(9 + 6\gamma - 5\gamma^2) - \beta^2(54 - 9\gamma - 18\gamma^2 + 5\gamma^3))}{2H_1^2}$$

$$\pi_1^{NS*} = \frac{a^2(3 - \beta^2)(3 - \gamma)^2(2 - \gamma)^2(9 - 3\beta^2 - \gamma^2)^2}{2H_1^2}$$

$$\pi_2^{NS*} = \frac{3a^2(2 - \gamma)^2(3 - \beta^2 - \gamma)^2(9 - 3\beta^2 - \gamma^2)^2}{2H_1^2}$$

CS^{NS*}

$$a^2(\beta^8(117 - 77\gamma^2 + 24\gamma^3) + 2\beta^4(3 - \gamma)^2(369 + 360\gamma - 414\gamma^2 + 8\gamma^3 + 30\gamma^4 + \gamma^5) - 2\beta^2(3 - \gamma)^3(270 + 345\gamma - 289\gamma^2 - 53\gamma^3 + 31\gamma^4 + 4\gamma^5) + (3 - \gamma)^4(153 + 228\gamma - 144\gamma^2 - 66\gamma^3 + 19\gamma^4 + 6\gamma^5) - 2\beta^6(702 + 153\gamma - 843\gamma^2 + 370\gamma^3 - 23\gamma^4 - 7\gamma^5))$$

$$= \frac{\hspace{15em}}{2H_1^2}$$

SW^{NS*}

$$= \frac{a^2(\beta^4(17 - 8\gamma) + (3 - \gamma)^2(25 - 6\gamma - 3\gamma^2) - 2\beta^2(60 - 41\gamma + 4\gamma^2 + \gamma^3))}{2H_1}$$

(ii) when the third private competitor make CSR efforts, the subscript ‘CS*’ in the following refers to the equilibrium result of Stackelberg competition with CSR.

$$q_0^{CS*} = \frac{a(9 - 6\beta^2 + \beta^4 - \gamma(2 + \gamma))}{H_2}$$

$$q_1^{CS*} = q_2^{CS*} = \frac{a(3 - \beta^2 + \gamma)(2 - \gamma)}{H_2}$$

$$Q^{CS*} = \frac{a(21 + \beta^4 - 2\beta^2(5 - \gamma) - 4\gamma - 3\gamma^2)}{H_2}$$

$$\pi_0^{CS*} = \frac{a^2(9 - 6\beta^2 + \beta^4 + 6\gamma - 5\gamma^2)(9 - 6\beta^2 + \beta^4 - 2\gamma - \gamma^2)}{2H_2^2}$$

$$\pi_1^{CS*} = \pi_2^{CS*} = \frac{a^2(3 - \beta^2)(2 - \gamma)^2(3 - \beta^2 + \gamma)^2}{2H_2^2}$$

$$CS^{CS*} = \frac{a^2(153 + \beta^8 + 228\gamma - 144\gamma^2 - 66\gamma^3 + 19\gamma^4 + 6\gamma^5 - 4\beta^6(3 + 2\gamma - \gamma^2) + 2\beta^4(31 + 34\gamma - 18\gamma^2 - \gamma^3) - 4\beta^2(39 + 52\gamma - 31\gamma^2 - 6\gamma^3 + 2\gamma^4))}{2H_2^2}$$

$$SW^{CS*} = \frac{a^2(25 + \beta^4 - 2\beta^2(5 - \gamma) - 6\gamma - 3\gamma^2)}{2H_2}$$

We have the following Proposition 3.

Proposition 3: *When the public firm acts as the leader of the industry, the optimal choice for the privatization of public firm is not to privatize.*

When the public firm is the leader of the industry and not privatize because its objective function is to maximize social welfare. On the contrary, privatization will reduce social welfare first. If a new firm enters, whether CSR efforts are made or not, it will not affect the zero degree of privatization, full nationalization. This result complements the so called “undesirable competition” in mixed Stackelberg model.

We have the following Proposition 4.

Proposition 4: *If $0 < \beta < 1$, $0 < \gamma < 1$, then*

- (i) $Q^* > Q^{S*}$, $CS^* > CS^{S*}$ and $SW^* > SW^{S*}$
- (ii) $Q^{N*} = Q^{NS*}$, $CS^{N*} = CS^{NS*}$ and $SW^{N*} = SW^{NS*}$
- (iii) $Q^{C*} = Q^{CS*}$, $CS^{C*} = CS^{CS*}$ and $SW^{C*} = SW^{CS*}$

The total output level, consumer surplus and social welfare when the public firm as industry leader and private firms as follower are lower than those under Cournot competition. On the one hand, market competition will incentivize them to increase production. On the other hand, as a leader, public firm captures the initial resource endowment which makes public firm acts a monopoly firm and sets price=MC to determine the output amount is the first-best solution. The entry of private firm pursuing its own profit as the follower may be due to the lack of comparative advantages in the industries, are not able to reverse the leading position of the public firm. Although the privatization policy of the government is not to privatize, the existence of the third firm enhances the degree of competition, and the positive effect brought by the increased competition degree is just equivalent to that of the government's optimal privatization choice in the previous section, resulting in the

outcome that total output level, consumer surplus and social welfare are equal to the situation of privatization.

6. Conclusions

We revisited a mixed triopoly with product differentiation and consumer cognition in which a public firm and CSR-concerned private firms conduct quantities competition. We found that the privatization degree of public firm is closely related to product differentiation and consumer cognition. When new firm enters, whether CSR efforts are made or not, the degree of privatization will be higher. When the entering firm makes CSR efforts, the degree of privatization becomes even higher than other cases.

Furthermore, if the public firm acts as the leader of the industry, the privatization policy is not to privatize. The entry of private firm pursuing its own profit as follower may be due to the lack of comparative advantages in the industries, are not able to reverse the leading position of the public firm. Although the privatization degree of the government is not to privatize, the entry of the third firm objectively strengthens the competition and other favorable factors, resulting in the outcome that total output level, consumer surplus and social welfare are equal to the scenario of non-privatization.

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