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Effect of corporate social responsibility on privatization policy: linear cost approach

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Abstract

This paper analyzes the effect of corporate social responsibility on the optimal degree of privatization in a mixed oligopoly where the technology of each firm is represented by a linear cost function. Some recent studies show that when costs are quadratic and firms are equally efficient, the government should decrease the degree of privatization if the level of CSR increases. In this paper, we highlight the sensitivity of the privatization policy to the cost structure of firms. In contrast to the result obtained when production costs are quadratic, we show that the optimal level of privatization increases with the level of CSR in the several relevant cases.

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1 Introduction

In critical sectors such as energy, infrastructure, transport and finance, governments continue to own commercial enterprises which compete with private firms. The privatization of the public firms has been one of the main issues in the mixed oligopoly literature. However, the discussion of the privatization of the public firms is based on the difference of efficiency between public and private firms.

For De Fraja and Delbono (1989), when public and private firms have the same quadratic cost function, the social welfare in the market can be improved by the privatization of the public firm. Matsumura (1998) assumes that a privatized firm maximizes a weighted sum of its profits and total surplus. He shows that the privatization of the public firm improves welfare in a model with a general cost function (including both quadratic and linear production costs). Assuming that the marginal cost of production is constant and the private firms are more efficient than the public firm, Bárcena-Ruiz and Garzón (2005) show that the government privatizes the public firm if the marginal cost of the public firm is high enough. However, if all firms have the same constant marginal cost of production, Bárcena-Ruiz (2012) obtain that the government does not privatize the public firm.

In this paper, we assume a mixed oligopoly in which the public firm competes with a socially responsible firm. In recent years, corporate social responsibility (CSR) becomes much popular in the business economics, and an increasing number of private firms adopted a regime of CSR in any industry[1]. The popularity of CSR has also grown in sectors like telecommunications oil and transportation. In these sectors, the public firms are active and the CSR activities of the private firms may modify the privatization policy of the public firm.

Assuming that the cost function is quadratic and both public and CSR firms are equally efficient, Ouattara (2017) examined the optimal privatization policies with the CSR activities of a private firm. He showed that government should decrease the degree of privatization if the level of CSR increases. Kim et al. (2019) also assumed a quadratic cost function and analyzed the case where the public firm is more efficient than private firms. They showed that the optimal degree of privatization is non-monotone with the CSR level in a significant heterogeneity of objectives among the firms.

In the mixed oligopoly literature, the models with quadratic cost function and those with constant marginal cost of production could have opposite policy implications (see Matsumura and Okamura (2015) or Haraguchi and Matsumura (2021)). The quadratic cost function leads to a higher marginal cost of production for the public firm after production decisions have been made (Gil-Moltó et al., 2020). However, with linear cost, the public firm serves the whole market if it is as efficient as private firms, and if it is less efficient this may encourage the government to privatize the public firm. For example, Matsumura and Okamura (2015) show that when the competition is tougher, the degree of the privatization is higher in the constant marginal cost model. They obtain the opposite result with the quadratic cost model.

[1] See for example the international survey by the consulting firm KPMG (2015).

Therefore, an issue that remains to be investigated is the effect of CSR on the privatization policy when the marginal cost of production is constant. In this paper, we consider that the public firm and the domestic CSR firm have a constant marginal cost of production and we introduce a cost difference between these two firms. We also consider the case of foreign-owned CSR firm and analyze the optimal privatization policy in both domestic and international mixed duopoly. In the mixed oligopoly literature, the question of the nationality of the private firms is important because it changes the objective function of the public firm (welfare function)[2].

We show that the optimal degree of privatization increases with the level of CSR in the several relevant cases. For example, when the semi-public firm is inefficient, the CSR activity of the domestic private firm has always a positive effect on the optimal degree of privatization. In the case of international mixed duopoly, we show that the optimal degree of privatization increases with CSR only if the marginal cost of production of the public firm is relatively low. The literature shows that when a semi-public and a domestic CSR firms have the same quadratic cost function, full nationalization is optimal if the level of CSR is high enough. In this paper, we obtain that if both firms have the same constant marginal cost of production, the government does not privatize the public firm regardless the level of CSR. Moreover, we find that CSR has a positive impact on social welfare.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 presents the equilibrium and section 4 concludes the paper. Proofs of Propositions and Lemma are presented in the appendixes.

2 The model

We consider an industry consisting of two firms with a single homogeneous output. One of the firm (firm 0) is a partially privatized public firm, and the other (firm 1) is a CSR firm.

The inverse demand function is given by: $p = 1 - Q$, where Q is the total output of the good. q_i refers to firm i's output, so $Q = q_0 + q_1$.

Both firms have different technology represented by the linear cost function $C_i(q_i) = c_i q_i \qquad (i = 0, 1)$.

To simplify the expositions of results, we normalize c_1 to 0 and c_0 to c. So the cost of the CSR firm is never higher than that of the semi-public firm[3]. We assume that in order to assure that all equilibrium market outcomes are strictly positive $c < \frac{1-\theta}{(\theta-2)^2} \equiv \widetilde{c}$.

The profit function of firm 0 and firm 1 are respectively given as:

$$\pi_i = pq_i - c_i q_i \tag{1}$$

Following the recent established literature on CSR[4], we assume that the CSR firm max-

[2]In domestic competition, the public firm maximizes the sum of the consumer and the producer surplus. However, in an international mixed oligopoly, the foreign firm profit is excluded from the producer surplus (Fjell and Pal, 1996).

[3]As Megginson and Netter (2001) and White (2002) we consider that the private firm can produce at lower costs than the public firm. This inefficiency of the public firm is justified by the informational and institutional aspects of the market (Hsin and Ogawa, 2005).

[4]See for example Goering (2007, 2008), Lambertini and Tampieri (2015).

imizes profit plus a fraction of the consumer surplus. Thus, the objective function of C*SR* firm is:

$$U_1 = \pi_1 + \theta CS \tag{2}$$

where consumer surplus, denoted by CS, is given by $CS = \frac{Q^2}{2}$. The parameter $\theta \in [0, 1]$ measures the degree of concern for consumers that the CSR firm has.

Following Matsumura (1998), we assumed that firm 0 maximizes a convex linear combination of social welfare and the firm's profit.

$$U_0 = (1 - \alpha)W + \alpha\pi_0 \tag{3}$$

where $\alpha \in [0, 1]$ represents the degree of privatization. If $\alpha = 0$, firm 0 is a fully nationalize firm and maximizes welfare, and if $\alpha = 1$ she is a fully privatized firm and maximizes profit. Higher value of α denotes higher degree of privatization.

The government's, which objective is to maximize the social welfare, decides on the degree of privatization α. We define the social welfare as the sum of the consumer surplus and the producer surplus (PS).

$$W = CS + PS \tag{4}$$

We consider two different configurations regarding the nationality of CSR firm. In the first configuration, the CSR firm is a domestic firm, and its profit is part of producer surplus ($PS = \pi_0 + \pi_1$). In the second configuration, the CSR firm is a foreign, and its profit is eliminated from producer surplus ($PS = \pi_0$). In these two cases, the objective function of the semi-public firm can be rewritten as:

$$U_0^D = (1 - \alpha)(CS + \pi_1) + \pi_0 \tag{5}$$

$$U_0^F = (1 - \alpha)(CS) + \pi_0 \tag{6}$$

where superscript D (F) denotes domestic (foreign) competition.

The game has a two stage structure. In the first stage, the government maximizes social welfare (4) to decide the optimal degree of privatization. In the second stage, observing α, the semi-public firm (firm 0) and the *CSR* firm (firm 1) simultaneously and independently choose their outputs respectively to maximize (3) and (2). We adopt a subgame perfect Nash equilibrium.

3 Equilibria

Given the CSR firm can be domestic or foreign, there are two cases: domestic competition (superscript D) and foreign competition (superscript F).

In the second stage of domestic competition, firm 0 and firm 1 choose respectively q_0 and q_1 to maximize (5) and (2). Solving this, we obtain the following result.

$$q_0^D = \frac{1-\theta-c(2-\theta)}{\alpha(2-\theta)+1}, \qquad q_1^D = \frac{c(1-\theta)+\alpha+\theta}{\alpha(2-\theta)+1}$$

$$CS^D = \frac{(1-c+\alpha)^2}{2(\alpha(2-\theta)+1)^2} \tag{7}$$

$$\pi_0^D = \frac{\alpha(1-\theta-c(2-\theta))^2}{(\alpha(2-\theta)+1)^2}, \qquad \pi_1^D = \frac{(\alpha(1-\theta)+c)(c(1-\theta)+\alpha+\theta)}{(\alpha(2-\theta)+1)^2}$$

$$W^D = \frac{\left[\begin{array}{c} \alpha^2(3-2\theta)+c^2(3-2\theta)-2c(1-\theta)+1 \\ +2\alpha(\theta(4c-1)+4c^2(1-\theta)-c\theta^2(1-c)-3c+2) \end{array}\right]}{2(\alpha(2-\theta)+1)^2} \tag{8}$$

Next, we solve the second stage of the game with a foreign CSR firm. In this stage, firm 0 and firm 1 choose respectively q_0 and q_1 to maximize (6) and (2). Solving this, we obtain the following result.

$$q_0^F = \frac{(2-\theta)(1-c)-\alpha}{2+\alpha-\theta}, \qquad q_1^F = \frac{\theta(1-c)+c+\alpha}{2+\alpha-\theta}$$

$$CS^F = \frac{(c-2)^2}{2(2+\alpha-\theta)^2} \tag{9}$$

$$\pi_0^F = \frac{((2-\theta)(1-c)-\alpha)((1-c)(\alpha-\theta)-c)}{(2+\alpha-\theta)^2}; \qquad \pi_1^F = \frac{(\theta(1-c)+c+\alpha)(c+\alpha-\theta)}{(\theta-\alpha-2)^2}$$

$$W^F = \frac{\left[\begin{array}{c} 2\alpha^2(c-1)-2\alpha(3c+c\theta(c-1)-2(c^2+1)) \\ +2\theta^2(c-1)^2+2(\theta(3c-2)(1-c)+2)+c(5c-8) \end{array}\right]}{2(2+\alpha-\theta)^2} \tag{10}$$

In the first stage of domestic (foreign) competition, the government chooses α to maximize W^D (W^F). We obtain:

$$\alpha^D = \frac{c(1-\theta)}{1-\theta-c(\theta-2)^2} \tag{11}$$

$$\alpha^F = \frac{(1-\theta)[c(1-\theta)+\theta]}{3-\theta-c(2-\theta)} \tag{12}$$

When $\theta = 1$, the government does not privatize the public firm regardless of the marginal cost of the public firm and the nationality of CSR firm. We also obtain that when the semi-public firm is as efficient as the CSR firm ($c = 0$), full nationalization is always the optimal policy in the domestic mixed duopoly ($\alpha^D|_{c=0} = 0$), however, in the international mixed duopoly, there exist some situations where partial privatization is the optimal policy ($0 < \alpha^F|_{c=0;\,\theta\neq 1} < 1$).

Proposition 1 *Partial privatization and the level of CSR*

i) In a domestic mixed duopoly, the optimal degree of privatization increases if the level of CSR increases for all $c > 0$. The government does not change the optimal degree of privatization if $c = 0$.

ii) In a foreign mixed duopoly, the optimal degree of privatization increases with CSR only if the public firm marginal cost is relatively low ($c < \frac{2\theta^2-10\theta+7-\sqrt{-20\theta+8\theta^2+13}}{2(1-\theta)(3-\theta)}$).

In contrast to the result obtained when production costs are quadratic and firms are equally efficient (Kim et al., 2019; Ouattara, 2017), the Proposition 1 *i)* shows that if all firms have the same constant marginal cost of production, the level of CSR does not change the optimal degree of privatization. Indeed, regardless of the level of the domestic firm's CSR, when all firms have the identical marginal cost of production, the nationalization of the semi-public firm is the optimal policy for the government. This result is also confirmed by Bárcena-Ruiz (2012) and Matsumura and Okamura (2015) in a model without CSR.

However, if the semi-public firm is inefficient, the CSR activity of the domestic private firms has a positive effect on the optimal degree of privatization. This result implies that the share of government in inefficient public firm should be lower when the private firm engages in CSR.

These results highlight that the relationship between CSR and the optimal privatization policy depends on the cost structure. Indeed, regardless of the cost structure (quadratic or linear), the CSR decreases the output of the public firm and increases both the output of the private firm and the consumer surplus. When the cost function is quadratic, the optimal degree of privatization is decreasing in θ because the CSR decreases the difference in marginal cost between the private and the public firm. In other words, an increase in the level of CSR mitigates the inefficiency in the distribution of production costs between both firms[5] and the decrease of α is socially optimal (productive and allocative efficiency). However, when the marginal cost of production is constant, the CSR has no effect on the difference in marginal cost between the private firm and the public firm. In this last case, the CSR increases the degree of privatization if the public firm is inefficient, but the government does not privatize the public firm when both firms have the same constant marginal cost of production.

Next, we analyze the link between CSR and the privatization policy in an international mixed duopoly (Proposition 1 *ii)*). In this case, we show that the optimal degree of privatization is non-monotone with the level of CSR. Depending on the semi-public firm's marginal cost, CSR can have a positive or negative impact on the optimal degree of privatization. For example, when the marginal cost of the semi-public firm is relatively low, the optimal degree of privatization increases with the level of CSR. This result is also in contrast with that obtained in the quadratic cost function case in a similar environment of competition (Ouattara, 2017), where the optimal degree of privatization is decreasing with the level of CSR. So when deciding the optimal degree of privatization, the government should take into account the level of the private firm's CSR and the cost structure of the different firms.

Proposition 2 *Partial privatization and the cost parameter*

> *If the semi-public firm's marginal cost of production increases, the optimal degree of privatization increases for all* $\theta < 1$*. However, an increase of the marginal cost yields to a more degree of privatization in an international duopoly than in a domestic duopoly.*

This proposition shows that when the level of the public firm's marginal cost of production increases, the optimal degree of privatization also increases. When c increases, the output of

[5] Given the shape of the cost function, efficiency requires that total output should be divided among firms as equally as possible (Bárcena-Ruiz, 2012)

the public firm decreases, the output of the CSR firm increases and the consumer surplus decreases. Nevertheless, producer surplus increases. In these conditions, it is optimal for the government to increase the privatization degree in order to induce more production substitution from the inefficient public firm to the CSR firm.

In addition, the increase of c exert more influence in the domestic optimal degree of privatization than that of the foreign optimal degree.

Proposition 3 *Partial privatization and the nationality of CSR firm*

> *The optimal degree of privatization is larger (lower) in the domestic mixed duopoly than in the international mixed duopoly when the marginal cost of production is high (low) enough.*

The privatization leads to a substitution effect between the production of the public firm and that of the CSR-firm. When the public firm's marginal cost of production is relatively high, this substitution effect is more socially beneficial (because productive efficiency improves), but only in the domestic mixed duopoly. Indeed, in the international mixed duopoly, this substitution effect of production is not beneficial for the domestic welfare, which does not include the profit of the foreign CSR firm.

Conversely, when the marginal cost of the public firm is relatively low, the government should choose a higher degree of privatization for public firms in competition with foreign firms than those with domestic firms.

Substituting α^D into (8)-(9), we obtain:

$$q_0^{D*} = 1-\theta-c\left(\theta-2\right)^2, \quad q_1^{D*} = c\left(1-\theta\right)\left(2-\theta\right)+\theta$$

$$\pi_0^{D*} = c\left(1-\theta\right)\left[1-\theta-c\left(\theta-2\right)^2\right]; \quad \pi_1^{D*} = c\left(2-\theta\right)\left(2c+\theta-3c\theta+c\theta^2\right) \tag{13}$$

$$CS^{D*} = \frac{(1-c(2-\theta))^2}{2}; \quad W^{D*} = \frac{2c(1-\theta)(2c-1)+c^2\theta^2+1}{2}$$

In the domestic mixed duopoly equilibrium, we obtain that the CSR firm produces more than the semi-public firm if the marginal cost of the semi-public firm is relatively high. However, when c is relatively low, the contrary result is obtained. Under these conditions, the CSR firm also achieves a higher (low) profit than that of the semi-public firm when the marginal cost is relatively high (low).

Lemma 1 $\frac{\partial(\pi_1^{D*}+\pi_0^{D*})}{\partial\theta} = 0$

This lemma shows that the increase in the level of CSR has no impact on the producer surplus because the additional profit of the CSR-firm is equivalent to the losses of the public firm ($\frac{\partial\pi_1^{D*}}{\partial\theta} = -\frac{\partial\pi_0^{D*}}{\partial\theta}$). In other words, the private firm's commitment to CSR results in a transfer of profit from the public firm to the socially responsible firm. As a result, the CSR has no effect on the producer surplus.

Substituting α^F into (10)-(11), we obtain:

$$q_0^{F*} = \frac{\theta^2(1-c)+(1-\theta)(3-4c)}{3-2\theta}, \quad q_1^{F*} = \frac{(2-\theta)(c(1-\theta)+\theta)}{3-2\theta}$$

$$\pi_0^{F*} = \frac{[c(1-\theta)+\theta]\left[\theta^2(1-c)+(1-\theta)(3-4c)\right]}{(3-2\theta)^2}, \quad \pi_1^{F*} = \frac{(2-\theta)(c(1-\theta)+\theta)(c(2-\theta)-\theta)}{(3-2\theta)^2} \tag{14}$$

$$CS^{F*} = \frac{(-\theta(1-c)-2c+3)^2}{2(3-2\theta)^2}; \quad W^{F*} = \frac{\theta^2(1-2c)-2c(1-\theta)(3-2c)+3+c^2\theta^2-2\theta}{2(3-2\theta)}$$

In contrast with the domestic mixed duopoly case, we obtain that in the international mixed duopoly, the public firm always produces more than the foreign CSR firm. This difference in results is explained by the aggressive behavior of the semi-public firm in the market when the rival is a foreign firm. As a result, in the presence of foreign competitor, the semi-public firm gains market share and has a greater profit than the foreign CSR firm.

Proposition 4 *Welfare analysis in equilibrium*

i) An increase in the level of CSR always increases the social welfare regardless the nationality of CSR firm

ii) The domestic (international) mixed duopoly leads to higher level of social welfare when the marginal cost is relatively low (high).

In the domestic mixed duopoly case, the increase in the level of CSR has a positive impact on social welfare. As shown in lemma 1, the increase in the level of CSR has no impact on the producer surplus and the increase in welfare is identical to that of the consumer surplus.

CSR also has a positive impact on social welfare in the international duopoly. This is explained by the fact that the increase in consumer surplus is always greater than the decrease in the profit of the semi-public firm.

In contrast to the case of quadratic cost (where social welfare is greater in the domestic mixed duopoly than in the international mixed duopoly), we show that this result holds only if the marginal cost of the public firm is relatively low. In the presence of a public firm with a marginal cost of production too high, competition with foreign CSR firms makes it possible to have a better level of social welfare.

4 Conclusion

The main purpose of the paper is to analyze the privatization policy when a public firm competes with a CSR firm and to examine whether the results derived in Ouattara (2017) and Kim et al. (2019) are robust when the costs of both firms are linear.

We highlight the sensitivity of the privatization policy to the cost structure of firms. In contrast to the result obtained when production costs are quadratic, we show that the optimal degree of privatization increases with the level of CSR in the several relevant cases. For example, in the case of domestic mixed duopoly, we show that CSR increases the optimal degree of privatization of the inefficient public firm. Moreover, if the public firm competes with a foreign CSR firm, we find that the degree of privatization increases with CSR when the marginal cost of production of the public firm is relatively low. Furthermore, in this linear cost case, we find that regardless of the level of CSR, full nationalization is optimal

when the public firm is as efficient as the CSR firm. This result is in contrast to that in Ouattara (2017) where full nationalization is never optimal when the level of CSR is low.

In this paper, we assume that the level of CSR is exogenously given. However, if firms can choose endogenously the level of CSR, the optimal privatization policy could change. An extension of our study to the endogenization of CSR level would have interesting implications. In future work, it would also be worthwhile to consider a generalization of demand and/or cost functions in order to obtain more general results on the relationship between the level of CSR and the optimal degree of privatization.

APPENDIXES

Appendix 1: Proof of Proposition 1

- $\frac{\partial \alpha^D}{\partial \theta} = \frac{c^2\theta(2-\theta)}{(4c+\theta-4c\theta+c\theta^2-1)^2} \geq 0$
- $\frac{\partial \alpha^F}{\partial \theta} = \frac{-7c-6\theta+c^2\theta^2+10c\theta+\theta^2-2c\theta^2-4c^2\theta+3c^2+3}{(-2c-\theta+c\theta+3)^2}$. The sign of this expression depends of that of $(-7c-6\theta+c^2\theta^2+10c\theta+\theta^2-2c\theta^2-4c^2\theta+3c^2+3)$.

Since $(-7c-6\theta+c^2\theta^2+10c\theta+\theta^2-2c\theta^2-4c^2\theta+3c^2+3)$ is a quadratic and convex function of c and is equal to zero when $c = \frac{2\theta^2-10\theta+7-\sqrt{-20\theta+8\theta^2+13}}{2(1-\theta)(3-\theta)}$, therefore $\frac{\partial \alpha^F}{\partial \theta} > 0$ if and only if $c < \frac{2\theta^2-10\theta+7-\sqrt{-20\theta+8\theta^2+13}}{2(1-\theta)(3-\theta)}$.

Appendix 2: Proof of Proposition 2

- $\frac{\partial \alpha^D}{\partial c} = \frac{(\theta-1)^2}{(4c+\theta-4c\theta+c\theta^2-1)^2} > 0; \qquad \frac{\partial}{\partial c}(\alpha^F) = \frac{(1-\theta)(3-2\theta)}{(-2c-\theta+c\theta+3)^2} > 0$
- $\frac{\partial \alpha^D}{\partial c} - \frac{\partial \alpha^F}{\partial c} = \frac{(2-\theta)\left(-2c^2\theta^4+15c^2\theta^3-41c^2\theta^2+49c^2\theta-22c^2-4c\theta^3+16c\theta^2-18c\theta+6c-\theta^2-2\theta+3\right)}{(-2c-\theta+c\theta+3)^2(4c+\theta-4c\theta+c\theta^2-1)^2} < 0 \quad \text{for } c < \frac{1-\theta}{(\theta-2)^2} \equiv \widetilde{c}$

Appendix 3: Proof of Proposition 3

$\alpha^D - \alpha^F = \frac{(1-\theta)\left[c\left(\theta^3+2\right)-\theta(\theta-1)(5c-1)+c^2(\theta-2)\left(3\theta-\theta^2-1\right)\right]}{(2c+\theta-c\theta-3)(4c+\theta-4c\theta+c\theta^2-1)}$. The sign of this expression depends of that of $(1-\theta)\left[c\left(\theta^3+2\right)-\theta\left(\theta-1\right)(5c-1)+c^2\left(\theta-2\right)(3\theta-\theta^2-1)\right]$.

Since $(1-\theta)\left[c\left(\theta^3+2\right)-\theta\left(\theta-1\right)(5c-1)+c^2\left(\theta-2\right)(3\theta-\theta^2-1)\right]$ is a quadratic and concave function of c and is equal to zero when $c = \frac{5\theta(1-\theta)+\theta^3+2-\sqrt{\begin{array}{c}28\theta-31\theta^2+2\theta^3\\+11\theta^4-6\theta^5+\theta^6+4\end{array}}}{2(2-\theta)(3\theta-\theta^2-1)}$, therefore $\alpha^D - \alpha^F > 0$ if and only if $c > \frac{5\theta(1-\theta)+\theta^3+2-\sqrt{\begin{array}{c}28\theta-31\theta^2+2\theta^3\\+11\theta^4-6\theta^5+\theta^6+4\end{array}}}{2(2-\theta)(3\theta-\theta^2-1)}$.

Appendix 4: Proof of Lemma 1

From (13), we obtain

$\frac{\partial \pi_0^{D*}}{\partial \theta} = c\left(8c + 2\theta - 10c\theta + 3c\theta^2 - 2\right)$
$\frac{\partial \pi_1^{D*}}{\partial \theta} = -c\left(8c + 2\theta - 10c\theta + 3c\theta^2 - 2\right)$
So $\frac{\partial \pi_0^{D*}}{\partial \theta} = -\frac{\partial \pi_1^{D*}}{\partial \theta}$

Appendix 5: Proof of Proposition 4

- $\frac{\partial W^{D*}}{\partial \theta} = \frac{\partial CS^{D*}}{\partial \theta} = c\left(c\theta - 2c + 1\right) \geq 0$; $\quad \frac{\partial W^{F*}}{\partial \theta} = \frac{(2c+\theta-c\theta-3)(-c-\theta+c\theta)}{(2\theta-3)^2} > 0 \quad$ for $c < \widetilde{c}$
- $W^{D*} - W^{F*} = \frac{1}{2}\frac{10c^2\theta^2 - 2c^2\theta^3 + 4c\theta - \theta^2 - 2c\theta^2 - 16c^2\theta + 8c^2}{3-2\theta}$. The sign of this expression depends of that of $\left(10c^2\theta^2 - 2c^2\theta^3 + 4c\theta - \theta^2 - 2c\theta^2 - 16c^2\theta + 8c^2\right)$.

Since $\left(10c^2\theta^2 - 2c^2\theta^3 + 4c\theta - \theta^2 - 2c\theta^2 - 16c^2\theta + 8c^2\right)$ is a quadratic and convex function of c and is equal to zero when $c = \theta\frac{\sqrt{-2\theta+3}-1}{-6\theta+2\theta^2+4}$, therefore $W^{D*} - W^{F*} > 0$ if and only if $c < \theta\frac{\sqrt{-2\theta+3}-1}{-6\theta+2\theta^2+4}$.

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