E C O N O M I C S B U L L E T I N

Bargaining over Managerial Contracts in Delegation Games: The Quadratic Cost Case

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Abstract

We again examine how the managers' bargaining power affects social welfare and the firms' profits in both quantity and price competition, in particular, in the case where each firm's production technology is represented by a quadratic cost function. We show that under both the competition types, if the relative bargaining power of managers is sufficiently low, increase in the power results in the decrease of each firm's profit and the increase of social welfare; on the other hand, if the managers' relative bargaining power is sufficiently high, its increase leads to the deterioration of social welfare due to the excessively high total cost in the market. This result is somewhat in contrast to the existing ones obtained in the constant marginal cost case, and hence, our findings show that they are not robust against the change in the type of each firm's cost function.

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1 Introduction

This paper presents a theoretical analysis of bargaining over managerial delegation between an owner-shareholder and a manager in the case in which each firm's production technology is represented by a quadratic cost function. For a long time, traditional economic theories have solely regarded a firm as a profit-maximizing agent. However, in particular, in large corporations, we usually observe the separation of ownership and management. The literature on industrial organization has challenged this difficult issue since the mid-1980s, adopting modern game theoretical techniques. Fershtman and Judd (1987), Sklivas (1987), and Vickers (1985) considered the situation where both an owner and a manager exist within a single firm and the owner provides the manager with the managerial incentive contract based on both the firm's profit and sales (*the sales delegation case*), adopting a multi-stage game. Then, the owner strategically manipulates the incentive parameter in the managerial contract, such that her/his profit-maximizing objective is fulfilled at maximum in the duopolistic market outcomes. In the above three works, they showed that in the case of quantity competition, the managerial incentive contracts lead to more aggressive behavior on the part of each firm in the marketplace than in a standard un-delegated duopolistic case, while in the case of price competition, it results in less aggressive behavior on the part of each firm. Subsequently, the literature in this area has developed towards the direction in which a new style of managerial contracts is proposed. Salas Fumas (1992) and Miller and Pazgal (2001) considered two-stage games in which the manager's incentive contract is based on a weighted sum of the firm's own profit and its rival's profit (*the relative performance case*). Jansen et al. (2007)) and Ritz (2008) examined the market share version of the delegation contract, i.e., the contract scheme on the basis of a combination of its own profit and market share (*market share case*).

In their recent work, van Witteloostuijn *et al.* (2007) considered the two-stage delegation games in which owner-shareholders negotiate the incentive parameter on the managerial contract with the managers in the first stage, and subsequently in the second stage, Cournot competition engaged in by each firm's manager evolves in a homogeneous goods market. They showed that in the sales delegation case, if the bargaining power of the managers increases, the equilibrium profit of each firm decreases and social welfare increases. In the context of both quantity and price competition, Nakamura (2008) and Kamaga and Nakamura (2008) extended their scope to the cases of differentiated goods and sequential competition, respectively, and thus considered the robustness of the result in van Witteloostuijn *et al.* (2007). In both the papers, they obtained a result similar to that in van Witteloostuijn *et al.* (2007).

This paper aims to examine the case where the production technology of each firm is represented by a quadratic cost function without capacity constraint against the case of a constant marginal cost function as in van Witteloostuijn *et al.* (2007), Nakamura (2008) and Kamaga and Nakamura (2008) and, further, to check the robustness of the result in their papers.[1] We work with the case of the simultaneous-move game under the the types of competition, quantity and price competition, in the same manner of Nakamura (2008) and Kamaga and Nakamura (2008). The result obtained in this paper is that if the relative bargaining power of managers is

[1] The assumption of each firm's cost function in this paper justifies the presence of a finite and small number of firms.

sufficiently high, the equilibrium social welfare deteriorates in both the competition types, unlike the results of the three papers, namely, van Witteloostuijn et al., Nakamura, and Kamaga and Nakamura. This is so because in the case of the quadratic cost function, in contrast to the constant marginal cost case, the decrease in the producer surplus outweighs the increase in the consumer surplus due to the excessively high total cost in the market as the relative bargaining power of managers increases, when it is sufficiently high.

The remainder of this paper is organized as follows. In Section 2, we formulate the basic setting of the delegation game of the two types of models considered in this paper. In Section 3, we consider the case of quantity competition. In Section 4, we investigate the case of price competition. Section 5 presents the concluding remarks. A detailed description of the equilibrium market outcomes in each competition is relegated to the Appendix.

2 Model

We consider a symmetric duopolistic model using a standard product differentiation model as in Singh and Vives (1984). A representative consumer's utility is denoted as

$$U(q_1, q_2) = a\left(q_1 + q_2\right) - \frac{1}{2}\left[\left(q_1\right)^2 + 2bq_1q_2 + \left(q_2\right)^2\right] + q,$$

where q_i represents the quantity of good i $(= 1, 2)$, and $b \in (0, 1)$ represents the degree of product differentiation. Note that q denotes a numeraire good. The utility function generates the system of linear demand functions:

$$q_i = \frac{a\left(1-b\right) - p_i + bp_j}{1-b^2}, \qquad b \in \left(0,1\right), \qquad i,j = 1,2,\ i \neq j.$$

Then, the inverse demand functions can be inverted to obtain

$$p_i = a - q_i - bq_j, \qquad b \in \left(0,1\right), \qquad i,j = 1,2,\ i \neq j,$$

where p_i represents the price of good i $(= 1, 2)$. We assume that the production technology of each firm is represented by a quadratic cost function. The profit of firm i is given by

$$\begin{aligned}\Pi_i &= \left(a - q_i - bq_j\right) q_i - \frac{1}{2}k\left(q_i\right)^2, \\ &= \frac{\left[a\left(1-b\right) - p_i + bp_j\right]\left\{2\left(1-b^2\right)p_i - k\left[a\left(1-b\right) - p_i + bp_j\right]\right\}}{2\left(1-b^2\right)^2}, \qquad i,j = 1,2,\ i \neq j.\end{aligned}$$

Usually, social welfare, denoted by W, is measured as the sum of consumer surplus (CS) and producer surplus (PS):

$$W = CS + PS,$$

where $PS = \Pi_1 + \Pi_2$, and CS is given by

$$\begin{aligned}CS &= \frac{1}{2}\left[\left(q_1\right)^2 + 2bq_1q_2 + \left(q_2\right)^2\right], \\ &= \frac{2a^2\left(1-b\right) + \left(p_1\right)^2 - 2bp_1p_2 + \left(p_2\right)^2 - 2a\left(1-b\right)\left(p_1 + p_2\right)}{2\left(1-b^2\right)}.\end{aligned}$$

We consider the situation in which a firm's owner decides to delegate the control of his or her assets to a manager, similar to the case in Fershtman and Judd (1987) and Sklivas (1987). Both the firms' owners can assess the performance of their managers according to two readily observable indicators–the output and profit of the firm. In this case, the objective of each manager is given by

$$U_i = \Pi_i + \theta_i q_i, \qquad \theta_i \in \mathbb{R}, \quad i = 1, 2,$$

where parameter θ_i measures the relevance of the sales. The manager of firm i can maximize his or her payoff by choosing the output q_i or the price p_i that maximizes U_i $(i = 1, 2)$. This can be supported by the assumption that the payoff to the manager of firm i is represented as $\lambda_i + \mu_i V_i$ for some real number λ_i and some positive number μ_i $(i = 1, 2)$. Similar to many existing works, we assume that the payoffs to the managers are negligible as compared to the profits, because we emphasize the impact of managerial delegation on the equilibrium outcomes.

We propose the following two-stage delegation game. In the first stage, an owner and his or her manager bargain over the incentive parameter θ_i in each firm $(i = 1, 2)$. Subsequently, in the second stage, each manager simultaneously decides his or her output or price, being aware of the level of his or her own incentive parameter. Thus, an owner and a manager bargain over their incentive parameters in the sales delegation contracts such that both their profits and payoffs are enhanced through their collusive market behaviors.

The bargaining in the first stage is generally formulated in the same manner as in Binmore *et al.* (1986). For each firm, the equilibrium outcome of the bargaining process coincides with the Nash bargaining solution of the following equation in terms of the incentive parameter θ_i:

$$B_i = U_i^{\beta} \cdot \Pi_i^{1-\beta}, \qquad i = 1, 2,$$

where $\beta \in [0, 1)$ denotes the measure for the relative bargaining power of the manager. Note that in this paper, we restrict our attention to the symmetric case in which all managers have the same bargaining powers denoted as β. As a result, we assume that owners select sufficiently homogeneous managers both in terms of their bargaining powers and the preferences to their payoffs. The disagreement point of both owner and manager is zero: If the bargaining process breaks down, the managers are unable to procure other jobs, and the owners are unable to operate their firms due to the lack of time or managerial skills.

3 Quantity Competition

In this section, we consider how profits, consumer surplus, and social welfare depend on the managers' relative bargaining power, β, for the sales delegation in the case of quantity competition in a differentiated-products duopolistic setting.

As usual, we begin by solving the second stage. Given a pair of incentive parameters θ_1 and θ_2, each manager maximizes his or her objective U_i with respect to q_i $(i = 1, 2)$. The condition for each manager is given by

$$\frac{\partial U_i}{\partial q_i} = a - (2 + k)\, q_i - b q_j + \theta_i = 0, \qquad i, j = 1, 2, \; i \neq j.$$

Solving the system of the above equations for q_0 and q_1, we obtain the output of each firm as follows:

$$q_i = \frac{a(2-b+k)+(2+k)\theta_i - b\theta_j}{(2+k)^2 - b^2}, \qquad i,j=1,2,\ i\neq j.$$

From the first-order condition of the above system, we have

$$U_i = \frac{2+k}{2}(q_i)^2, \qquad \Pi_i = \frac{2+k}{2}(q_i)^2 - \theta_i q_i, \qquad i=1,2.$$

Thus, we obtain the following results:

$$\frac{\partial U_i}{\partial \theta_i} = \frac{(2+k)^2 q_i}{(2+k)^2 - b^2} > 0, \qquad \frac{\partial^2 \Pi_i}{\partial \theta_i^2} = -\frac{(2+k)\left[(2+k)^2 - 2b^2\right]}{\left[(2+k)^2 - b^2\right]^2} < 0, \qquad \forall b \in (0,1), \quad i=1,2.$$

In short, similar to the results of the sales delegation case of van Witteloostuijn *et al.* (2007), we obtain the result that the objective function of the manager U_i is an increasing function of θ_i, and the profit of each firm is an concave function of θ_i $(i=1,2)$. The interests of the owner and manager of each firm are different. Therefore, it is appropriate for them to bargain over the incentive parameter, θ_i $(i=1,2)$. Furthermore, the use of the weighted Nash product as a solution concept in our model is supported by Kaneko's (1980) extension of the Nash bargaining problem to the case with a compact but not necessarily convex payoff possibility set, similar to the argument in Kamaga and Nakamura (2008).

We now proceed to the analysis of the first stage of the game. Considering the outcomes in the first stage, we rewrite the Nash product for the bargaining problem of each firm as follows:

$$B_i = U_i^{\beta} \cdot \Pi_i^{1-\beta} = \left[\frac{2+k}{2}(q_i)^2\right]^{\beta} \cdot \left[\frac{2+k}{2}(q_i)^2 - \theta_i q_i\right]^{1-\beta}, \qquad i=1,2.$$

Thus, analogous to van Witteloostuijn *et al.* (2007), we obtain the following first-order condition for the bargaining of each firm:

$$\frac{\partial B_i}{\partial \theta_i} = 0 \Leftrightarrow q_i\left[\beta - 1 + (2+k)\frac{\partial q_i}{\partial \theta_i}\right] - \theta_i(1+\beta)\frac{\partial q_i}{\partial \theta_i} = 0, \qquad i=1,2.$$

Taking into account that $\partial q_i/\partial\theta_i = 2/\left(4-b^2\right)$ and that the problem's symmetry is $\theta = \theta_1 = \theta_2$, we obtain

$$\theta^* = \theta_i^* = \frac{a\left[b^2(1-\beta) + (2+k)^2\beta\right]}{(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)}, \qquad i=1,2.$$

Furthermore, we obtain the following result:[2]

$$\frac{\partial \Pi_i^*}{\partial \beta} = -\frac{a^2(2+k)\left[(2+k)^2 - 2b^2\right]\left[\beta(2+k)^2 + b(2+k)(1+\beta) + b^2(1-\beta)\right]}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)\right]^3} < 0,$$

[2]The explicit expressions for the equilibrium market outcomes under both the Cournot and Bertrand competitions are given in the Appendix.

$$\forall b \in (0,1), \ \forall \beta \in [0,1).$$

Thus, we find that the equilibrium profit of each firm decreases for all the values of $b \in (0,1)$ and $\beta \in [0,1)$ as the relative bargaining power of the manager, β, increases. On the other hand, we obtain

$$\frac{\partial CS^*}{\partial \beta} = \frac{2a^2 (1+b)(2+k)^2 (1+\beta) \left[(2+k)^2 - 2b^2 \right]}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2 (1-\beta) \right]^3} > 0, \qquad \forall b \in (0,1), \ \forall \beta \in [0,1),$$

and

$$\frac{\partial W^*}{\partial \beta} = \frac{2a^2 (2+k) \left[(2+k)^2 - 2b^2 \right] \left\{ (2+k) [1 - \beta (1+k)] - b^2 (1-\beta) \right\}}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2 (1-\beta) \right]^3} \gtreqless 0,$$
$$\Leftrightarrow \beta \lesseqgtr \frac{2 - b^2 + k}{2 - b^2 + 3k + k^2}.$$

In the marginal cost case in van Witteloostuijn *et al.* (2007), Nakamura (2008), and Kamaga and Nakamura (2008), as the value of the relative bargaining power of managers, β, is increasing, the increase of consumer surplus outweighs the decrease of producer surplus. On the other hand, in the case where the production technology of each firm is represented by a quadratic cost function, if the value of β is sufficiently large, social welfare may deteriorate, since the total cost in this market predominantly raises with the increase of the output of each firm. The following proposition tells us these properties led by the introduction of the bargaining over the delegation parameter between an owner and a manager in the quadratic cost case.

Proposition 1. *In the delegation game with the bargaining over the sales delegation parameter between an owner and a manager, there exists a unique subgame perfect Nash equilibrium, which depends on the managers' bargaining power β. In the equilibrium, if the relative bargaining power of managers increases, the profit of each firm decreases, whereas the consumer surplus increases. Furthermore, as the relative bargaining power of managers, β, increases, the equilibrium social welfare improves if $\beta \in \left[0, \ \left(2 - b^2 + k\right) / \left(2 - b^2 + 3k + k^2\right)\right)$, while it deteriorates if $\beta \in \left(\left(2 - b^2 + k\right) / \left(2 - b^2 + 3k + k^2\right), \ 1\right)$, and thus the maximum value of the equilibrium social welfare is achieved when $\beta = \left(2 - b^2 + k\right) / \left(2 - b^2 + 3k + k^2\right)$.*

Note that similar to the constant marginal cost case as in van Witteloostuijn *et al.* (2007), Nakamura (2008) and Kamaga and Nakamura (2008), as the relative bargaining power of managers, β approaches 1, the equilibrium profit of each firm, Π_i^*, approaches 0.

4 Price Competition

In this section, we analyze the price competition case in which each firm produces a differentiated good. We again use backward induction and consider a two-stage process in which the an owner and a manager bargain over the incentive parameter in the first stage, and both the firms compete with regard to prices in the second stage.

Given a pair of incentive parameters θ_1 and θ_2, each manager maximizes the objective function U_i with respect to p_i $(i = 1, 2)$. The first-order condition for each manager is given by

$$\frac{\partial U_i}{\partial p_i} = \frac{a(1-b)\left(1-b^2+k\right) - \left(2-2b^2+k\right)p_i + b\left(1-b^2+k\right)p_j - \left(1-b^2\right)\theta_i}{\left(1-b^2\right)^2} = 0,$$
$$i, j = 1, 2, \; i \neq j.$$

Solving the system of the above equations for p_0 and p_1, we obtain the price of each firm as follows:

$$p_i = \frac{a\left[2 - b(1+k) - b^2(3+2k) + b^3 + b^4 + k(3+k)\right] - \theta_i\left(2-2b^2+k\right) - b\theta j\left(1-b^2+k\right)}{b^4 + (2+k)^2 - b^2(5+2k)},$$
$$i, j = 1, 2, \; i \neq j.$$

Considering the first-order condition of each manager, we obtain

$$U_i = \frac{\left[a(1-b) - p_i + bp_j\right]\left\{2\left(1-b^2\right)p_i - k\left[a(1-b) - p_i + bp_j\right] + 2\left(1-b^2\right)\theta_i\right\}}{2\left(1-b^2\right)^2},$$
$$\Pi_i = \frac{\left[a(1-b) - p_i + bp_j\right]\left\{2\left(1-b^2\right)p_i - k\left[a(1-b) - p_i + bp_j\right]\right\}}{2\left(1-b^2\right)^2}, \qquad i, j = 1, 2, \; i \neq j.$$

Thus, we obtain the following results:

$$\frac{\partial U_i}{\partial \theta_i} = \frac{\left(2-b^2+k\right)\left(2-2b^2+k\right)}{b^4 + (2+k)^2 - b^2(5+2k)} q_i > 0, \quad \frac{\partial^2 \Pi_i}{\partial \theta_i^2} = -\frac{(2+k)^3 + b^4(4+k) - 2b^2\left(6+5k+k^2\right)}{\left[b^4 + (2+k)^2 - b^2(5+2k)\right]^2} < 0,$$
$$\forall b \in (0,1), \; i = 1, 2.$$

Therefore, similar to quantity competition, we find that in price competition, the objective function of each manager U_i is an increasing function of θ_i, and the profit of each firm is a concave function of θ_i $(i = 1, 2)$; further, by the same argument as in the previous section, the use of the weighted Nash product as a solution concept of the owner-manager negotiation is supported by Kaneko's (1980) extension as indicated in Kamaga and Nakamura (2008).

Next, we analyze the bargaining between an owner and a manager in the first stage. In the case of price competition, the bargaining problem is as follows:

$$B_i = U_i^{\beta} \cdot \Pi_i^{1-\beta}$$
$$= \left\{\frac{\left[a(1-b)-p_i+bp_j\right]\left\{2\left(1-b^2\right)p_i - k\left[a(1-b)-p_i+bp_j\right] + 2\left(1-b^2\right)\theta_i\right\}}{2\left(1-b^2\right)^2}\right\}^{\beta} \cdot \left\{\frac{\left[a(1-b)-p_i+bp_j\right]\left\{2\left(1-b^2\right)p_i - k\left[a(1-b)-p_i+bp_j\right]\right\}}{2\left(1-b^2\right)^2}\right\}^{1-\beta},$$
$$i, j = 1, 2, \; i \neq j.$$

Considering the problem's symmetry, $\theta = \theta_1 = \theta_2$, we obtain

$$\frac{\partial B_i}{\partial \theta_i} = 0 \Leftrightarrow a\left(2-b-b^2+k\right)\left[(2+k)^2\beta - b^2(1+k+5\beta+2k\beta) + b^4(1+\beta)\right]$$
$$- \theta\left[(2+k)^3 + b(2+k)^2\beta - 2b^2\left(6+5k+k^2\right) - b^3(1+k+5\beta+2k\beta) + b^4(4+k)\right] = 0,$$

yielding

$$\theta^* = \theta_i^* = \frac{a\left[(2+k)^2\beta + b^4(1+\beta) - b^2(1+k+5\beta+2k\beta)\right]}{(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)}, \qquad i = 1, 2.$$

Using the equilibrium market outcomes represented in the Appendix, we obtain the following result:

$$\frac{\partial \Pi_i^*}{\partial \beta} = -\frac{a^2\left(2-b^2+k\right)\left[(2+k)^2-b^2(4+k)\right]\left\{\beta(2+k)^2+b(2+k)(1+\beta)+b^2[1-\beta(3+k)]-b^3(1+\beta)\right\}}{\left[(2+k)^2+b(2+k)(1+\beta)-b^2(3+k-\beta)-b^3(1+\beta)\right]^3} < 0,$$
$$\forall b \in (0,1),\ \forall \beta \in [0,1).$$

Thus, we find that the equilibrium profit of each firm decreases for all the values of $b \in (0,1)$ and $\beta \in [0,1)$ as the relative bargaining power of the manager, β, increases. On the other hand, we obtain

$$\frac{\partial CS^*}{\partial \beta} = \frac{2a^2(1+b)\left(2-b^2+k\right)^2(1+\beta)\left[(2+k)^2-b^2(4+k)\right]}{\left[(2+k)^2+b(2+k)(1+\beta)-b^2(3+k-\beta)-b^3(1+\beta)\right]^3} > 0, \quad \forall b \in (0,1),\ \forall \beta \in [0,1),$$

and

$$\frac{\partial W^*}{\partial \beta} = \frac{2a^2\left[(2+k)^3-2b^2\left(6+5k+k^2\right)+b^4(4+k)\right]\left\{(2+k)[1-\beta(1+k)]-b^2[2-\beta(2+k)]\right\}}{\left[(2+k)^2+b(2+k)(1+\beta)-b^2(3+k-\beta)-b^3(1+\beta)\right]^3} \gtreqless 0 \Leftrightarrow \beta \lesseqgtr \frac{2-2b^2+k}{(2+k)\left(1-b^2+k\right)}.$$

In the case of both price competition and quantity competition, if the value of β is sufficiently large, social welfare may decrease due to the excessively high total cost in the market, owing to the aggressive behavior of each firm. This fact is stated in the following proposition:

Proposition 2. *In the delegation game with the bargaining over the sales delegation parameter between an owner and a manager, there exists a unique subgame perfect Nash equilibrium, which depends on the managers' bargaining power* β*. In the equilibrium, if the relative bargaining power of managers increases, the profit of each firm decreases, whereas the consumer surplus increases. Furthermore, as the managers' relative bargaining power,* β *increases, the equilibrium social welfare improves if* $\beta \in \left[0,\ \left(2-2b^2+k\right)/(2+k)\left(1-b^2+k\right)\right)$*, while it deteriorates if* $\beta \in \left(\left(2-2b^2+k\right)/(2+k)\left(1-b^2+k\right),\ 1\right)$*; thus, the maximum value of the equilibrium social welfare is achieved when* $\beta = \left(2-2b^2+k\right)/(2+k)\left(1-b^2+k\right)$*.*

Note that analogous to quantity competition, as β approaches 1, the equilibrium profit of each firm, Π_i^*, approaches 0.

5 Conclusion

This paper examined the bargaining between an owner and a manager over managerial incentive contracts for the sales delegation case in two types of differentiated-products markets under Cournot and Bertrand competitions. In particular, we focused on the case where the production technology of each firm is represented by a quadratic cost function. We analyzed whether or not the results in the constant marginal cost case as in van Witteloostuijn *et al.* (2007), Nakamura (2008) and Kamaga and Nakamura (2008) – that the equilibrium social welfare is positively associated with the increase of the relative bargaining power of managers, β – is consistent with that obtained in this paper. Consequently, we obtained the result that under the two types of market competition, Cournot and Bertrand competition, the equilibrium social welfare decreases as the relative bargaining power of managers increases, provided the value of β is sufficiently large. This phenomenon occurs since the total cost in this market is too high to the degree that the decrease in the producer surplus outweighs the increase in the consumer surplus due to the aggressive behavior of each firm. Therefore, the result of the managerial delegation game with bargaining between an owner and a manager is not robust against the change in the style of each firm's cost function.

Future research should address the application of other delegation regimes, such as the market share delegation in Jansen et al. (2007)) and the relative performance case in Miller and Pazgal (2002), to this model. We must examine the robustness of the result in this paper against such the other delegation regimes.

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Appendix

Solving the game by backward induction, we derive the following equilibrium market outcomes in each competition type.

Cournot Competition:

$$q_i^* = \frac{a(2+k)(1+\beta)}{(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)}; \quad p_i^* = \frac{a\left[(2+k)(1+k-\beta) - b^2(1-\beta)\right]}{(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)};$$

$$\Pi_i^* = \frac{a^2(2+k)\left(1-\beta^2\right)\left[(2+k)^2 - 2b^2\right]}{2\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)\right]^2}; \qquad i = 1, 2;$$

$$CS^* = \frac{a^2(1+b)(2+k)^2(1+\beta)^2}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)\right]^2};$$

$$W^* = \frac{a^2(2+k)\left\{(1+b)(2+k)(1+\beta)^2 - \left[2b^2 - (2+k)^2\right]\left(1-\beta^2\right)\right\}}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(1-\beta)\right]^2}.$$

Bertrand Competition:

$$p_i^* = \frac{a\left[(2+k)(1+k-\beta) - b^2(2+k-2\beta)\right]}{(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)};$$

$$q_i^* = \frac{a\left(2-b^2+k\right)(1+\beta)}{(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)};$$

$$\Pi_i^* = \frac{a^2\left(2-b^2+k\right)\left[(2+k)^2 - b^2(4+k)\right](1-\beta)(1+\beta)}{2\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)\right]^2}; \qquad i = 1, 2;$$

$$CS^* = \frac{a^2(1+b)(1+\beta)^2\left(2-b^2+k\right)^2}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)\right]^2};$$

$$W^* = \frac{a^2(1+\beta)\left\{\left(2-b^2+k\right)(1-\beta)\left[(2+k)^2 - b^2(4+k)\right] + (1+b)(1+\beta)\left(2-b^2+k\right)^2\right\}}{\left[(2+k)^2 + b(2+k)(1+\beta) - b^2(3+k-\beta) - b^3(1+\beta)\right]^2}.$$