Title	ON THE EFFECT OF TRADE LIBERALIZATION UPON COLLUSION
Sub Title	
Author	TAKAHASHI, Takaaki
Publisher	Keio Economic Society, Keio University
Publication year	1997
Jtitle	Keio economic studies Vol.34, No.2 (1997.) ,p.33- 50
JaLC DOI	
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Notes	
Genre	Journal Article
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=AA00260492-19970002-0033

KEIO ECONOMIC STUDIES 34(2), 33–50 (1997)

ON THE EFFECT OF TRADE LIBERALIZATION UPON COLLUSION

Takaaki TAKAHASHI

Graduate Institute of Policy Studies, Saitama, Japan

First version received November 1996; final version accepted July 1997

Abstract: I show that collusive behavior may appear when firms expect that barriers to international trade will be removed in the future. For that purpose, applying the spatial competition model à la Hotelling, I construct a two-stage game in which two firms compete by setting their prices for two stages. One property of the game critical to the result is that the second stage game has multiple and asymmetric equilibria.

Key-words: asymmetric equilibria, collusion, finite stage game, Hotelling model, multiple equilibria, outside good, spatial competition, trade barriers

1. INTRODUCTION

Removal of barriers to international trade, dramatically altering economic environment in respective trading countries, has an impact on various aspects in the organization of industries. It is likely that mere expectation of the future removal is enough to affect firms' current behaviors. Anticipating the elimination of protective tariff a decade later, for instance, firms may enter or exit from industries today, or more subtly, change their policies concerning advertising, research and development, pricing behavior, product choice or collusive behavior.

In this paper, I examine the effect of the expectation about the future removal of trade barriers upon collusive behaviors of domestic firms in a duopolistic industry. It is shown that collusion may appear between the two firms when they expect the future trade liberalization, although the firms would have no incentive to collude without this expectation. For that purpose, I construct a model of spatial competition in which two firms compete by setting their prices for two periods. The model prescribes that the two firms end up exporting no product to foreign markets. This greatly helps us to focus on the strategic interactions between the two domestic firms, abstracting the interactions between each domestic firm and a foreign firm. Thereby, the removal of trade barriers, which may take place

Acknowledgement. I wish to thank Kyle Bagwell, Robert Porter and Asher Wolinsky as well as an anonymous referee for helpful comments and am especially grateful to Kiminori Matsuyama for numerous insightful discussions and suggestions.

at the beginning of the second period, affects the domestic industry only through the decline in the price of an outside good or "import". I analyze the model as a two-stage game to show that collusion at the first period is supported by a subgame perfect Nash equilibrium if the price of the outside good falls within a certain range at the second period. Furthermore, the collusion is, it is shown, supportable only when the price of the outside good is declining, that is, when the firms expect the trade liberalization to take place at the beginning of the second period: no collusion appears as an equilibrium outcome when the price of the outside good remains unchanged.

Among the properties of the two-stage game presented in the paper, two are worthy of a special emphasis.

First, the stage game, which is a price game with an outside good, a variant of the Hotelling location game (Hotelling (1929)), may have multiple asymmetric equilibria.[1] Economides (1984) shows that there are multiple equilibria when the price of the outside good falls within a certain range. His intention is, notwithstanding, not to fully explore the properties of the multiple equilibria but to solve the price game in order to discuss the location-then-price game. For that purpose, he concentrates on the symmetric equilibria. What is more, his analysis is limited to the case of linear transportation cost. The multiplicity of the equilibria is, however, not peculiar to the linearity of transportation cost. In this paper, I scrutinize the multiplicity and the asymmetry results of the equilibria for more general transportation cost cases because those results will play critical roles in the analysis of the two-stage game.

Second, the game, in which collusion evolves, contains only finite stages but not infinite stages. This point may be subject to the criticism that infinitely repeated games describe the real world better than two-stage games. The use of the two-stage game in this paper would, however, be justified by the following grounds. First of all, this paper is intended to be only the first step toward the complete treatment of the problem. Having studied the two-stage game, one can extend it to the infinitely repeated game. The second point is more important. If I relied on the model with an infinitely repeated game, the result that the cooperative behavior emerges would not be too interesting: We know, as the folk theorem, that the cooperative behavior is supported as an equilibrium outcome in an infinitely repeated game; and furthermore, an abundance of research has been conducted in various fields along this line. For many of the finite stage games including finitely repeated games, on the other hand, collusion does not constitute an equilibrium, which would be understood by recalling that players have an incentive

[1] The price game with an outside good originates with Lerner and Singer (1937) and has been developed by Salop (1979) and Economides (1984), among others. Salop reveals that when the outside good is introduced into the Hotelling model, demand curves become kinked even though firms make symmetric "Nash" conjectures. It is well known in the classical literature of the kinked demand theory (see, for example, Sweezy (1939)) that there can exist multiple equilibria in the price game if demand curves are kinked. Salop does not, however, refer to this possibility.

to cheat at the final stage and applying the backward induction. Benoit and Krishna (1985) and Friedman (1985) have, however, shown that games consisting of stage games with multiple equilibria may yield cooperative outcomes; and further, Benoit and Krishna have proven a limit folk theorem for finitely repeated games. The game presented in this paper is not the repeated game which they have studied since the firms do not play the same stage games (the price of the outside good is declining). However, this paper provides one of the first examples that illustrate their logic and result that cooperative outcomes may be supported by subgame perfect Nash equilibria.

The rest of the paper consists of 3 sections. In the next section, I present the one-stage price game (stage game). The analysis is extended in section 3 to the two-stage price game with the declining price of the outside good. Finally, section 4 concludes.

2. STAGE GAME

In a home country, consumers are uniformly distributed with the unit density over a linear segment with the length one. There are two domestic firms, 1 and 2, located at the two endpoints of the segment. They sell a homogeneous good at mill prices p_1 and p_2 respectively.

It takes $f(d)$ to transport one unit of the good from a firm's location to a consumer's location where d is the distance between the two locations. Function $f(\cdot)$ is assumed to be continuous, thrice differentiable, strictly increasing and convex; and further I assume that it goes through the origin and that its third derivative is non-positive, i.e., $f(0)=0$, $f'(d)>0$, $f''(d)\geq 0$, and $f'''(d)\leq 0$ for $d\geq 0$.[2]

The good produced in a foreign country is referred to as an outside good. I assume that the price of the outside good is given and that its delivered price, namely mill price plus transportation cost, is equal to r at all locations in the home country. Marginal cost is given and equal to average cost for both the domestic good and the outside good. I assume that it is lower for the outside good than for the domestic good and that their difference is large enough to exceed the transportation cost to ship one unit of the domestic product to the foreign country. This assumption implies that the domestic firms do not export their product. Without loss of generality, I set the marginal cost in the home country at zero.[3]

The transportation cost is paid by the consumers. Each consumer buys one unit of the good with the lowest delivered price, namely mill price plus transportation

[2] When the transportation cost function is of the form $f(d)=vd^{\tau}$, these conditions imply that $1\leq\tau\leq 2$.

[3] This implies that the marginal cost in the foreign industry is negative. In order to allow non-negative marginal cost in the foreign country, one could alternatively set the marginal cost in the home country at a positive level. However, this does not affect the qualitative results of the model.

cost, if and only if it does not exceed the price of the outside good.

Now let us study the price game in which each firm simultaneously chooses its price once.

Salop (1979) and Economides (1984) distinguish three regimes for a firm's demand curve depending on the relative levels of the prices; *super-competitive regime* (S regime) in which a firm undercuts the competitor's price by charging a price low enough to attract the entire demand; *competitive regime* (C regime) in which both firms attract positive demand and all the market is split out into the two firms' market areas; and *monopoly regime* (M regime) in which both firms are local monopolists, i.e., their market areas do not touch each other. In addition, special attention is paid in this paper to the critical case between the C and M regimes, where the marginal consumer pays a delivered price exactly equal to the price of the outside good. I call this regime *competitive-monopoly regime* (CM regime).

In other words, the S regime occurs if and only if $p_1 - p_2 < -f(1)$ or $p_1 - p_2 > f(1)$. The C regime occurs if and only if the following two statements hold: first, $p_1 - p_2 \in [-f(1), f(1)]$, and second, there exists $x \in [0, 1]$ such that

$$p_1 + f(x) = p_2 + f(1-x) < r \,. \tag{1}$$

Let $x_1 \equiv x$ and $x_2 \equiv 1 - x$. We can interpret x_i as a market share of, or demand for, firm i ($i = 1, 2$) at the C regime. Furthermore, the CM regime occurs if and only if there exists $y \in [0, 1]$ such that

$$p_1 + f(y) = r = p_2 + f(1-y) \,. \tag{2}$$

We can interpret $y_1 \equiv y$ and $y_2 \equiv 1 - y$ as market shares of firm i ($i = 1, 2$) at the CM regime. Finally, the M regime occurs if and only if there exists $z_1 \in [0, 1]$ such that

$$p_1 + f(z_1) = r < p_2 + f(1 - z_1) \,. \tag{3}$$

Here, variable z_1 represents a market share of firm 1 at the M regime. The market share of firm 2, denoted by z_2, is given as a solution to $p_2 + f(z_2) = r$. However, this, along with (3), implies $f(z_2) < f(1 - z_1)$, i.e., $z_2 < 1 - z_1$ or $z_1 < 1 - z_2$. Therefore, $f(z_1) < f(1 - z_2)$ and consequently $p_1 + f(z_1) = r < p_1 + f(1 - z_2)$. We have proved that z_2 satisfies

$$p_2 + f(z_2) = r < p_1 + f(1 - z_2) \,. \tag{4}$$

Suppose that a firm gradually lowers its price given the competitor's price. In the M regime, the firm can appropriate all the additional area where the price of the outside good now becomes higher than its delivered price. As soon as it enters the C regime, however, this changes; the firm cannot capture all of the additional area where the price of the outside good exceeds the delivered price because some of the area is taken away by the competitor. This causes the demand curve to be kinked between the C regime and the M regime, namely, at the CM regime.

Now I examine Nash equilibria in the price game.

First, any price pair associated with the S regime is not a Nash equilibrium. This is because the firm which attracts the entire demand can charge a slightly higher price, still attract the entire demand and, therefore, earn a higher profit. Recall that I have defined the S regime excluding the critical cases where $p_1 - p_2 = -f(1)$ and where $p_1 - p_2 = f(1)$.

Second, consider the C regime. Suppose that x satisfies (1). Then, firm i's profit is given by $\Pi_i^C(p_1, p_2) \equiv p_i x_i$ $(i=1, 2)$. The following lemma gives the equilibrium (the proof is relegated to the Appendix):

Lemma 1. *There exists a unique Nash equilibrium associated with the C regime if and only if*

$$r > r'' \equiv f(1/2) + f'(1/2)\,, \tag{5}$$

and it is, when it exists, given by $(p_1, p_2) = (f'(1/2), f'(1/2))$.

Notice that this equilibrium outcome is not Pareto efficient with respect to the two firms but both can earn higher profits by, for example, raising their prices up to $r - f(1/2)$ together and acquiring the equal market shares.

Third, consider the M regime. Suppose that z_i satisfies (3) or (4), accordingly $(i=1, 2)$. Then, firm i's profit is given by $\Pi_i^M(p_i) \equiv p_i z_i$ $(i=1, 2)$. The first order conditions are (identically) given by

$$r - f(z_i) - z_i f'(z_i) = 0\,. \tag{6}$$

The following lemma follows from this condition (the proof is relegated to the Appendix):

Lemma 2. *There exists a unique Nash equilibrium associated with the M regime if and only if* $r < r' \equiv f(1/2) + f'(1/2)/2$. *The equilibrium is symmetric, i.e.,* $p_1 = p_2$, *and the equilibrium price is increasing in* r.

Notice that the equilibrium outcome is Pareto efficient with respect to the two firms.

Finally, consider the CM regime. Suppose that y satisfies (2). A price pair (p_1, p_2) associated with this regime is a Nash equilibrium if and only if a firm can, given the competitor's price, earn a higher profit neither by slightly reducing its price so that the C regime occurs nor by slightly raising its price so that the M regime occurs. That is, (y_1, y_2) yields a Nash equilibrium if and only if the following two sets of conditions are met; first, $\partial \Pi_i^C(p_1, p_2)/\partial p_i \geq 0$ for $i=1, 2$ when evaluated at $x_i = y_i$ and $p_i = r - f(y_i)$, and second, $d\Pi_i^M(p_i)/dp_i \leq 0$ for $i=1, 2$ when evaluated at $z_i = y_i$ and $p_i = r - f(y_i)$. On the one hand, since

$$\frac{\partial \Pi_i^C(p_1, p_2)}{\partial p_i} = x_i - \frac{p_i}{f'(x_1) + f'(x_2)} = y_i - \frac{r - f(y_i)}{f'(y_1) + f'(y_2)}\,,$$

the first set of conditions can be rewritten as $\beta(y_i) \geq r$ for $i=1, 2$ where

$\beta(\lambda) \equiv f(\lambda) + \lambda[f'(\lambda) + f'(1-\lambda)]$. On the other hand,

$$\frac{d\Pi_i^{\mathrm{M}}(p_i)}{dp_i} = z_i - \frac{p_i}{f'(z_i)} = y_i - \frac{r - f(y_i)}{f'(y_i)}$$

implies that the second set of conditions are reduced to $\alpha(y_i) \leq r$ for $i = 1, 2$ where $\alpha(\lambda) \equiv f(\lambda) + \lambda f'(\lambda)$. Therefore, these four conditions can be summarized by

$$\max[\alpha(y), \alpha(1-y)] \leq r \leq \min[\beta(y), \beta(1-y)] . \tag{7}$$

It is useful to note two observations regarding functions $\alpha(\cdot)$ and $\beta(\cdot)$. First, $\alpha(1-\lambda)$ is a mirror image of $\alpha(\lambda)$ with respect to the line represented by $\lambda = 1/2$. The similar remark applies to the relationship between $\beta(\lambda)$ and $\beta(1-\lambda)$. Second, since $\alpha'(\lambda) = (2+\lambda)f'(\lambda) > 0$, $\alpha(\cdot)$ is an increasing function. On the other hand, $\beta(\lambda)$ is increasing as long as $\lambda \leq 1/2$ because $\beta'(\lambda) = 2f'(\lambda) + f'(1-\lambda) + \lambda[f''(\lambda) - f''(1-\lambda)] > 0$ for $\lambda \leq 1/2$. Fig. 1 describes $\alpha(y)$, $\alpha(1-y)$, $\beta(y)$ and $\beta(1-y)$ that satisfy (7). For a given value of r, y is supported by an equilibrium associated with the CM regime if and only if (y, r) falls inside, or at the boundary of, quadrilateral ABCD.

The following lemma can be easily proved (the proof is relegated to the Appendix).

LEMMA 3. *There exists a Nash equilibrium associated with the CM regime if and only if r satisfies*

$$r' \equiv \alpha\left(\frac{1}{2}\right) \leq r \leq \beta\left(\frac{1}{2}\right) \equiv r'' . \tag{8}$$

The key observation behind (8) is that the marginal profit function has a kink (or a stationary point) at the equilibrium associated with the CM regime because this regime is a critical regime between the other two. Notice that this equilibrium outcome is Pareto efficient with respect to the two firms.

An essential property of the equilibrium associated with the CM regime is that *there may exist asymmetric and multiple equilibria*. Indeed, I derive the following proposition whose proof is relegated to the Appendix.

PROPOSITION 1. *There is a unique Nash equilibrium if $r \leq r'$ or $r \geq r''$, and there are multiple equilibria if $r \in (r', r'')$.*

In the standard location model in which r is infinitely large, no price dispersion occurs.

In regard to the multiple equilibria, we can, for each r satisfying (8), derive the lower and the upper limits of the values of y which yields the equilibria associated with the CM regime. Now, $\alpha(1-y)$ is a decreasing function of y and $\beta(y)$ is an increasing function of y for $y \leq 1/2$. Therefore, there exists a unique solution to $\alpha(1-y) = \beta(y)$ in interval $[0, 1/2]$. I denote such y by y'. Similarly, there is a unique solution to $\alpha(y) = \beta(1-y)$ in interval $[1/2, 1]$, which is denoted by y''.

Because $\alpha(y)$ and $\beta(1-y)$ are mirror images of $\alpha(1-y)$ and $\beta(y)$, respectively, it must be true that $\alpha(y'')=\alpha(1-y')=\beta(y')=\beta(1-y'')$. Let r^* be this common value, i.e., $r^*\equiv\alpha(y'')=\alpha(1-y')=\beta(y')=\beta(1-y'')$. Since $\alpha(\cdot)$ is an increasing function, we can define its inverse, denoted by $\alpha^{-1}(\cdot)$. For $\beta(\lambda)$, we know that it is increasing for $\lambda\leq 1/2$. Therefore, its inverse, $\beta^{-1}(\mu)$, can be defined for $\mu\leq\beta(1/2)=r''$. Then, the lower and the upper limits of y are equal to $1-\alpha^{-1}(r)$ and $\alpha^{-1}(r)$ respectively when $r\in[r', r^*]$, and to $\beta^{-1}(r)$ and $1-\beta^{-1}(r)$ respectively when $r\in(r^*, r'']$ (see Fig. 1). Using (2), we can translate these limits into the upper and lower limits of the equilibrium prices: For the case with $r\in[r', r^*]$, the upper and the lower limits of the equilibrium prices are equal to $r-f(1-\alpha^{-1}(r))$ and $r-f(\alpha^{-1}(r))$, respectively. Those limits are strictly increasing in r since

$$\frac{d[r-f(1-\alpha^{-1}(r))]}{dr}=1-\frac{f'(1-\alpha^{-1}(r))}{\alpha'(\alpha^{-1}(r))}>0$$

and

$$\frac{d[r-f(\alpha^{-1}(r))]}{dr}=1-\frac{f'(\alpha^{-1}(r))}{\alpha'(\alpha^{-1}(r))}>0\,.$$

For the case with $r\in(r^*, r'']$, the upper and the lower limits of the equilibrium prices are respectively given by $r-f(\beta^{-1}(r))$ and $r-f(1-\beta^{-1}(r))$, which are also strictly increasing in r.

Furthermore, using (2), I represent firm i's profit for the CM regime as the function of y_i, that is, $\bar{\Pi}_i^{\mathrm{CM}}(y_i)=y_i[r-f(y_i)]$. Since

$$\frac{d[\bar{\Pi}_1^{\mathrm{CM}}(y_1)+\bar{\Pi}_2^{\mathrm{CM}}(y_2)]}{dy}=f(1-y)-f(y)-yf'(y)+(1-y)f'(1-y)$$

and

$$\frac{d^2[\bar{\Pi}_1^{\mathrm{CM}}(y_1)+\bar{\Pi}_2^{\mathrm{CM}}(y_2)]}{dy^2}=-2[f'(y)+f'(1-y)]-yf''(y)-(1-y)f''(1-y)<0\,,$$

a joint profit of the two firms for the CM regime is maximized at $y=1/2$. In other words, when $r\in[r', r'']$, the firms maximize their joint profit by charging a price $r-f(1/2)$, each capturing a half of the market.

Suppose that y^* satisfies (7). Let $y_1^*=y^*$ and $y_2^*=1-y^*$. Then,

$$\frac{d\bar{\Pi}_i^{\mathrm{CM}}(y_i^*)}{dy_i}=r-f(y_i^*)-y_i^*f'(y_i^*)\geq 0 \tag{9}$$

for $r\in[r', r'']$, since $r\geq\alpha(y_i^*)$ $(i=1, 2)$ (see (7)). That is, for a given $r\in[r', r'']$, the lower a firm's equilibrium price is, the higher its corresponding profit is. Therefore, for a given $r\in[r', r'']$, a firm's equilibrium profit level always lies between the two equilibrium profit levels which correspond to the upper and lower limits of the equilibrium prices. Furthermore, given $r\in[r', r'']$, a firm earns the highest (or the lowest) profit among the equilibrium profits when it charges a price equal to the lower (upper) limit of the equilibrium prices and the opponent charges a price equal to their upper (lower) limit. In addition, for $r \in (r', r'')$, (9) holds with a strict inequality at least for the firm that has a market share smaller than 1/2, because $r > \alpha(y_i^*)$ for $y_i^* < 1/2$ by the definition of r'. When there are multiple equilibria, therefore, firms are not indifferent among the outcomes of those equilibria.

The following example describes these arguments for the linear transportation cost case.

EXAMPLE. Suppose that the transportation cost function is linear, i.e., $f(d) = td$. We can easily obtain the following equilibria for the price game. First, if $r < r' = t$ (M regime), there exists a unique Nash equilibrium, which is given by $(p_1, p_2) = (r/2, r/2)$ from (3), (4) and (6). Second, let us define function g as $g(\theta) \equiv 2r - t - \theta$. This function, for the CM regime, gives the price charged by firm 2 when the price charged by firm 1 is equal to θ. If $r \in [r', r^*] = [t, 6t/5]$ (CM regime), any price pair $(p_1, p_2) = (\theta, g(\theta))$ with $\theta \in [r/2, 3r/2 - t]$ is a Nash equilibrium and such equilibrium exists. There is no other equilibrium. Third, if $r \in (r^*, r''] = (6t/5, 3t/2]$ (CM regime), any price pair $(p_1, p_2) = (\theta, g(\theta))$ with $\theta \in [4r/3 - t, 2r/3]$ is a Nash equilibrium and such equilibrium exists. There is no other Nash equilibrium. Finally, if $r > r'' = 3t/2$ (C regime), there exists a unique Nash equilibrium given by $(p_1, p_2) = (t, t)$.

In this example, price dispersion occurs only if $r \in (t, 3t/2)$. The equilibrium is unique for $r \leq t$ and $r \geq 3t/2$ and there are multiple equilibria for $r \in (t, 3t/2)$. For $r \in [r', r'']$, the upper and the lower limits of the equilibrium prices are computed from the functions α and β, $\alpha(y) = 2ty$ and $\beta(y) = 3ty$ (see Fig. 1). For each level of the price of the outside good, the equilibrium prices are shown in Fig. 2. The dotted line corresponds to the symmetric equilibria. Note that, for any $r \in (t, 3t/2)$, the equilibrium price charged by firm 2 is located at the position which is symmetric to the price charged by firm 1 with respect to the dotted line.

3. TWO-STAGE GAME

In this section, I examine a two-stage game to show that there may appear collusion when firms expect the future removal of trade barriers.

The removal of trade barriers causes the decline in the price of the outside good ("import"). I suppose that it falls from r_1 at the first stage to r_2 at the second stage if trade barriers are removed at the beginning of the second stage; otherwise, it remains unchanged at r_1. Here, let us assume that r_1 is high enough for a unique Nash equilibrium associated with the C regime to exist in the corresponding stage game, i.e., $r_1 > r''$. Furthermore, I assume that $r_2 \in (r', r'')$ so that there are, in the corresponding stage game, multiple equilibria associated with the CM regime. I define U as a set of the pair of such parameters, that is, $U \equiv \{(r_1, r_2) \mid r_1 > r'', r_2 \in (r', r'')\}$.

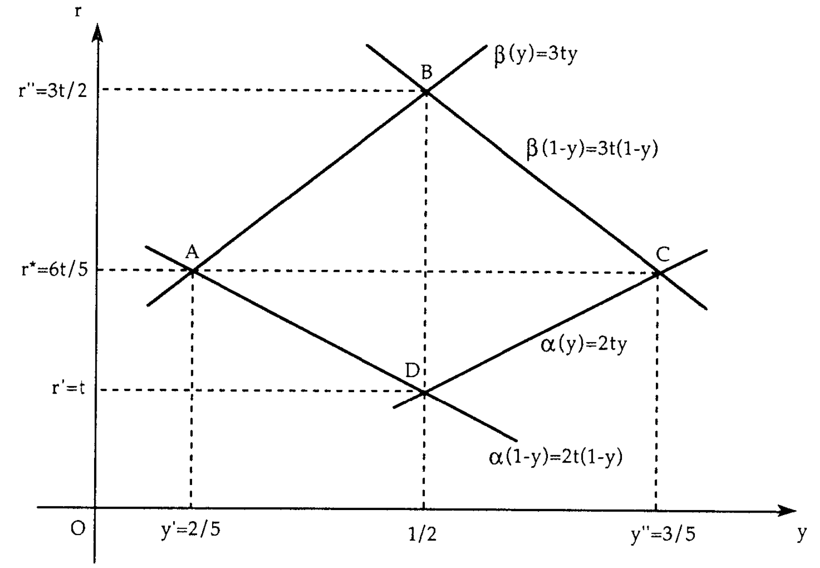


Fig. 1. Functions $\alpha(y)$, $\alpha(1-y)$, $\beta(y)$ and $\beta(1-y)$ in the Case of Linear Transportation Cost Function.

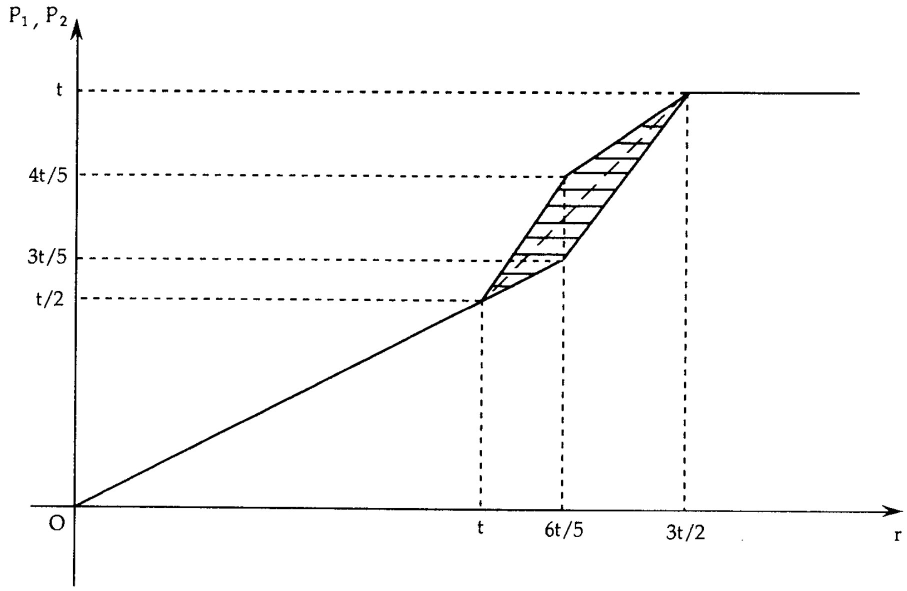


Fig. 2. Equilibrium Prices and the Reservation Value in the Case of Linear Transportation Cost Function.

The two firms choose their prices simultaneously at each stage given the price of the outside good, which is equal to r_1 or r_2.

In this game, there may be a subgame perfect Nash equilibrium in which, at the first stage, the two firms do not charge the competitive prices but cooperate with each other to earn a higher profit. The following two conditions are necessary for this to be possible: First, the equilibrium outcome in the first stage game needs to be not Pareto efficient with respect to the two firms. This enables both firms to earn, at the same time, higher profits at that stage. By construction, the equilibrium outcome of our first stage game, which is associated with the C regime, is not Pareto efficient indeed. Second, in the second stage game, there need to exist multiple equilibria among whose outcomes firms are not indifferent. If there existed, in the second stage game, a unique equilibrium or multiple equilibria among whose outcomes firms are indifferent, a cooperating firm would have no chance to punish its defecting opponent. Our second stage game, in fact, results in the multiple equilibria associated with the CM regime when the price of the outside good falls to r_2. When it remains at r_1, however, the equilibrium in the second stage game is associated with the C regime, and therefore, it is unique. Consequently, the two conditions mentioned above are satisfied only when the price of the outside good is declining, that is, collusion may evolve only when the firms expect the future removal of trade barriers.

For the rest of this section, I concentrate on the case in which the firms expect the future trade liberalization, that is, r is given by r_2 at the second stage, and show that how the collusion is supported as an equilibrium outcome. Now, let us consider the following trigger strategy. At the first stage, a firm charges a price higher than the competitive price and tries to earn a higher profit by cooperating with the opponent. If the opponent as well as the firm itself has behaved cooperatively at the first stage, it, at the second stage, charges the CM regime equilibrium price which maximizes the joint profit. Instead, if the opponent has not behaved cooperatively albeit the firm itself has, the latter punishes the opponent at the second stage by charging a price which is equal to the lower limit of the equilibrium prices associated with the CM regime. Furthermore, if the firm has withdrawn itself from the cooperation at the first stage despite the opponent's cooperative behavior, it accommodates the punishment by charging a price which is equal to the upper limit of the equilibrium prices associated with the CM regime. Finally, we can arbitrarily specify the firms' actions at the second stage when both firms have behaved noncooperatively at the first stage, as long as the specified actions constitute a Nash equilibrium in this subgame.

More precisely, a representative firm, according to the prescribed strategy, charges a price $q-f(1/2)$ with $q \in (r'', r_1]$ at the first stage so that the delivered price at the center of the market is equal to q. Parameter q represents a degree of the cooperation between the two firms at the first stage. The maximum cooperation is achieved when $q=r_1$, that is, when the firm charges a price equal to $r_1-f(1/2)$; and no cooperation is achieved when $q=r''$, that is, when it charges a competitive price $r''-f(1/2)=f'(1/2)$. If the opponent has at the first stage "cooperated" by charging a price no lower than $q-f(1/2)$, the firm charges a joint profit maximizing equilibrium price $r_2-f(1/2)$ at the second stage. Instead, if the opponent has not cooperated but charged a price lower than $q-f(1/2)$, the firm charges a punitive price $r_2-f(1-b)$ at the second stage. Since the punitive price is supposed to be equal to the lower limit of the equilibrium prices associated with the CM regime, $1-b=\alpha^{-1}(r_2)$ when $r_2 \in (r', r^*]$ and $1-b=1-\beta^{-1}(r_2)$ when $r_2 \in (r^*, r'')$. Then, by definition, b satisfies

$$\alpha(1-b)=f(1-b)+(1-b)f'(1-b)=r_2 \tag{10}$$

when $r_2 \in (r', r^*]$, and

$$\beta(b)=f(b)+b[f'(b)+f'(1-b)]=r_2 \tag{11}$$

when $r_2 \in (r^*, r'')$. The delivered price becomes equal to the price of the outside good, r_2, at the distance $1-b$ from the firm's location. In other words, the firm obtains $1-b$ of the entire market. It is worth the emphasis to note that $1-b>1/2$. Finally, if the firm has not cooperated at the first stage by charging a price lower than the price set by the opponent, then at the second stage, the firm charges an accommodating price $r_2-f(b)$ where $b<1/2$ is given by (10) or (11). Thus, it acquires b of the entire market. By construction, a pair of the prescribed strategy constitutes a Nash equilibrium in all the subgames in the second stage.

Next I study the profitability of a deviation from the prescribed strategy for the entire game. Suppose that in the first stage game, the firm's best response when the competitor charges the price $q-f(1/2)$ is to charge a price p_a which yields a market share equal to a. Then, when q is not too high, the best response is an interior solution of the profit maximization problem of the deviating firm. When it is sufficiently high, instead, the best response is a corner solution with a being equal to unity.[4] Indeed, the best response share of the deviating firm, a, is an interior solution if and only if $\partial \Pi_i^C(p_1, p_2)/\partial p_i$ evaluated at $x_i=1$ is positive. This condition is reduced to

$$q<\gamma \equiv f\left(\frac{1}{2}\right)+f(1)+f'(0)+f'(1) .$$

For this case, the best response share is computed from the first order condition $\partial \Pi_i^C(p_1, p_2)/\partial p_i=0$ evaluated at the point with $p_{-i}=q-f(1/2)$. It is given as a solution to

$$f\left(\frac{1}{2}\right)+f(a)-f(1-a)+a[f'(a)+f'(1-a)]=q , \tag{12}$$

and, furthermore, p_a is equal to

$$p_a=q-f\left(\frac{1}{2}\right)+f(1-a)-f(a)=a[f'(a)+f'(1-a)] . \tag{13}$$

Now, by the concavity of function $f'(\cdot)$, we have

[4] I assume that the profit function for the deviating firm is concave, that is,

$$2[f'(x)+f'(1-x)]^2+\left[q-f\left(\frac{1}{2}\right)-f(x)+f(1-x)\right][f''(x)-f''(1-x)] \geq 0$$

for $x \in [0, 1]$.

$$f'\left(\frac{1}{2}\right) \geq \frac{f'(a)+f'(1-a)}{2}.$$

If $a \leq 1/2$,

$$f'\left(\frac{1}{2}\right) \geq a[f'(a)+f'(1-a)]+f(a)-f(1-a) \equiv \eta$$

since $f(a)-f(1-a) \leq 0$. However, $f'(1/2)<\eta$ by (12) and the assumption that $q>f'(1/2)+f(1/2)$. This is a contradiction, and therefore, we must have $a>1/2$. That is to say, the price p_a is lower than the competitor's price and the firm acquires a market area larger than 1/2. When $q \geq \gamma$, on the other hand, the best response share is unity and the corresponding mill price p_a is given by

$$p_a = q - f\left(\frac{1}{2}\right) - f(1). \tag{14}$$

At the second stage, the firm faces the opponent's punitive behavior provided that the opponent plays the prescribed strategy.

Thus, we can derive the following incentive compatibility condition for a representative firm:

$$p_a a - \frac{q-f(1/2)}{2} \leq \delta\left[\frac{r_2-f(1/2)}{2} - b\{r_2-f(b)\}\right], \tag{15}$$

where δ is a discount factor ($\delta \in (0, 1]$) and p_a and a are respectively given either by (13) and (12) for $q<\gamma$, or by (14) and $a=1$ for $q \geq \gamma$. The left and the right hand sides of (15) respectively represent a net gain at the first stage and a net loss at the second stage due to the deviation from the prescribed strategy. Thus, we have proved the following proposition.

PROPOSITION 2. *A pair of the prescribed strategy with parameter q constitutes a subgame perfect Nash equilibrium if and only if* (15) *is satisfied.*

The left hand side of (15) is increasing in q. To see this, let L be the left hand side of (15). Then, we have

$$\frac{dL}{dq} = a\frac{dp_a}{dq} + p_a\frac{da}{dq} - \frac{1}{2}.$$

For the case of interior solution ($q<\gamma$), we obtain

$$\frac{da}{dq} = [2\{f'(a)+f'(1-a)\} + a\{f''(a)-f''(1-a)\}]^{-1}$$

from (12) and

$$\frac{dp_a}{dq}=\frac{da}{dq}\,[f'(a)+f'(1-a)+a\{f''(a)-f''(1-a)\}]$$

from (13). Therefore, $dL/dq=a-1/2>0$ since $a>1/2$. For the other case ($q\geq\gamma$), $dL/dq=1/2>0$. Hence, the left hand side of (15) is increasing in q for both the cases. Thus, there is a critical value q^* for a given r_2 such that any q no higher than $q^*(r_2)$ satisfies (15) but any q strictly higher than $q^*(r_2)$ does not. For each r_2, therefore, there is an upper bound to the degree of the first stage cooperation which is supportable by the prescribed strategy. If the degree of the cooperation is measured with the level of the delivered price at the center of the market, the upper bound, $\Psi(r_1, r_2)$, is given by $\min[q^*(r_2), r_1]$. I call this upper bound a cooperation frontier. A cooperation supportable set, denoted by V, is defined as $V\equiv\{(r_1, r_2, q)\,|\,q>r'', q\leq\Psi(r_1, r_2), (r_1, r_2)\in U\}$. It is a set of triplets (r_1, r_2, q) such that cooperation of degree q ($q>r''$) is supportable by the prices of the outside good r_1 and r_2. Furthermore, since maximum cooperation is supportable if and only if $r_1\leq\Psi(r_1, r_2)$ for $(r_1, r_2)\in U$, I call set $W\equiv\{(r_1, r_2)\,|\,(r_1, r_2, r_1)\in V\}$ a maximum cooperation supportable set. By definition, $W=\{(r_1, r_2)\,|\,r_1\leq q^*(r_2), (r_1, r_2)\in U\}$.

Several observations follow. First, for any $(r_1, r_2)\in U$, the cooperation frontier lies strictly above the delivered price associated with the competitive equilibrium, that is, $\Psi(r_1, r_2)>r''\equiv f(1/2)+f'(1/2)$ for any $(r_1, r_2)\in U$. This implies that, for any $(r_1, r_2)\in U$, at least some cooperation is supportable. Second, when r_2 is low enough, the higher the parameter r_2 is, the more cooperation is supportable. Finally, the critical value $q^*(r_2)$ does not depend on r_1, because the maximum profit that a defecting firm can earn at the first stage does not depend on r_1. Those observations are summarized in the following proposition (the proof is relegated to the Appendix).

PROPOSITION 3.

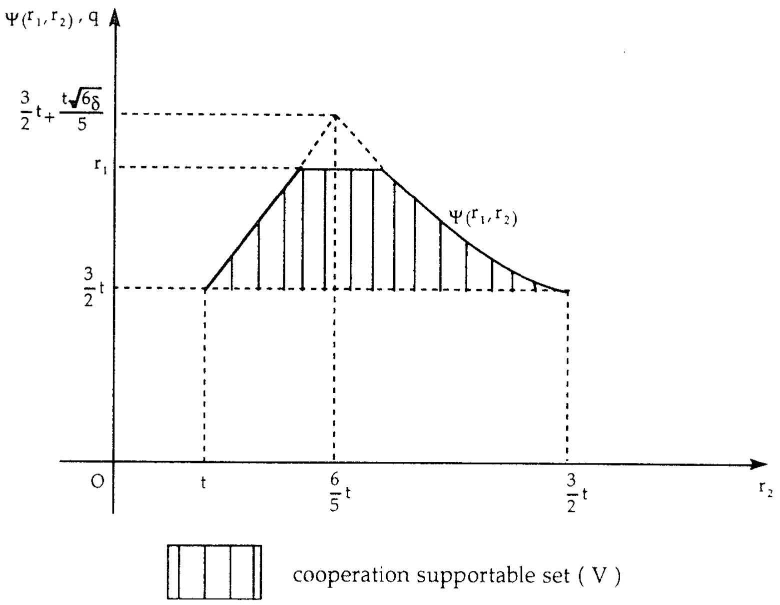
i) $V\neq\emptyset$ for any $(r_1, r_2)\in U$.

ii) $q^*(r_2)$ is strictly increasing in r_2 for $r_2\in(r', r^*)$.

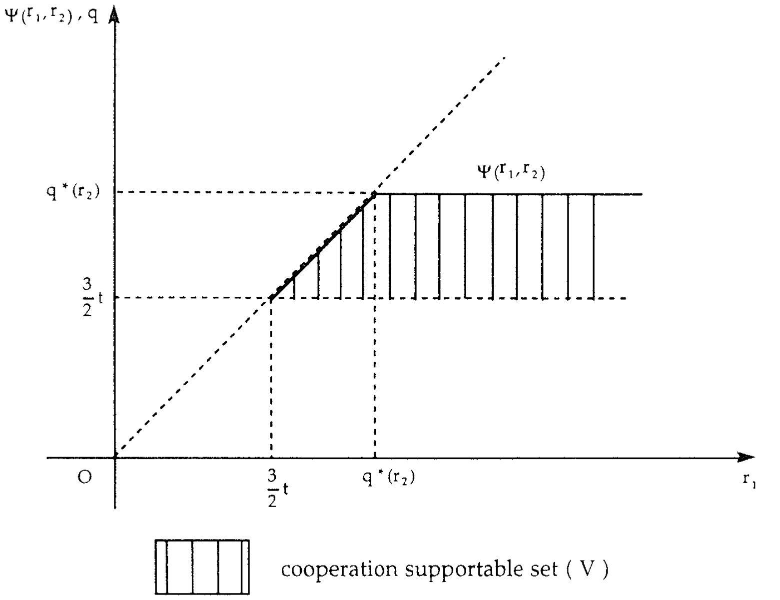
iii) $q^*(r_2)$ is independent of r_1.

It is worth noting that when one firm charges the punitive price and the other the accommodative price, the resulting outcome is Pareto efficient (with respect to the two firms). In other words, the equilibrium outcome of the stage game in the punishment phase is Pareto efficient. This contrasts sharply with the analysis of Friedman (1985). His sufficient conditions for a finitely repeated game to have a trigger strategy equilibrium require that payoffs prescribed by the equilibrium strategy profile be *not Pareto efficient* at the stage games in the punishment phase. In this case, the problem of renegotiation arises. In my model, however, there is no such problem as long as there is no possibility of side payments.

The following example for the linear transportation cost case illustrates the concepts and properties discussed above.



(a) The Case in Which r_1 Is Given.



(b) The Case in Which r_2 Is Given.

Fig. 3. Cooperation Frontier and Cooperation Supportable Set in the Case of Linear Transportation Cost Function.

EXAMPLE. Consider again the linear transportation cost function $f(d)=td$. Using (12), (13) and (14), we can derive the first stage market share of a deviating firm, a, and the corresponding mill price, p_a: $a=1/8+q/(4t)$ and $p_a=t/4+q/2$ for $q<\gamma=7t/2$, and $a=1$ and $p_a=-3t/2+q$ for $q\geq 7t/2$. First, suppose that $r_2\in(r', r^*]$. Then, by (9), the second stage market share of a deviating firm, b, is given by $b=1-r_2/(2t)$. We can compute the function $q^*(r_2)$ from the equation which is

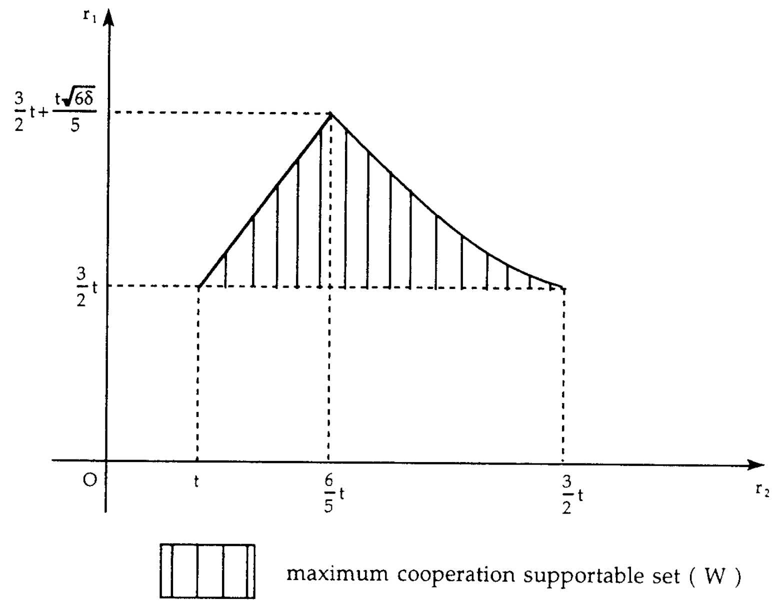


Fig. 4. Maximum Cooperation Supportable Set in the Case of Linear Transportation Cost Function.

obtainable by putting the equality to (15): $q^*(r_2)=3t/2+\sqrt{6\delta}(r_2-t)$ for $r_2 \in (r', r^*]$. It is (linearly) increasing in r_2. Second, suppose that $r_2 \in (r^*, r'')$. In this case, we get $b=r_2/(3t)$. The function $q^*(r_2)$ is given by

$$q^*(r_2)=\frac{3t}{2}+\frac{\sqrt{2\delta\{-8(r_2)^2+18r_2t-9t^2\}}}{3}$$

for $r_2 \in (r^*, r'')$. It is decreasing and convex at point $r_2=r''=3t/2$. In both cases, the market share, a, is given as an interior solution of the maximization problem, that is, cooperation of degree q with $q \geq \gamma = 7t/2$ is not supportable for any $(r_1, r_2) \in U$.

Thus, we have obtained the following cooperation frontier:

$$\Psi(r_1, r_2)=\begin{cases} \min\left[r_1, \dfrac{3t}{2}+\sqrt{6\delta}(r_2-t)\right] & \text{for} \quad r_2 \in (r', r^*] \\ \min\left[r_1, \dfrac{3t}{2}+\dfrac{\sqrt{2\delta\{-8(r_2)^2+18r_2t-9t^2\}}}{3}\right] & \text{for} \quad r_2 \in (r^*, r''). \end{cases}$$

Fig. 3 (a) and (b) show the cooperation frontiers as a function of r_2 given r_1 and as a function of r_1 given r_2, respectively. They also show the cooperation supportable set. Fig. 4 illustrates the maximum cooperation supportable set.

4. CONCLUDING REMARKS

In this paper, I have shown that collusion may appear if firms expect the future removal of trade barrier, analyzing a two-stage game which is based upon the spatial competition model with an outside good. Two properties of the game are responsible for this result: first, the equilibrium outcome in the first stage game is not Pareto efficient (with respect to the two firms), and second, in the second stage game, there are multiple equilibria and firms are not indifferent among the corresponding equilibrium outcomes. We have seen that these properties apply to the case in which the price of the outside good is declining but not to the case in which the price remains unchanged. This implies that collusion may evolve only when firms expect the future trade liberalization.

The analysis presented in the paper should be regarded as just a starting point. Obviously, we are urged to examine this finding in the light of observations in the real world. In addition, the setting of the model is very simple. For one thing, I have formalized the game in a way that the domestic firms end up exporting no product. Furthermore, the amount of the decline in the price of the outside good induced by the trade liberalization is assumed to be given and the same at all the locations in the home country. Those simplifications are made in order to focus the analysis on the strategic interaction between the domestic firms. The next step would, however, be to incorporate the strategic interaction not only among the domestic firms but also among the domestic firms and foreign firms.

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APPENDIX

PROOF OF LEMMA 1. The first order conditions for the profit maximization of the two firms are given by $x_i - p_i/A = 0$ $(i=1, 2)$ where $A \equiv f'(x) + f'(1-x)$. These equations, along with (1), yield the equation $A(1-2x) - f(x) + f(1-x) = 0$. By the assumptions on the function f, there is a unique solution, $x = 1/2$. The second order conditions are satisfied since

$$\frac{\partial^2(p_i x_i)}{\partial p_i^2} = -\frac{2}{A} - \frac{p_i[f''(x_i) - f''(x_{-i})]}{A^3},$$

which is negative at $x_i = 1/2$ $(i = 1, 2)$. Therefore, when a Nash equilibrium associated with the C regime exists, it is unique and given by $(p_1, p_2) = (f'(1/2), f'(1/2))$. Next, I prove the "only if" part. Suppose that there exists a unique Nash equilibrium associated with the C regime. Then, substituting the equilibrium prices just obtained to (1), we get (5). Finally, to prove the "if" part, suppose that we have (5). For $(p_1, p_2) = (f'(1/2), f'(1/2))$ and $x = 1/2$, both the first order condition and (1) are satisfied. QED

PROOF OF LEMMA 2. Because the left hand side of (6) is decreasing in z_i, there is at most one solution to it. The second order conditions are satisfied since

$$\frac{\partial^2(p_i z_i)}{\partial p_i^2} = -\frac{2}{f'(z_i)} - \frac{p_i f''(z_i)}{f'(z_i)^3} < 0 .$$

Therefore, when a Nash equilibrium associated with the M regime exists, it is unique and symmetric.

Next, I prove the "only if" part. Suppose that the statement is not true. That is, we have $r \geq r'$ when there exists an equilibrium associated with the M regime. Since $f(z_i) + z_i f'(z_i)$ is increasing in z_i and the first order condition must be satisfied, z_i must be greater than or equal to 1/2 at the equilibrium. This implies that $f(z_i) \geq f(1 - z_i)$. This contradicts (3) for $i = 1$ and (4) for $i = 2$ since $p_1 = p_2$ at the equilibrium.

Moreover, to prove the "if" part, I suppose that $r < r'$. Since $f(z) + zf'(z)$ is increasing in z and non-negative for $z \geq 0$, there exists some $z \in [0, 1/2)$ for which $r - f(z) - zf'(z) = 0$ is satisfied. We have $f(z) < f(1 - z)$ for such z. Then, $z_1 = z$ and $z_2 = z$ satisfy (3) and (4) for the equilibrium price given by $(p_1, p_2) = (zf'(z), zf'(z))$, respectively, as well as the first order condition, (6).

Finally, since

$$\frac{dp_i}{dz_i} = 1 \Big/ \frac{dz_i}{dr} - f'(z_i)$$

by (3) for $i = 1$ and by (4) for $i = 2$, we have

$$\frac{dp_i}{dr} = \frac{dz_i}{dr}\frac{dp_i}{dz_i} = \frac{f'(z_i) + z_i f''(z_i)}{2f'(z_i) + z_i f''(z_i)} > 0$$

where (6) is used. Thus, the equilibrium price is increasing in r. QED

PROOF OF LEMMA 3. What we must prove is that there is some y which satisfies (7) if and only if (8) holds. The "if" part is trivial: when (8) holds, we can choose 1/2 for y and have (7) satisfied. To prove the "only if" part, suppose that we have both $\alpha(y) \leq r$ and $\alpha(1 - y) \leq r$. If $y = 1/2$, we trivially have $\alpha(1/2) \leq r$. If $y > 1/2$, $\alpha(1/2) \leq r$ still holds since α is an increasing function. Finally, if $y < 1/2$, it must be the case that $1 - y > 1/2$. However, since $\alpha(1 - y) \leq r$, we again have $\alpha(1/2) \leq r$. The similar argument applies to the part involving function β. QED

PROOF OF PROPOSITION 1. Lemma 1 to Lemma 3 imply that there is a unique Nash equilibrium if $r \leq r'$ or $r \geq r''$. Now, the existence of an asymmetric equilibrium is, in this case, both necessary and sufficient for the existence of multiple equilibria. Therefore, it suffices to prove that there exists an equilibrium (p_1, p_2) with $p_1 \neq p_2$ if and only if (8) holds with both signs being strict inequalities. The "if" part is easy to prove. When (8) holds with both signs being strict inequalities, by continuity, there exists, at the neighborhood of 1/2, some $y \neq 1/2$ which satisfies (7). Therefore, an equilibrium (p_1, p_2) with $p_1 \neq p_2$ exists. For the "only if" part, suppose that (8) holds with at least one sign being an equality. On the one hand, consider the case in which $r = r'$. Then, $r < \alpha(1-y)$ for $y < 1/2$ and $r < \alpha(y)$ for $y > 1/2$. On the other hand, consider the case in which $r = r''$. Then, $r > \beta(y)$ for $y < 1/2$ and $r > \beta(1-y)$ for $y > 1/2$. Therefore, for any $y \neq 1/2$, (7) is not satisfied. Hence, (8) must hold with both signs being strict inequalities. QED

PROOF OF PROPOSITION 3.

i) The right hand side of (15) is positive for $r_2 \in (r', r'')$ since

$$\frac{\partial b[r_2 - f(b)]}{\partial b} = r_2 - f(b) - bf'(b) > 0$$

for $b < 1/2$. The left hand side of (15) approaches 0 when q goes to r''. Therefore, by continuity, there exists some q near r'' which satisfies both (15) and the condition $q > r''$. Consequently, $q^*(r_2) > r''$, which implies $\Psi(r_1, r_2) > r''$. Hence, $V \neq \varnothing$ for any $(r_1, r_2) \in U$.

ii) Note that

$$\frac{dr_2}{db} = -2f'(1-b) - (1-b)f''(1-b) < 0$$

and that $r_2 - f(b) - bf'(b) > 0$ since $b < 1/2$. Therefore,

$$\frac{dq^*(r_2)}{dr_2} = \frac{1 - 2b - 2(db/dr_2)[r_2 - f(b) - bf'(b)]}{2a - 1} > 0$$

for $q < \gamma$ and

$$\frac{dq^*(r_2)}{dr_2} = 2[1 - 2b - 2(db/dr_2)\{r_2 - f(b) - bf'(b)\}] > 0$$

for $q \geq \gamma$.

iii) It is obvious from (15). QED