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A Differentiated Oligopoly in Which Every Firm Welcomes Tougher Competition

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We offer an example in which increased competition (softening of product differentiation) increases the profit of all incumbent firms.

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1. Introduction

Increased market competition—defined as any exogenous factor that lowers equilibrium prices without shifting the scale of demand—is generally presumed to decrease profit. Here, "increased competition" could mean entry of new firms or softening of product differentiation. Some recent papers have qualified this presumption that increased competition harms profit, by offering examples in which increased market competition actually increases the profit of at least one incumbent firm …but not all incumbent firms. We offer an example in which increased competition (softening of product differentiation) does increase the profit of all incumbent firms.

Ishida et. al. (2011) present an asymmetric Cournot oligopoly model in which each firm has a constant marginal cost that it can lower by investing in R&D. When a firm with high marginal cost enters the market it can stimulate R&D investment by a low-cost firm by enough to increase the profit of that low-cost firm compared to the pre-entry equilibrium. However, incumbent firms with high marginal cost suffer losses. Mukherjee and Zhao (2009) show that entry by a Stackelberg follower with high marginal cost can increase the profit of the more efficient Stackelberg leader. Matsushima and Mizuno (2010) develop an example in which stronger upstream competition (introducing a rival into the upstream) actually increases the profit of an incumbent upstream firm. Correa-López (2007) shows that when downstream firms change from quantity competition to price competition, their prices fall but their profits can increase because the wage set by negotiation between the firm and its labor union becomes low. The upstream suppliers (the labor unions) are worse off in the end. Finally, Fanti (2013) analyses a duopoly model with partial cross ownership and wage negotiation between each firm and its labor union, and shows that profits of both firms can increase as their products become more homogenous, but again the upstream labor union is worse off. In all of these examples, increased competition benefits some firms. We offer an example in which it benefits all firms.

In our example, the profit of every firm in a vertical industry increases as the products become more homogenous. In the example, each of multiple manufacturers forms a differentiated final product by assembling *n* components that are provided from its own n independent suppliers. Each supplier produces a unique component and sells to only one of the manufacturers. The multiple manufacturers attain a product-differentiated Cournot oligopoly equilibrium. We will show that if the products are sufficiently homogeneous to begin with and the number of suppliers is large enough, then every firm—including manufacturers and suppliers—earns more profit as the final goods become more homogenous.

2. The Model

Suppose that $m (m \geqq 2)$ competing manufacturers i (=1,..,m) with the same Leontief technology, each obtains from its own suppliers the n components (inputs) needed to assemble a final product. Each supplier ij (j=1,...,n) provides a different component to manufacturer i. Each component is produced at zero marginal cost. No additional cost is required for production of the final goods.

The inverse demand function facing each manufacturer i is given by

$$p_i = a - q_i - b\sum_{h \neq i} q_h \,, \; i = 1, \dots, m; \; h = 1, \dots, n, \text{and } i \neq h, \tag{1}$$

where p_i stands for the price of good i, q_i is the supply of good i, the parameter $a > 0$ shows the market size, and $b \in (0,1)$ shows the degree of product differentiation.

We will consider the following game:

Stage 1: Each supplier ij sets its component price w_{ij}

Stage 2: Each manufacturer i, after observing the component prices of all suppliers—its own suppliers and those of its rivals—decides its output quantity q_i and purchases from its suppliers the components needed to produce such quantity. The outputs of the m manufacturers are sold at the market-clearing prices.

3. The Sub-game Perfect Equilibrium.

We derive the sub-game perfect equilibrium of the game by backward induction. In the second stage, given the component prices w_{ij}, each manufacturer i determines its supply q_i to maximize its profit

$$y_i = \left(a - q_i - b\sum_{h \neq i} q_h - \sum_j w_{ij} \right) q_i \tag{2}$$

where $\sum_j w_{ij} \equiv c_i$ is the marginal cost of manufacturer i. By the profit-maximizing condition, the equilibrium output of manufacturer *i* in the second-stage game is given by

$$q_i(\boldsymbol{w}) = \frac{(2-b)\left(a - \sum_j w_{ij}\right) + b\sum_{h\neq i}\sum_j w_{ij}}{(2-b)(2+b(m-1))}, \tag{3}$$

where $\boldsymbol{w}$ is the vector whose elements w_{ij} are the shipping prices of the *nm* component suppliers. One may interpret Eq. (3) as the derived demand facing the *n* suppliers of components to manufacturer *i*.

From (3), the derived demand function facing the *ij* component supplier, $q_i(w_{ij} : \boldsymbol{w}_{-ij})$ where $\boldsymbol{w}_{-ij}$ denotes the component price vector excluding w_{ij}, is negatively sloped with respect to w_{ij}. Moreover,

$$\frac{\partial^2 q_i}{\partial w_{ij}\partial b} = -\frac{b(4+b(m-2))(m-1)}{{D_0}^2} < 0, \tag{4}$$

where $D_0 = 2 + b(m-1) > 0$. As the final products become more homogenous, the slope of the derived demand becomes steeper. We also have that if marginal cost, $\sum_j w_{ij} = c_i$, is the same for all manufacturers *i* (a condition which is satisfied at sub-game perfect equilibria), then $\partial q_i/\partial b < 0$. Accordingly, as the final products become closer substitutes, the derived demand for components shifts downward and becomes more elastic at each price.

The equilibrium final price and profit of manufacturer *i* are as follows:

$$p_i(\boldsymbol{w}) = \frac{(2-b)a + (2-b^2)\sum_j w_{1j} + b\sum_{h\neq i}\sum_j w_{ij}}{4-b^2} \tag{5-1}$$

$$y_i(\boldsymbol{w}) = \frac{\left((2-b)a - \sum_j w_{ij} + b\sum_j w_{hj}\right)^2}{(4-b^2)^2} \tag{5-2}$$

In the first stage, anticipating the second-stage equilibrium, each supplier *ij* sets its component price w_{ij} to maximize its profit z_{ij}, given the component prices of the other suppliers

$$z_{ij} = w_{ij}q_i(\boldsymbol{w}) \quad j = 1, \ldots n$$

By the profit-maximizing condition, we obtain the reaction function of component supplier *ij*,

$$w_{ij}(\boldsymbol{w}_{-ij}) = \left\{(2-b)a + b\sum_{h\neq i}\sum_{j} w_{hj}\right\}/(4+2b(m-2)) - \sum_{j\neq i} w_{ij}/2\,. \qquad (6)$$

From (6), we find that the component price of each supplier is a strategic substitute for the component prices of the suppliers servicing the same manufacturer, while it is a strategic complement with the component prices of the suppliers servicing the rival manufacturers. We can infer that as the final goods becomes less differentiated (the market competition becomes tougher), each supplier reduces its component price:

$$\partial w_{ij}/\partial b = -\sum_{h}(a - \sum_{j} w_{hj})/(2+b(m-2))^2 < 0.$$

From the *nm* reaction functions similar to that of supplier ij shown by (6), we derive the perfect-equilibrium component price which is the same for every component supplied to every manufacturer:

$$w^* = \frac{(2-b)a}{D_1}, \qquad (7)$$

where $D_1 = b(m-1) + (2-b)(n+1) > 0$. The equilibrium values of other variables are

$$q^* = \big(2 + b(m-2)\big)a/(D_0 \cdot D_1) \qquad (8\text{-}1)$$

$$p^* = \big\{\big(2 + b(m-2)\big) + (2-b)(2 + bn(m-1))\big\}a/(D_0 \cdot D_1) \qquad (8\text{-}2)$$

$$c^* = nw^* = n(2-b)a/D_1 \qquad (8\text{-}3)$$

$$y^* = q^2 \qquad (8\text{-}4)$$

$$z^* = (2-b)\big(2 + b(m-2)\big)a^2/\big({D_0}^2 \cdot {D_1}^2\big) \qquad (8\text{-}5)$$

Each manufacturer's price-cost margin, $\theta^* = p^* - c^*$, is equal to its output, q^*.

4. Comparative Statics and Results

In this section, based on the comparative static analysis of the perfect equilibrium, we derive our main results.

By differentiating q^* and p^* with respect to the parameter, b, we find that as the goods become more homogeneous, the inverse residual demand for each final good, $p_i = (a - b\sum_{j\neq i} q_j) - q_i$, shifts downward and each manufacturer decreases its supply. Owing to the downward shift in demand, each component supplier decreases its price,

$\frac{\partial w^*}{\partial b} = -2(m-1)/{D_1}^2 < 0$, implying that the marginal cost of every manufacturer, c^*, also decreases. Moreover, we have

$$\frac{\partial^2 w^*}{\partial b^2} = \frac{4(m-1)(m-n-2)}{{D_1}^2} \lesseqgtr 0, \quad \text{iff } n \lesseqgtr m-2.$$

That is, when $n > m-2$, as b becomes larger, the component prices decrease by ever-increasing decrements, and so each manufacturer's marginal cost decreases by ever-increasing decrements. To put it another way, as b becomes larger (the products of differing manufacturers become more homogeneous), the vertical strategic effects become stronger. Here, "vertical strategic effect" means that as manufacturer i supplies less output, it induces suppliers of components to its rival manufacturers to raise their prices, increasing the marginal costs of the rivals. As b and n become large the vertical strategic effects become great enough to outweigh the horizontal strategic effects that are also present, and the price-cost margin θ^* increases. The horizontal strategic effect is that as a Cournot manufacturer supplies more output, its rivals react by suppling less output.

Differentiating the manufacturer price-cost margin θ^* with respect to b, we have

$$\frac{\partial \theta^*}{\partial b} = \frac{(m-1)b^2(m-2)(n-m+2) - 4(1-b)}{{D_1}^2}.$$

While the sign of $\frac{\partial \theta^*}{\partial b}$ is negative if $n<m-2$, in the case where $n>m-2$

$$\frac{\partial \theta^*}{\partial b} \gtreqless 0 \quad \text{iff} \quad b \gtreqless \frac{2}{n-m+2+n(n-m+2)^{1/2}} = b_0.$$

That is, $\theta^*(b)$ is a decreasing (increasing) function in the interval $b < b_0$ $(b > b_0)$, and attains its minimum value at $b = b_0$. Noting that $n > \frac{m^2}{m+2} \equiv n_0$ is needed for $b < 1$, we have

Lemma 1: If $n > n_0$, the equilibrium manufacturer price-cost margin function $\theta^*(b)$ is single-caved in the interval $b \in (0,1)$ and attains its minimum value at $b_o \in (0,1)$.

Noting that $q^* = \theta^*$ and $y^* = \theta^* q^*$, from Lemma 1, the equilibrium profit function y^* is also single-caved in the interval $b \in (0,1)$. Hence, the manufacturer's profit attains a maximum either at $b = 0$ or $b = 1$. Denoting the equilibrium profit with given b and n by $y^*(b,n)$, we have

$$\mathrm{y}^*(1,n) = \{\frac{ma}{(m+1)(m+n)}\}^2 > \{\frac{ma}{(m+1)(m+n)}\}^2 = y^*(0,n) \text{ if } n > m.$$

Therefore, the following proposition is established.

Proposition 1: When $b \geq b_0$, each manufacturer's profit increases as the goods become less differentiated. Moreover, when $b \geq b_0$ and $n > m$, the profit attains a maximum when the goods are completely homogeneous, $b = 1$.

Next, we examine the profits of the suppliers. Differentiating each supplier's profit z with respect to b, we have

$$\frac{\partial z^*}{\partial b} = \frac{(m-1)g(b,n)}{{D_0}^2{D_1}^3},$$

where $g(b,n) =$

$$(2-b)b\big(4+b(m-2)\big)n + b(m-2)\Big(2\big((5-b)b-8\big) - (4-b)m\Big) - 16.$$

Notice that $g(b,n)$ is a cubic polynomial in b, its third-degree coefficient is negative, and $g(0,n) = -16 < 0$. Hence, if $g(1,n) > 0$, there is only one root, b_1, in the interval $b \in (0,1)$. A sufficient condition for $g(1,n) > 0$ is $n > n_1 \equiv m(3m+2)/(m+2)$.

Lemma 2: If $n > n_1$, the equilibrium profit function z^* is single-caved in the interval $b \in (0,1)$ and attains its minimum at $b_1 \in (0,1)$.

Consider the case in which the goods are sufficiently homogeneous. Each supplier reduces its component price a bit as b increases. When in this case there are many suppliers, each manufacturer's marginal cost, $c^* = nw^*$, decreases with b. This induces each manufacturer to increase its output (increase the derived demand facing each component supplier), implying that each component supplier's profit, $z^* = w^*q^*$, also increases. Denoting the equilibrium component supplier's profit with given b and n by $z^*(b,n)$, we have

$$z^*(1,n) = \frac{m}{(m+1)(m+n)2} > \frac{(n+1)^2}{2} = z(0,n), \text{ if } n > n_2 \equiv m + (2m^2+2m)^{1/2}$$

Then we obtain

Proposition 2: When $n > n_1$ and $b \geq b_1 \in (0,1)$, each component supplier's profit increases as the goods become less differentiated. If in this situation, $n > n_2$, and the component supplier profit attains its maximum when the goods are completely homogeneous, $b = 1$.

Here, we will show that $b_1 > b_0$ holds. Suppose not, i.e. suppose $b_0 \geqq b_1$. Then, $\partial y(b_1)/\partial b \leqq \partial y(b_0)/\partial b = 0$ holds. Because $\partial z/\partial b = (\partial w/\partial b) \cdot q + (\partial z/\partial b) \cdot \mathrm{w}$, we have

$$0 = \partial z(b_1)/\partial b = (\partial w(b_1)/\partial b) \cdot q + (\partial q(b_1)/\partial b) \cdot w < 0, (\because\ \partial w(b_1)/\partial b < 0)$$

which results in contradiction.

Finally, we establish our main result.

Proposition 3: Suppose that the number of component suppliers is larger than $\max\{n_1, n_2\}$. When $b \geq b_1$, as the goods becomes less differentiated, $b \to 1$, the profit of every manufacturer and of every supplier increases. Moreover, the profit of each agent is maximal when the goods are completely homogeneous, $b = 1$.

Note that $n > n_1$ is a sufficient condition but not a necessary condition for the existence of an interval for which $\partial z^*/\partial b > 0$. When $g(1, n) < 0$, there is no root in the interval $b \in (0,1)$, or there are two roots, b_1 and b_2. In the former case $\partial z^*/\partial b < 0$ in the interval $b \in (0,1)$, and in the latter case $\partial z^*/\partial b > 0$ in the interval $b \in (b_1, b_2)$.

4. Concluding Remarks

Increased competition means anything that lowers price while holding the scale of demand unchanged. A widely held presumption is that increased competition lowers the profits of at least some incumbent firms. We have constructed an example in which, on the contrary, increased competition—meaning reduced product differentiation—increases the profit of every incumbent upstream and downstream firm in a symmetric Cournot oligopoly supplied by independent producers of components. This seems to be the first example in the literature in which all incumbent firms welcome greater competition.

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