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EXCESS INFORMATION AND THE TRAGEDY OF THE COMMONS

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Abstract: We consider the situation of suppliers' providing excessive information, and show that when excessive information bores consumers and discourages them from searching for and buying goods, both price and total welfare decline when a new producer enters the market.

Key words: Information pollution, catalog sales, tragedy of the commons.
JEL Classification Number: C72, D62, L13.

1. INTRODUCTION

In this paper, we consider the model of oligopolistic competition with **information pollution**. Our model treats a situation in which the cost for consumers to search a good increases when suppliers' advertising increases. We assume that the search cost for consumer depends linearly on the amount of advertisements, and derive that an increase in the number of firms leads to a decrease in both the price and the total surplus. In particular, a monopoly improves the total surplus compared with the competitive situation, although the price behaves as in the usual model (Hicks (1939)).

There have been numerous studies focusing on the effect on entry in an oligopolistic situation. Suzumura (2012) provides a detailed survey of 'excess entry' results first proposed by Suzumura and Kiyono (1987).[1] The difference between their results and those in this paper is as follows. First, in their models, the source of the social cost of entry is the fixed entry cost. In contrast, there is no entry cost in our model, and the search cost for the catalog is introduced. Second, in their model, the optimal number of firms depends on the fixed entry cost. In contrast, in our model, monopoly is always optimal.

This theory is also categorized as a theory of **advertisement**. In our model, advertisements are simply a variable of the utility function. There are many ways to treat advertisements, and it is sometimes seen as one that causes radical changes in people's

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[1] A simplified version is found in Chapter 10 of Kajii and Matsui (2000).

preference (see Bagwell (2007)). The motivation to treat advertisements as described above is to simplify the model. However, other treatments may be also useful for analyzing the information pollution situation. Note that we explain the source of the power of advertisements: that is, we explain the consumer's preference change **because** a thicker catalog causes consumers spend more time seeking goods, and thus too much information will bore the consumer. This differs from other general models of advertisement.

The main result is given in Section 2.

2. MODEL AND RESULT

Consider a two-stage game. In the first stage, N suppliers[2] simultaneously determine the thickness of the catalog $q_n \geq 0$ and price function $p_n : [0, q_n] \to \mathbb{R}_+$.[3] Note that q_n does not imply q_n units of a certain commodity, but q_n different commodities, and therefore the thickness of the catalog q_n also refers to the number of commodities cataloged. In the second stage, one consumer chooses an action for each commodity from "search and buy" or "not buy". Let H^n be a subset of $[0, q_n]$ such that $x \in H^n$ means that the consumer buys commodity x from producer n. Therefore, the strategy of producer n is to choose a real number $q_n \geq 0$ and a nonnegative measurable function $p_n : [0, q_n] \to \mathbb{R}_+$, and the action of the consumer is to choose a measurable subset $H^n \subset [0, q_n]$ for any $n = 1, \ldots, N$.

If the consumer buys a good, he/she gains $u > 0$. However, to find this good in a catalog, the consumer must pay a search cost $c_0(q) = a_0 + b_0 q$, where q denotes the total thickness of the catalog. This q is the same as $\sum_n q_n$: if the consumer wants to buy a good, he/she must struggle to search for this good in a pile of catalogs, and thus the consumer's total effort depends on the sum of the thicknesses of the catalogs. We assume that $a_0 \geq 0, b_0 > 0$. If the consumer chooses to buy, his/her payoff from this commodity is $u - p_n(x) - c_0(\sum_k q_k)$. Therefore, the consumer's total payoff is

$$\sum_n \int_{H^n} \left(u - p_n(x) - c_0\left(\sum_k q_k \right) \right) dx \,. \tag{1}$$

The payoff for supplier n is

$$\int_{H^n} p_n(x) dx - b_1 q_n \,, \tag{2}$$

where $b_1 q_n$ denotes the sum of the costs of production and of the catalog. We assume $b_1 > 0$.

Our main interest is the case where catalog sales are effective. Hence, we assume that

$$u > a_0 + b_1 \,, \tag{3}$$

We define the total surplus of this model as the sum of the payoffs of all players.

[2] Hereafter, n represents a typical supplier.

[3] We assume that all commodities made by a producer are cataloged. Notably, the result does not change even if we relax this assumption.

Proposition. The set of subgame-perfect Nash equilibria (SPE) of this game is non-empty. In any SPE of this game, $q_n = \frac{u-a_0-b_1}{(N+1)b_0}$ and $p_n(x) = \frac{1}{N+1}(u - a_0) + \frac{N}{N+1}b_1$ for almost all $x \in [0, q_n]$, and $\lambda(H^n) = q_n$ for all n and every supplier who takes (q_n, p_n), where λ is the Lebesgue measure. Every supplier gains $\frac{(u-a_0-b_1)^2}{(N+1)^2 b_0}$, and the consumer gains 0.

Remarks. In the SPE, $p_n(x)$ is a constant function for almost all goods, and for almost all x, $u = p_n + c_0(\sum_n q_n)$. This means that the catalog is the thickest one from which consumer can buy. Therefore, consumer's payoff becomes zero, and the total surplus is simply the sum of suppliers' profits.

Because $u - a_0 > b_1$, p_n decreases as N increases. However, the total surplus $\frac{N}{(N+1)^2}\frac{(u-a_0-b_1)^2}{b_0}$ also decreases as N increases. Therefore, the monopoly has the highest total surplus, and the competition has the lowest one, while, as usual, the price of the latter is less than that of the former.

The key idea in this proposition is as follows. If a supplier catalogs his/her product, the catalog thickness increases and consumers' purchase motivation decreases. This implies that consumers tend not to buy the products of other suppliers, and triggers a price down. This situation resembles the "tragedy of the commons", where the grass of the commons is the motivation of consumers.

Proof. First, consider a strategy profile in which $q_n = \frac{u-a_0-b_1}{(N+1)b_0}$, $p_n(x) = \frac{1}{N+1}(u - a_0) + \frac{N}{N+1}b_1$, and $H^n = \{x \in [0, q_n] | u - p_n(x) - c_0(\sum_m q_m) \geq 0\}$. We will show that this strategy profile is an SPE.

The choice of (H^n) is clearly a best response in any subgame. Therefore, it suffices to show that above q_n and $p_n(x)$ is a best response of supplier n. Because $u - p_n(x) - c_0(\sum_m q_m) = 0$, this supplier can gain $\frac{(u-a_0-b_1)^2}{(N+1)^2 b_0} > 0$ by obeying the strategy $(q_n, p_n(x))$. Suppose that $(q_n', p_n'(x))$ is another strategy of n, and K^n is the response of the consumer to this new strategy. Then, $p_n'(x) \leq u - c_0(q_n' + \sum_{m\neq n} q_m)$ on K^n. If $c_0(q_n' + \sum_{m\neq n} q_m) \geq u - b_1$, then the payoff of n is,

$$\begin{aligned}
&\int_{K^n} p_n'(x)dx - b_1 q_n' \\
&\quad \leq \int_{K^n} p_n'(x)dx - b_1\lambda(K^n) \\
&\quad = \int_{K^n} (p_n'(x) - b_1)dx \\
&\quad \leq 0\,,
\end{aligned}$$

and thus, his/her payoff cannot exceed 0. If $c_0(q_n' + \sum_{m\neq n} q_m) < u - b_1$, then the payoff of n is

$$\int_{K^n} p_n'(x)dx - b_1 q_n'$$

$$\leq \int_{[0,q'_n]} (u - c_0(q'_n + \sum_{m \neq n} q_m) - b_1) dx$$
$$= q'_n \left(u - b_1 - a_0 - b_0 q'_n - b_0 (N-1) \frac{(u - a_0 - b_1)}{(N+1) b_0} \right)$$
$$= -b_0 \left(q'_n - \frac{(u - a_0 - b_1)}{(N+1) b_0} \right)^2 + \frac{(u - a_0 - b_1)^2}{(N+1)^2 b_0},$$

which implies that his/her payoff cannot exceed $\frac{(u-a_0-b_1)^2}{(N+1)^2 b_0}$. These imply that $(q_n, p_n(x))$ is actually the best response. Hence, this strategy profile is an SPE.

Conversely, suppose that $((q_n, p_n(x))_n, (H^n)_n)$ is an SPE.

First, suppose $u - c_0(\sum_n q_n) < b_1$. Then, we can find a supplier m with $q_m > 0$. However, in this case, $p_m(x) < b_1$ for almost all $x \in H^m$, because if $p_m(x) \geq b_1$ with a positive measure, then the consumer gains by changing H^m, which contradicts the SPE assumption. Then, the payoff of supplier m must be less than zero. In contrast, if supplier m deviates to the strategy to $q'_m = 0$ and $p'_m(x) \equiv 0$, then his/her payoff is equal to zero, a contradiction. Hence, we have $u - c_0(\sum_n q_n) \geq b_1$.

Second, suppose $u - c_0(\sum_n q_n) = b_1$. Then, we can find a supplier m with $q_m > 0$. Again in this case, $p_m(x) \leq b_1$ for almost all $x \in H^m$, and thus his/her payoff must be less than or equal to zero. However, if he/she chooses $q'_m = \frac{q_m}{2}$ and set $p'_m(x) \equiv p \in]b_1, u - c_0(q'_m + \sum_{n \neq m} q_n)[$, then he/she can gain a positive payoff, a contradiction. Therefore, we have $u - c_0(\sum_n q_n) > b_1$.

Third, suppose that $q_m = 0$ for some m. Then, the payoff of supplier m is zero. If m chooses a sufficiently small $q'_m > 0$ and $p'_m \equiv p \in]b_1, u - c_0(\sum_{n \neq m} q_n + q'_m)[$, then the payoff of supplier m becomes positive, a contradiction. Therefore, we have $q_n > 0$ for any n.

Fourth, suppose that $\lambda(H^m) < q_m$ for some m. Define $p'_m(x) = \max\{p_m(x) - \varepsilon, 0\}$ on H^m and $p'_m(x) = p$ on $[0, q_m] \setminus H^m$, where $p \in]b_1, u - c_0(\sum_n q_n)[$ and $\varepsilon > 0$ is so small that $(p - b_1)(q_m - \lambda(H^m)) > \varepsilon \lambda(H^m)$. Then, m gains by choosing $q_m, p'_m(x)$, a contradiction. Therefore, $\lambda(H^n) = q_n$ for all n.

Hence, we have that $q_n = \lambda(H^n) > 0$ for all n. Suppose that $\lambda(\{x \in [0, q_m] | p_m(x) < u - c_0(\sum_n q_n)\}) > 0$ for some m. This implies that $\lambda(\{x \in [0, q_m] | p_m(x) < u - c_0(\sum_n q_n) - \frac{1}{M}\}) > 0$ for sufficiently large $M \in \mathbb{N}$. Choose any $p \in]u - c_0(\sum_n q_n) - \frac{1}{M}, u - c_0(\sum_n q_n)[$ and define $p'_m(x) = p$ if $p_m(x) < u - c_0(\sum_n k_n) - \frac{1}{M}$ and $p'_m(x) = p_m(x) - \varepsilon$ otherwise. Then, for any sufficiently small $\varepsilon > 0$, $p'_m \geq 0$ and m gains by choosing $q_m, p'_m(x)$, a contradiction. Therefore, we have that $p_n(x) = u - c_0(\sum_m q_m)$ for all n and almost all $x \in [0, q_n]$.

Finally, if $q_m \neq \frac{u - b_1 - c_0(\sum_{n \neq m} q_n)}{2b_0}$ for some m, then this supplier can gain by choosing $q'_m = \frac{u - b_1 - c_0(\sum_{n \neq m} q_n)}{2b_0}$ and $p'_m \equiv u - c_0(\sum_{n \neq m} q_n + q'_m) - \varepsilon$, where $\varepsilon > 0$ is sufficiently small, a contradiction. Hence, $q_m = \frac{u - b_1 - c_0(\sum_{n \neq m} q_n)}{2b_0}$ for all m. These linear equations have a unique solution: that is, $q_n = \frac{u - a_0 - b_1}{(N+1) b_0}$ for all n. This completes the proof. ■

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