



# The competition of investments for endogenous transportation costs in a spatial model

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## ABSTRACT

This paper proposes a two-stage spatial duopoly model to explore how the firms improve the value of product by service enhancement. In the model, we assume that the higher service ability means lower transportation cost. The results show that when two private firms participate in competition, no firm tends to invest more under the profit-maximizing objection. But when one is a public firm, the private firm may participate in competition with better service and higher price relative to the public one.

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## 1. Introduction

Ever since Hotelling (1929) introduced the spatial competition model, there has been a long debate in the literature about how much firms will differentiate their products. Most of the papers focused on models where the transportation costs are treated as exogenous. That is, the firms have no right to change. But Von Ungem-Sternberg (1988) firstly assumed the transportation costs as an endogenous variable. Hendel and Figueiredo (1997) provided a model wherein the firms can choose the degree of transportation costs. They choose the lower transportation cost means choose the popularization strategy, otherwise, means the strategy they chose is more specialized. Because the consumers pay the transportation cost, the firm reduces the transportation cost of the product will attract more consumers which means adding the value of the product. Furthermore, the pre and post-sale services may bring about the change of transportation cost, so, services can be seen as the main reason of the production differences. Firms provide more services to enhance the competition of the product to earn more markets or value, this phenomenon can be defined as Service Enhancement (e.g., Berger and Lester, 1997; Gann and Salter, 2002). From the view of the consumers, the service can satisfy the consumers' diverse demands.

In our model, the ability of the service is reflected in the change of transportation cost, a lower transportation cost means higher service ability. But the high service ability needs investment. For example, purchase of equipment, staff training, etc. So we assume an investment function to reflect the change of transportation cost and investment.

Relative studies have been appeared (i.e., Ishibashi, 2001; Ma and Burgess, 1993; Matsumura and Matsushima, 2004, 2007).

On the other hand, most of the classical Hotelling type studies adopt a location-price two-stage game. In the first stage, the firms choose locations simultaneously, in the second stage, they simultaneously choose their prices. Under this assume, they regard the price choice as a short-term strategy and location choice as a long-term strategy. But in the real world, we observe cases that the location change needs more fixed investments and longer construction cycle, so, we assume that the location of the firm is fixed.

In our model, we study a subgame perfect equilibrium in a two-stage game. In the first stage, the two firms simultaneously choose an investment to improve the service by changing the transportation cost. In the second stage, the two firms simultaneously choose a price competition. The result is that no firm tends to invest more under the profit-maximizing objection.

We also considered the extension of the above model which has two firms in the market; one firm has only one plant in the center of the market while another has two plants located at the two terminals of the linear market. Pal and Sarkar (2002) analyze the spatial Cournot competition among multi-store firms. The result is similar to the initial model.

Another extension is a mixed duopoly competition model. In real life, public firms and partial public firms exist and compete with private firms in many regions, such as education, health care, broadcasting, telecommunications, etc. In Hotelling-type spatial competition, there also exist relative results, for example, Cremer et al. (1991) studied the market location problem in public enterprise in linear market and Matsushima and Matsumura (2003) studied the sequential-move games. We investigate where a partial public firm competes against a profit maximizing private firm. The result is opposite to the competition between the two private firms, that is private firm will participate in

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competition with better service and higher price relative to the public one.

**2. The model**

We study a Hotelling-type linear city model. Consumers are uniformly distributed along the unit interval market [0,1]. The location of each consumer is denoted by  $x \in [0,1]$ . There are two firms that supply a physically homogenous good to the market. We assume that the marginal costs are zero. Firm 1 locates at the left extreme  $\alpha_1 = 0$  while firm 2 locates at the right extreme  $\alpha_2 = 1$ , i.e., we assume maximal differentiation and do not consider location choices. A consumer living at point  $x$  pays a transportation cost of  $t_i|x - a_i|$  when purchasing the product of firm  $i$ , where  $t_i$  is transport rate. The disutility of transportation yields a measure of consumers' taste for the good. Firms that decrease  $t_i$  can be realized from an improve service quality. The net surplus of a consumer located at  $x$  when buying from firm  $i$  is given as  $u_x^i = v - p_i - t_i|x - a_i|$ , where  $p_i$  is the firm's market price, and  $v$  is the gross consumer surplus, that is, the reservation price that a consumer is willing to pay for the good. We assume that  $v$  is sufficiently large that each consumer purchases one unit of the product.

Then we consider the following scenario. In order to enhance the market competitiveness, firms may invest in 'service quality'.  $t_i$  captures the service quality by the firm. We assume that the initial state is  $t_i^0 = t$  ( $i = 1,2$ ).  $t_i$  depends on firm  $i$ 's investment  $f(t_i)$  which can be viewed as an irreversible investment in transportation-reducing R&D, for example, purchase of equipment, staff training, etc. We assume that  $f(t_i) = \lambda(t - t_i)^2$ .

We define the indifferent consumer, when unique, as  $\bar{x}$  such that:  $p_1 + t_1x = p_2 + t_2(1 - x)$ , this yields:

$$\bar{x} = \frac{p_2 - p_1 + t_2}{t_1 + t_2} \tag{1}$$

When  $0 \leq \bar{x} \leq 1$ , the demand functions are, respectively:

$$D_1 = \bar{x}, D_2 = 1 - \bar{x} \tag{2}$$

Since there are no production costs, firm  $i$ 's profit is:

$$\pi_i = p_i D_i - f(t_i) = \frac{p_i(p_j - p_i + t_j)}{t_i + t_j} - \lambda(t - t_i)^2, \quad (i \neq j, i = 1, 2) \tag{3}$$

In the spirit of Hotelling, we study a subgame perfect equilibrium in a two-stage game. In the first stage, the two firms simultaneously choose  $t_i$  ( $i = 1, 2$ ) which means the service quality is the firm's choice. In the second stage, the two firms simultaneously choose price,  $p_i \in [0, \infty)$ . The solution concept is a subgame perfect equilibrium through a backward induction.

In the second stage, with fixed  $t_1, t_2$ , the first order condition is:

$$\frac{\partial \pi_i}{\partial p_i} = 0 \Leftrightarrow \frac{p_j - 2p_i + t_j}{t_i + t_j} = 0, \quad (i \neq j, i = 1, 2) \tag{4}$$

which yields the following Bertrand-Nash equilibrium prices:

$$p_i(t_1, t_2) = \frac{t_i + 2t_j}{3}, \quad (i \neq j, i = 1, 2) \tag{5}$$

Substituting prices (5) to (1), we obtain the market demands of the two firms as:

$$D_i(t_1, t_2) = \frac{t_i + 2t_j}{3(t_i + t_j)}, \quad (i \neq j, i = 1, 2) \tag{6}$$

Substituting prices (5) and market demands (6) to (3), we obtain:

$$\pi_i(t_1, t_2) = \frac{(t_i + 2t_j)^2}{9(t_i + t_j)} - \lambda(t - t_i)^2, \quad (i \neq j, i = 1, 2) \tag{7}$$

In the first stage, firm 1 maximizes  $\pi_1(t_1, t_2)$  w.r.t.  $t_1$ , while firm 2 maximizes  $\pi_2(t_1, t_2)$  w.r.t.  $t_2$ .

Notice that  $\frac{\partial \pi_i}{\partial t_i} = \frac{t_i(t_i + 2t_j)}{9(t_i + t_j)^2} + 2\lambda(t - t_i) > 0$ . This shows that the greater  $t_i$ , the greater  $\pi_i$ , so no firm has an incentive to improve service capacity. We obtain the equilibrium levels of  $D_1, t_1$  and  $t_2$  in the two-stage game as follows:

$$D_1 = \frac{1}{2}, \quad t_1 = t_2 = t, \quad p_1 = p_2 = t. \tag{8}$$

In summary, we have:

**Proposition 1.** No firm is willing to invest in transportation-reducing R&D in the equilibrium.

The intuition of Proposition 1 is that if one firm invests to enhance the service, its rival will reduce their price to attract the consumers, which will intensify the competition. For firm 1, the payoff is lower than before; the action is cutting off your nose to spite your face. So no firm tends to invest to enhance the service.

We discuss the subgame perfect equilibrium in a two-stage game. Another question naturally arises: What are the optimal investments in the presence of externality? The social surplus,  $S$ , which is the consumer surplus plus the firms' profits, are defined by:

$$S = v - t_1 \int_0^1 x dx - t_2 \int_{D_1}^1 (1-x) dx - f(t_1) - f(t_2) \tag{9}$$

The welfare-maximizing social planner maximizes (9) w.r.t.  $D_1, t_1$  and  $t_2$ . The first-order conditions are:

$$\frac{\partial S}{\partial t_1} = -\frac{1}{2} D_1^2 + 2\lambda(t - t_1) = 0, \tag{10}$$

$$\frac{\partial S}{\partial t_2} = -\frac{1}{2} + D_1 - \frac{1}{2} D_1^2 + 2\lambda(t - t_2) = 0 \tag{11}$$

$$\frac{\partial S}{\partial D_1} = -D_1 t_1 + t_2 - D_1 t_2 = 0. \tag{12}$$

Solving these equations simultaneously, we obtain the optimal levels of  $D_1, t_1, t_2$  and  $f$  as

$$D_1^{opt} = \frac{1}{2}, \quad t_1^{opt} = t_2^{opt} = t - \frac{1}{16\lambda}, \quad f^{opt}(t_1) = f^{opt}(t_2) = \frac{1}{16\lambda} \tag{13}$$

**Proposition 2.** Supposing there is a market regulator between the firms. The market share of the two firms is equal and the optimal investment is inversely proportional to  $\lambda$ .

**3. The first extension of the model**

Suppose there are two firms in the market, firm 2 has only one store which is located in the center of the market, i.e.,  $\alpha_2 = \frac{1}{2}$ , while firm 1 has two stores which are located at the two terminals of the market. Let  $\alpha_{1,j}$  denote the location of private firm 2's store  $j$  ( $j = 1,2$ ), i.e.,  $\alpha_{1,1}, \alpha_{1,2} = 1$ . All the other conditions and timing of the game stay the same.

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