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Additional Transportation Costs benefit Consumer Surplus and Social Welfare in a Bilateral Duopoly

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Abstract

This paper examines the location selection by retailers in a bilateral duopoly. We suppose that the location is unconstraint. We compare two cases. One case is that each retailer incurs its transportation costs in order to purchase goods from its manufacturer. Another case is that it does not pay the transportation costs. Our conclusions are two. One is that both retailers locate inside the city, when retailers incur the transportation costs. The other is that consumer surplus and social welfare is larger under retailers' paying transportation costs than under retailers' no-paying transportation costs.

JEL classification numbers: D21, L13, R39

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1 Introduction

Spatial differentiation can be used in oligopolistic market as a means of softening the competition and gaining the market power. Since the pioneering contribution of Hotelling (1929), there are two standard location-price models of a linear city.[3] One restricts the locations of firms within the linear city.[4] Another does not restrict the locations of firms within the linear city (Tabuchi and Thisse, 1995, Lambertini, 1997, Li and Shuai, 2017). The latter literature shows that, under a uniform distribution and quadratic transportation costs, firms choose to locate outside the market. It reflects the fact that the price-location competition under quadratic transportation costs is extremely intense, inducing firms to

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[3] Hotelling model is used in a case where consumers are heterogeneous. In other word, each consumer has a different preference for the brands sold in the market.

[4] See d'Aspremont et al. (1979) and Meza and Tombak (2009) for details. Especially, Meza and Tombak (2009) analyze the location problem under Stackelberg model.

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set up far apart from each other.

However, in reality, most of commercial facilities tend to be located densely in central business districts of cities. Matsumura and Matsushima (2012) also claim that locating in central business district of commercial facilities is effective for consumers who do not own individual means of transportation. The motivation of this paper is theoretically to analyze whether firms can choose to locate inside the city or not.

This paper studies a three-stage game in a bilateral duopoly in which each upstream firm sells its product through its separated downstream firms. As Li and Shuai (2017), each upstream firm sets the wholesale prices and each downstream firm sets the location and retail prices in sequence. We compare two cases. One case is that the downstream firms incur their transportation costs in order to purchase goods from its upstream firm. Another case is that they do not bear the transportation cost. From the viewpoint of downstream firms, we show a trade-off between competition and transportation cost. If there are no transportation costs, they choose to locate outside the city in order to mitigate the competition between them. However, if they incur the transportation, they choose to location inside the city in order to decrease the transportation. Conventional wisdom suggests that if the locations of firms is not restricted within the city, firms choose to locate outside the city. Our conclusion is remarkable different from the conventional results of Tabuchi and Thisse (1995), Lambertini (1997), Li and Shuai (2017). Differently from Tabuchi and Thisse (1995) and Lambertini (1997) that equilibrium locations are given by (x_a, x_b)=$(-1/4, -5/4)$[5], we analyze a vertically related market in which each manufacturer exogenously located in the center of the city and each retailer pays the transportation costs in order to purchase a goods from its exclusive manufacturer. So, from the viewpoint of each retailer, the closer it locates from its manufacturer, the smaller its transportation costs are. Li and Shuai (2017) is similar to our model in the context of a vertically related market. However, they assume that each upstream firm locates outside the city and no transportation costs for downstream firms. In our model, there are two opposing forces governing the choice of location. From the standpoint of each downstream firm, by moving closer to its exclusive upstream firm, the firm will gain the lower marginal costs. This is the marginal cost effect, which is centripetal force in our model. The downside of moving closer to the center of the city is that price competition between downstream firms becomes more intense. This is the competition effect, which is the centrifugal force in our model. Consequently, the competition effect is overwhelmed by the marginal cost effect. This paper also shows that both consumer surplus and social welfare are higher under transportation costs than under no transportation costs. This result is sharply surprising from the point that the additional costs of firms will decrease the consumer surplus and social welfare.

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[5] If the firms' location choices are restricted to the interval $[0, 1]$, we would have equilibrium locations at the endpoints, as d'Aspremont et al. (1979).

The remainder of the paper is organized as follows. In Section 2, we set up the model. Section 3 analyses two models. Finally, Section 4 concludes.

2 The Model

In this section, we describe the basic notation and common elements of the model to be examined in the remainder of the paper. Consider a two-tier market in which each manufacturer produces a consumer good at constant marginal cost c. Its exclusive retailer sells it to consumers. Following much of the literature on vertical market structure, we do not allow for cross supply.[6] Consumers are uniformly distributed over a linear city, which is represented by a unit interval $[0, 1]$. The location of each consumer is uniformly distributed over a linear city, which is represented by a unit interval $x \in [0, 1]$. Without loss of generality, we assume that the locations of manufacturers are given and located at the center of the linear city. Denoting each retailer's location as $x_i, i = a, b$, we have $x_i \in [-\infty, \infty]$ in the unconstrained model. For simplicity, we assume that the transportation cost identically incurred by both consumers and retailers. It is assumed to be a quadratic function of distance.[7]

Given the retailers' locations and prices, when a representative consumer who is located at x purchases from retailer i, she enjoys an indirect utility of

$$U_i = V - p_i - t(x - x_i)^2, \tag{1}$$

where V is the consumer's reservation utility, p_i is retailer i's price, and t is the parameter of the transportation cost.

Each consumer purchases one unit of good from either retailer. We assume that V is sufficiently large, so that all consumers purchase the good in equilibrium (i. e., covered market). Given the retailers' locations and prices, the marginal consumer, who is indifferent between purchasing from either retailer, is given by[8];

$$\hat{x} = \frac{p_b - p_a + t(x_b^2 - x_a^2)}{2t(x_b - x_a)}, \tag{2}$$

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[6] Exclusive dealing is widely used in industries including fast food chains, franchise and gasoline. It has been an important topic in the antitrust literature. It is a common assumption in the literatures (e.g., Mcguire and Staelin 1983; Bonanno and Vickers 1988; Rey and Stiglitz 1995).

[7] For the quadratic transportation cost, see d'Aspremont et al. (1979) and Tirole (1988), and Tabuchi and Tisse (1995). The quadratic transportation cost ensures that there exists a pure strategy equilibrium in the location-price game.

[8] There exists a consumer $\hat{x} \in [x_a, x_b]$ who is indifferent between two products. The indifferent consumer is given by $V - p_i - t(\hat{x} - x_a)^2 = V - p_j - t(\hat{x} - x_b)^2$. We can solve for $\hat{x}$ and obtain Eq. (2).

Without loss of generality, we assume that retailer a is located to the left of the center and retailer b is located to the right of the center. For $x_b > x_a$, retailer a and b's profits of both with and without transportation cost are, respectively, described as follows:

$$\pi_a = \left[p_a - w_a - t\left(\frac{1}{2} - x_a\right)^2\right]\hat{x},\ \pi_b = \left[p_b - w_b - t\left(x_b - \frac{1}{2}\right)^2\right](1-\hat{x}), \quad (3\text{-}1)$$

$$\pi_a = [p_a - w_a]\hat{x}, \qquad \pi_b = [p_b - w_b](1-\hat{x}), \quad (3\text{-}2)$$

where w is the wholesale price.

On the other hand, manufacturer a and b's profits are, respectively, described as follows:

$$\Pi_a = [w_a - c]\hat{x},\ \Pi_b = [w_b - c](1-\hat{x}). \quad (4)$$

We posit a three-stage game. At stage 1, each manufacturer chooses its wholesale prices (w_a, w_b). At stage 2, each retailer sets its locations $[x_a,\ x_b]$. Finally, at stage 3, each retailer chooses its prices (p_a, p_b). We solve a sub-game perfect Nash equilibrium (SPNE) through backward induction.

In our model which both firms set the wholesale-location-price competition simultaneously, we assume uniformly distributed consumers and quadratic transportation costs which is the standard Hotelling model. In reality, the consumers may be distributed asymmetric and firms may decide their strategic variables sequentially.

3 Analysis

In this section, we analyze two cases. One is that each retailer incurs its transportation cost in order to purchase the good from its manufacturer. The other is that each retailer does not bear the transportation cost.

3.1. Consumers' and Retailers' Transportation Cost

To begin with, we examine the case that each consumer and retailer incur transportation cost. At stage 3, given the wholesale prices (w_a, w_b) and the retailers' locations (x_a, x_b), each retailer sets its prices so as to maximize its profits. Retailer a's maximization problem is as follows:

$$max_{p_a} \quad \pi_a = \left[p_a - w_a - t\left(\frac{1}{2} - x_a\right)^2\right]\hat{x} = \left[p_a - w_a - t\left(\frac{1}{2} - x_a\right)^2\right]\left[\frac{p_b - p_a + t(x_b^2 - x_a^2)}{2t(x_b - x_a)}\right],$$

where $t\left(\frac{1}{2} - x_a\right)^2$ denotes the transportation cost for retailer a.

From the F. O. C., the equilibrium prices are

$$p_a = \frac{[3-4(4-x_a)x_a+4(1+2x_b)x_b+4(2w_a+w_b)]}{12},\ p_b = \frac{[3-4(4-x_b)x_b+4(1+2x_a)x_a+4(w_a+2w_b)]}{12}. \tag{5}$$

Inserting Eq. (5) into Eq. (2), the location of the indifference consumer is

$$\hat{x} = \frac{2(x_a+x_b)+1}{6} - \frac{w_a-w_b}{6(x_b-x_a)t}. \tag{6}$$

We suppose that the retailers' locations are symmetric. Then, the indifference consumer will purchase the good from retailer $a(b)$, if $w_a < w_b (w_a > w_b)$.

At stage 2, given the wholesale prices (w_a, w_b), each retailer chooses its location in order to maximize its profits. Retailer a's maximization problem is as follows:

$$max_{x_a} \quad \pi_a = \left[p_a - w_a - t\left(\frac{1}{2} - x_a\right)^2\right]\hat{x}.$$

From the F. O. C., we obtain the equilibrium locations as follows:

$$x_a = \frac{3t-8(w_a-w_b)}{24t},\ x_b = \frac{21t-8(w_a-w_b)}{24t}. \tag{7}$$

We suppose that the wholesale prices are symmetric (i. e., $w_a = w_b$). Then, both retailers will choose their locations inside the city.

Inserting Eq. (7) into Eq. (2), the location of the indifference consumer is as follows:

$$\hat{x} = \frac{1}{2} + \frac{4(w_a-w_b)}{9t}. \tag{8}$$

We suppose that the wholesale prices are symmetric (i. e., $w_a = w_b$). Then, the location of the indifference consumer will locate at the center of the city.

Finally, at stage 1, each manufacturer chooses its wholesale prices in order to maximize its profits. Manufacturer a's maximization problem is as follows:

$$max_{w_a} \quad \Pi_a = [w_a - c]\hat{x} = [w_a - c]\left[\frac{1}{2} + \frac{4(w_a-w_b)}{9t}\right].$$

From the F. O. C., we obtain the equilibrium wholesale prices as follows:

$$w_a^D = w_b^D = c + \frac{9t}{8}. \tag{9}$$

Finally, we obtain the equilibrium locations, prices, profits, consumer surplus (CS), and social welfare (SW) as follows:

$$x_a^D = \frac{1}{8},\ x_b^D = \frac{7}{8},\ p_a^D = p_b^D = c + \frac{129t}{64},\ \pi_a^D = \pi_b^D = \frac{3t}{8},\ \Pi_a^D = \Pi_b^D = \frac{9t}{16},$$

$$CS^D = V - c - \frac{197t}{96},\ SW^D = V - c - \frac{17t}{96}, \tag{10}$$

where the superscript 'D' denotes the case that both consumers and retailers incur transportation costs.

Under retailers' transportation costs, the retailers choose their locations inside the consumer space, compared with the standard unconstrained location-price model in which the firms choose locations outside the consumer space to alleviate price competition.

3.2. Consumers' Transportation Costs

We turn to a case that only consumers incur transportation costs. At stage 3, given the wholesale prices, locations, and rival's prices, each retailer chooses its prices so as to maximize its profits. Retailer a's maximization problem is as follows:

$$max_{p_a} \quad \pi_a = [p_a - w_a]\hat{x} = [p_a - w_a]\left[\frac{p_b - p_a + t(x_b^2 - x_a^2)}{2t(x_b - x_a)}\right].$$

From the F. O. C., the equilibrium prices are as follows:

$$p_a = \frac{[t(x_b - x_a)(2 + x_b + x_a) + (2w_a + w_b)]}{3},\ p_b = \frac{[t(x_b - x_a)(4 - x_b - x_a) + (w_a + 2w_b)]}{3}. \tag{11}$$

Inserting Eq. (11) into Eq. (2), the location of the indifferent consumer is

$$\hat{x} = \frac{(x_b - x_a)(x_b + x_a + 2)t - w_a + w_b}{6(x_b - x_a)t}. \tag{12}$$

At stage 2, given the wholesale prices (w_a, w_b), each retailer chooses its location in order to maximize its profits. Retailer a's maximization problem is as follows:

$$max_{x_a} \quad \pi_a = [p_a - w_a]\hat{x} = \left[\frac{[t(x_b - x_a)(2 + x_b + x_a) - (w_a - w_b)]}{3}\right]\left[\frac{(x_b - x_a)(x_b + x_a + 2)t - w_a + w_b}{6(x_b - x_a)t}\right].$$

From the F. O. C., we obtain the equilibrium locations as follows:

$$x_a = \frac{4(w_b - w_a) - 3t}{12t},\ x_b = \frac{4(w_b - w_a) + 15t}{12t}. \tag{13}$$

We suppose that the wholesale prices are symmetric (i. e., $w_a = w_b$). Then, both retailers will choose their locations outside the city.

The location of the indifference consumer is

$$\hat{x} = \frac{1}{2} + \frac{2(w_b - w_a)}{9t}. \tag{14}$$

We suppose that the wholesale prices are symmetric (i. e., $w_a = w_b$). Then, the location of the indifference consumer will locate at the center of the city.

Finally, at stage 1, each manufacturer chooses its wholesale prices in order to maximize its profits. Manufacturer a's maximization problem is as follows:

$$max_{w_a} \quad \Pi_a = [w_a - c]\hat{x} = [w_a - c]\left[\frac{1}{2} + \frac{2(w_a - w_b)}{9t}\right].$$

From the F. O. C., we obtain the equilibrium wholesale prices as follows:

$$w_a^S = w_b^S = c + \frac{9t}{4}. \tag{15}$$

Finally, we obtain the equilibrium locations, prices, profits, consumer surplus (CS), and social welfare (SW) as follows:

$$x_a^S = -\frac{1}{4},\ x_b^S = \frac{5}{4},\ p_a^S = p_b^S = c + \frac{15t}{4},\quad \pi_a^S = \pi_b^S = \frac{3t}{4},\ \Pi_a^S = \Pi_b^S = \frac{9t}{8},$$

$$CS^S = V - c - \frac{193t}{48},\ SW^S = V - c - \frac{13t}{48}, \tag{16}$$

where the superscript 'S' denotes the case that only consumers incur transportation costs.

4 Results

We examine two models. One is the case that both consumers and retailers incur transportation costs. The other is the case that only consumers incur transportation costs. A straightforward comparison of locations gives us the following result.

Proposition 1 *When both consumers and retailers incur transportation costs, each retailer chooses the location inside the consumer space.*

The intuition of this result can be explained as follows. When retailers incur transportation costs, they are confronted by a trade-off between competition-alleviating effect and transportation cost-saving effect. As they locate far away from the center of the city, it has the advantage of softening competition, but has disadvantage of incurring high costs. On the other hand, as they approach to the center of the city, it has the advantage of enjoying cost-saving, but has disadvantage of facing fierce competition. Proposition 1 is in sharp contrast to the conventional wisdom (e. g., see Tabuchi and Thisse (1995), Lambertini (1997), and Li and Shuai (2017). These studies show that firms choose to locate outside the city in an unconstraint Hotelling model with quadratic transportation costs. Proposition 1 indicates that incorporating retailers' transportation costs into the model of Li and Shuai (2017) drastically changes the results.

Comparing retail prices of two cases, we obtain the following result.

$$p_a^S - p_a^D = \frac{111t}{64}. \quad (17)$$

This finding is summarized in Proposition 2.

Proposition 2 *Retail prices are lower under D case than under S case.*

Proposition 2 is in sharp contrast to the conventional wisdom that firms with higher costs set the higher prices. The intuition of this result can be explained as follows. When retailers incur transportation costs, they are willing to approach to the center of the city in order to decrease transportation costs. It will bring a fiercer competition to retailers. The strong competition makes manufacturers set lower wholesale prices. In the end, retail prices are lower under *D* case than under *S* case.

Comparing consumer surplus and social welfare of two cases, we obtain the following results.

$$CS^D - CS^S = \frac{189t}{96} \text{ and } SW^D - SW^S = \frac{9t}{96}. \quad (18)$$

These findings are summarized in Proposition 3.

Proposition 3 *Both consumer surplus and social welfare are higher under D case (i. e., the case in which consumers and retailers incur transportation) than under S case (i. e., the case in which consumers only incur transportation).*

We now discuss the intuition behind this result. From the standpoint of consumers view, D case has two different effects compared to S case. One is that D case saves consumers transportation costs. The competition between retailers is fiercer under *D* case than under *S* case. Therefore, consumers purchase the good at a low price.

Note that social welfare is organized by the sum of consumer surplus and total industry profits. Retail competition is fiercer under D case than under S case. It means that total industry profits are higher under S case than under D case. Under D case, however, increase in consumer surplus dominates decrease in total industry profits. Therefore, social welfare is larger under D case than under S case. These results are in sharp contrast to the conventional results that if there exist inefficient firms in an industry, consumer surplus and social welfare will decrease.

4 Conclusion

This paper extended an unconstraint Hotelling model with retailers' transportation costs in a vertical structure. We modeled the retail competition as a three-stage wholesale price-location-price game. We compared two cases: *D* case and *S* case. Our analysis was focusing on the effects of retailers' transportation costs on their location choices and consumer surplus and social welfare. We found that if retailers pay transportation costs, they are confronted by a trade-off between competition-alleviating effect and transportation cost-saving effect. Contrary to the previous research, retailers located inside the city in an unconstraint Hotelling model. In this paper, downstream firms acquire inputs through bilateral monopoly with upstream input suppliers. The existence of bilateral monopolies can be explained by the notion of asset specificity, which potentially creates a 'lock-in' effect. Sunk investments increase the value of trade between downstream firm and upstream firm. Applying an unconstrained Hotelling model we showed that the presence of downstream firms' transportation costs induces the downstream firms to locate closer to the center of the city compared with downstream firms' not-transportation costs. The policy implication of the result is as follows. A raise in cost reduces product differentiation and prices.[9]

In modeling wholesale-location-price competition, we have followed by assuming a covered market. If the reservation utility is likely binding such that consumer demand is elastic, competition between the

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[9] See Brécard (2010) for a theoretical model.

retailers would be intensified. It can alter the magnitude of two effects that we compare. Also, in our model, we assume that the manufacturers use a linear tariff contract. In reality, it is possible that the retailer may bargain with the manufacturer about wholesale price (under two-part tariff). How such profit division rules affect wholesale pricing and the choice of location is open for future research.

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