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# Spatial Competition in Variety and Number of Stores

Shin-Kun Peng\* and Takatoshi Tabuchi†

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## Abstract

We propose location-then-variety competition for a multi-product and multi-store oligopoly, in which the number of firms, the number of stores and their location, and the number of varieties are endogenously determined. We show that as compared to price-then-variety competition, location-then-variety competition with multi-stores yields a much richer set of equilibrium outcomes, such as market segmentation, interlacing, sandwich and enclosure.

**Keywords:** multi-store firms, multi-product firms, variety competition, spatial preemption, natural oligopoly

**J.E.L. Classification:** D43, L13, R30

## 1 Introduction

One of the most unsatisfactory aspects of the Hotelling's (1929) model of spatial competition is that it assumes that retail firms sell a single product. In reality, thousands of diverse goods are sold in supermarkets and convenience stores, and quite a few varieties are even sold in specialty stores. To this effect, we assume that retail firms are able to sell *any number of goods*.

Another drawback of the Hotelling's model is the assumption that firms establish a single store. Multi-store firms are quite common in the retail industry nowadays. For example, there are many chains of convenience stores, supermarkets, and fast food restaurants.<sup>1</sup> We therefore allow firms to establish *multiple stores* at different locations in an oligopolistic market.

We introduce two kinds of heterogeneity: geographic and product heterogeneity. Geographic heterogeneity is represented by the location of firms, which affects the degree of local competition:

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<sup>1</sup>In Japan, the sales share of convenience stores in the retail industry steadily increased from 0.8% in 1985 to 5.4% in 2004. There were 41,114 convenience stores administered by 33 firms, which implies 1,246 stores per firm in 2003. In addition, there were 34,762 fast food restaurants administered by 208 firms, which implies 167 stores per firm.

it is keen between neighboring firms, but weak between remote firms. Such location-related competition has been dealt with address models of spatial competition in an oligopolistic market in the literature.<sup>2</sup>

However, characteristic space is not necessarily analogous to geographic space. For example, consider the case in which 12 firms are located equidistantly on the circumference of a circle. The geographic interpretation is straightforward: consumers located at the 1 o'clock position prefer firm 1 to 2, and firm 2 to 3 on the basis of proximity. On the other hand, a characteristic interpretation is not so obvious. Suppose an airline has flights departing every hour. Some consumers prefer flight 1 to 3 and 3 to 2 because consumers' preference is not necessarily monotonic. In other words, there is no reason to use address models in the case of characteristic space. It may be more appropriate to treat all varieties as more or less symmetrically substitutable by each other. We therefore deal with geographic heterogeneity using an address model of oligopoly to capture location sensitivity, whereas we treat product heterogeneity using a non-address model of monopolistic competition according to Dixit-Stiglitz (1977).

The main objective of our paper is to *propose an analytically tractable model of spatial competition in variety, which is contrasted with that in price.*<sup>3</sup> The properties of price competition are well known and reported in the literature. For example, competition is localized in that prices of neighboring firms have a strong impact, and therefore firms do not locate close to each other in order to relax price competition (d'Aspremont, Gabszewicz and Thisse, 1979). It is revealed in this paper that a similar property holds for variety competition. However, to deter other firms from locating nearby, firms use price discounting in price competition, whereas they increase the number of brands in variety competition. The former may depict competition between discount stores, in which prices are the crucial factor. On the other hand, the latter may describe competition between convenience stores, between dollar stores, or between department stores, in which variety of choice is important for consumers.

There are two reasons that price competition is not at work between chain stores. Dobson and Waterson (2005) show that firms owning chains have a strong incentive to precommit to uniform pricing because it softens price competition between itself and rival firms. They exemplify the uniform pricing by Argos and Marks&Spenser in U.K., Zara in Spain, and IKEA in Sweden.

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<sup>2</sup>Alternatively, this location-related competition could be interpreted as brand competition in the case of two firms producing an operating system, such as Windows and Mac, with many software packages compatible with either operating system. Consumers select only one of the operating systems together with a set of software packages.

<sup>3</sup>de Palma, Lindsey, von Hohenbalken and West (1994) developed a single-stage variety game based on the logit model. However, spatial competition was not taken into account.

Another reason is resale-price maintenance. This is commonly used in practice: books and music CD's should be sold at regular prices in several countries like Japan. Given the constraint of regular prices, these retail stores would strategically provide an array of varieties in order to attract customers, while taking display costs of varieties into account. In fact, it is shown here that variety competition yields richer market outcomes than those of price competition in a spatial economy, and better explains real world behavior. In particular, firms establish multiple stores in order to exercise spatial preemption, and the number of stores is not necessarily the same between firms in location-then-variety competition, which never happens in location-then-price competition (Martinez-Giralt and Neven, 1988).

The remainder of the paper is organized as follows. A model of spatial variety competition is presented in Section 2. A single-store duopoly of simultaneous entry and sequential entry is analyzed in Section 3. This is extended to a multi-store duopoly of sequential entry in Section 4. We show that multi-store variety competition yields a richer set of spatial configurations than price competition. Section 5 concludes.

### **Related literature on multi-store spatial competition**

There are few papers in the literature on multi-store spatial competition in comparison with single-store spatial competition possibly due to the nonexistence of equilibrium mentioned in footnote 4. A pioneering work on multi-store spatial competition was carried out by Judd (1985) using a multi-stage game with entry and exit. Judd showed that a multi-store firm is very vulnerable to a new single-store firm. Nevertheless, as documented by Dobson and Waterson (2005), we often observe numerous chain stores together with an oligopolistic market structure in the retail sector in the real world, which is consistent with our model.

A one-stage location game with multiple stores has been analyzed by Gabszewicz and Thisse (1986) and Chisholm and Norman (2004). Two-stage price-then-location games have been examined by Martinez-Giralt and Neven (1988) and Janssen, Karamychev and van Reeve (2005). The two-stage quantity-then-location game has been investigated by Pal and Sarkar (2002). This paper considers a two-stage variety-then-location game with multiple stores.

## **2 The model**

Consumers are uniformly distributed on a unit segment  $x \in [0, 1]$  with density 1. There are two retail firms,  $R = A, B$ . Firm  $R$  establishes  $n_R$  stores  $r = r_1, r_2, \dots, r_{n_R}$  at locations  $x = x_{r_1}, x_{r_2}, \dots, x_{r_{n_R}}$  with  $x_{r_i} < x_{r_{i+1}}$  for  $i = 1, \dots, n_R - 1$ , and sells  $v_R$  varieties of horizon-

tally differentiated goods in each store.<sup>4</sup> Consumers visit only one of the stores, and purchase  $(q_{r1}, q_{r2}, \dots, q_{rv_R})$  units of varieties from multi-product store  $r$ . Their preferences are identical across individuals and are given by the utility:

$$U_r = \alpha \log \left( \sum_{v=1}^{v_R} q_{rv}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} + q_0, \quad (1)$$

where  $\sigma (> 1)$  is the elasticity of substitution between the varieties, and  $q_0$  is the numéraire quantity.<sup>5</sup> We normalize  $\alpha = 1$  by choosing a unit of the numéraire. A consumer who visits store  $r$  maximizes utility (1) subject to the budget constraint:

$$y = \sum_{v=1}^{v_R} p_{rv} q_{rv} + q_0 + \tau (x - x_r)^2, \quad (2)$$

where  $y$  is the consumer's income,  $p_{rv}$  is the price of variety  $v$  at store  $r$ , and  $\tau$  is the unit cost of transporting all varieties per visit. The demand for variety  $v$  at store  $r$  by a consumer at  $x$  is computed as:

$$q_{rv}(x) = \frac{p_{rv}^{-\sigma}}{\sum_{u=1}^{v_R} p_{ru}^{1-\sigma}}.$$

Under the exogenous constant price  $p$ ,<sup>6</sup> this is reduced to

$$q_{rv}(x) = \frac{1}{pv_R}. \quad (3)$$

Substituting Eqs. (3) and (2) into Eq. (1), we obtain the indirect utility:

$$V_r = \frac{1}{\sigma - 1} \log v_R - \tau (x - x_r)^2 + y_0,$$

where  $y_0 \equiv y - \log p - 1$  is constant. The utility of a marginal consumer is indifferent between visiting two neighboring stores  $r$  and  $s$ , located at  $x_r$  and  $x_s$  ( $x_r < x_s$ ), respectively. Solving  $V_r = V_s$  yields the location of a marginal consumer:

$$\hat{x}_{rs} = \frac{x_r + x_s}{2} + \frac{\beta \log(v_R/v_S)}{2(x_s - x_r)},$$

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<sup>4</sup>If firms are allowed to sell different numbers of varieties depending on store locations, then the existence of equilibrium in variety competition is not necessarily guaranteed. This is because the number of stores ( $n_a, n_b$ ) that should have been determined in the first stage can be decreased in the last stage of variety competition by setting zero variety (i.e. selling no goods) in some stores. That is, since the number of stores cannot be pre-committed in the first stage, the subgame perfect Nash equilibrium (SPNE) is not well defined. As shown in Appendix A1, assumption of the same number of varieties always ensures the existence of equilibrium in variety competition. The assumption is not unrealistic, because many chain stores, such as Seven-Eleven and Denny's, offer almost the same array of varieties in each store.

<sup>5</sup>This utility function is often used in new economic geography (Martin and Rogers, 1995; Pflüger, 2004).

<sup>6</sup>In the case of department stores and shopping malls, price competition should also be involved. See Appendix A2 for an endogenous price determination.

where

$$\beta \equiv \frac{1}{\sqrt{(\sigma - 1)\tau}} > 0$$

for  $x_r \leq \hat{x}_{rs} \leq x_s$ , otherwise locating a store at  $x_r$  or  $x_s$  is not profitable at all.

Retailing technology involves a fixed display cost per variety  $f$ . When store  $r$  is located such that  $x_t < x_r < x_s$ , the profit of store  $r$  providing  $v_r$  varieties is expressed as:

$$\pi_r = \sum_{v=1}^{v_R} pq_{rv}(\hat{x}_{rs} - \hat{x}_{tr}) - fv_R$$

as long as the value is non-negative. Otherwise, firms do not open a store at location  $r$ . The profit of firm  $R$  running  $n_R$  stores at  $r = r1, r2, \dots, rn_R$  is therefore given by:

$$\pi_R = \sum_{i=1}^{n_R} \pi_{ri}. \quad (4)$$

### 3 Single-store duopoly

As a first step, we consider a standard duopoly in which each firm can establish a single store  $(n_A, n_B) = (1, 1)$  for simultaneous entry and sequential entry in this section.

#### 3.1 Simultaneous entry

Consider the game in which both firms simultaneously enter and select store location  $(x_a, x_b)$  in the first stage, and both firms simultaneously choose the number of varieties  $(v_A, v_B)$  in the second stage. We assume that firms enter the market only if profits are positive. Following the spirit of Hotelling, we seek an SPNE for a given parameter value  $\beta$  by backward induction.

In the second stage, given the locations of both firms  $x_a$  and  $x_b$ , each firm  $R$  maximizes  $\pi_R$  of Eq. (4) with respect to the number of varieties  $v_R$ . Computing the first-order conditions, we readily have the equilibrium number of varieties:

$$v_A^* = v_B^* = \frac{\beta^2}{2f(x_b - x_a)} \quad \text{for } x_a < x_b. \quad (5)$$

This is a unique Nash equilibrium in variety competition because concavity of the profit functions is assured. It shows that the number of varieties increases when the distance between firms decreases. Such aggressive reaction in augmenting varieties acts as a dispersion force, just as reducing prices is a dispersion force in price competition.

Substituting the equilibrium number of varieties given by Eq. (5) into Eq. (4), we obtain:

$$\begin{aligned} \tilde{\pi}_A(ab) &= \frac{1}{2} \left( x_a + x_b - \frac{\beta^2}{x_b - x_a} \right) \\ \tilde{\pi}_B(ab) &= \frac{1}{2} \left( 2 - x_a - x_b - \frac{\beta^2}{x_b - x_a} \right) \end{aligned} \quad \text{for } x_a < x_b, \quad (6)$$

where  $\tilde{\pi}_R(rs)$  is the profit of firm  $R$  having a single store  $r$  located to the left of a single store  $s$  of a rival firm. If  $x_a = x_b$ , the profits given by Eq. (6) are negative, implying that the principle of minimum differentiation never arises. Put differently, firms avoid fierce competition in variety by locating apart. This observation is in accord with price competition identified by d'Aspremont *et al.* (1979).

The profits given by Eq. (6) decrease in  $\beta = 1/\sqrt{(\sigma-1)\tau}$ , which is interpreted as *the intensity of variety competition*. In fact, when  $\beta$  is large, firms sell many varieties as shown by Eq. (5) to attract consumers. Thus, variety competition is keen when goods are poor substitutes and consumers look for variety ( $\sigma$  low), and/or when shopping trips are not costly ( $\tau$  low). However, the fixed cost  $f$  is irrelevant to the profits given by Eq. (6).

In the first stage, each firm  $i$  maximizes profit given by Eq. (6) with respect to location  $x_i$ . Computing the first-order conditions, the reaction functions of firm  $i$  are given by:

$$x_i = \begin{cases} x_j + \beta & \text{for } x_j \leq 1/2 \\ x_j - \beta & \text{for } x_j > 1/2 \end{cases} \quad \text{for } i \neq j. \quad (7)$$

That is, each firm chooses a location with a larger hinterland at a distance of  $\beta$  from its opponent. While the number of varieties given by Eq. (5) depends on the fixed cost  $f$ , the location choice given by Eq. (7) is independent of the fixed cost. Inserting Eq. (7) into Eq. (6) yields:

$$\pi_A^*(ab) = x_b^* - \beta = x_a^* \quad \pi_B^*(ab) = 1 - x_a^* - \beta = 1 - x_b^*. \quad (8)$$

For these profits to be positive,  $0 < x_a^* < 1 - \beta$  and  $\beta < x_b^* < 1$  should hold. We thus obtain the following.

**Proposition 1** *For simultaneous entry of single-store duopolists, two cases may arise.*

- (i) *When  $\beta \geq 1$ , only one firm enters and locates at any point inside the line segment.*
- (ii) *When  $0 \leq \beta < 1$ , two firms enter and locate at*

$$(x_a^*, x_b^*) = (x, x + \beta) \quad \text{for } x \in [\max\{0, 1/2 - \beta\}, \min\{1 - \beta, 1/2\}].$$

Three remarks are in order. First, when the intensity of competition is strong ( $\beta \geq 1$ ), both profits in Eq. (8) cannot be positive, which implies that one of the firms monopolizes the market. Such spatial monopoly is reminiscent of the *natural oligopoly* of Shaked and Sutton (1983). Note, however, that the determinants of the number of firms differ between their and our models. The number of firms is determined by the production cost structure in Shaked and Sutton (1983), whereas it depends on the substitutability  $\sigma$  and the transport cost  $\tau$ , but is independent of the production cost  $f$  in our model.

Second, when the intensity of competition is weak ( $\beta < 1$ ), both firms enter the market, and there is a *continuum of equilibria* with a distance of  $\beta$  between the them. A continuum exists because the reaction functions of Eq. (7) for the two firms do not cross, but overlap for all relevant values of  $(x_a, x_b)$ . In any equilibrium, *the locations of firms are always inside the line segment*, which is in contrast to the edge locations (Neven, 1985) or outside the segment (Tabuchi and Thisse, 1995) in location-then-price competition. Casual empiricism suggests that firms hardly establish stores at edges of or outside consumer distributions. Hence, location-then-variety competition is able to describe the real world better than location-then-price competition. Stated differently, the price competition effect (a dispersion force) is so strong that it dominates the market area effect (an agglomeration force) that is generated by the demand segment (Fujita and Thisse, 1996). On the other hand, the variety competition effect balances with the market area effect, which yields the interior locations of firms.

Third, when the intensity of competition  $\beta$  approaches 0, both firms locate at the center of the line segment, which is merely the location equilibrium of two firms (Lerner and Singer, 1937). That is, the one-stage game of location competition is considered as a special case of our game when competition in variety is sufficiently weak. Note, however, that when competition is weak enough, we see in the next section that firms then open multiple stores.

### 3.2 Sequential entry

We next examine sequential entry of firms to refine the continuum of equilibria that appeared in the simultaneous entry game above. The game now consists of three stages: firm  $A$  selects store location  $x_a$  in the first stage, firm  $B$  selects store location  $x_b$  in the second stage, and both firms simultaneously choose the number of varieties  $(v_A, v_B)$  in the third stage.

The last stage of variety competition is the same as that for simultaneous entry. In the second stage, firm  $B$  maximizes its profit for its location  $x_b$  given firm  $A$ 's location  $x_a$ . We already know from Eq. (7) that firm  $B$ 's best locational reply is  $x_b = x_a + \beta$  given  $x_a \in [0, 1/2]$ . Inserting this into Eq. (6) yields the profit of firm  $A$  as  $\pi_A(ab) = x_a$ . Firm  $A$ 's best locational reply is therefore given by  $x_a^* = 1/2$ , and hence the equilibrium profits are:

$$\pi_A^*(ab) = 1/2 \qquad \pi_B^*(ab) = 1/2 - \beta.$$

Thus, we have the following.

**Proposition 2** *For sequential entry of single-store duopolists, two cases may arise.*

- (i) *When  $\beta \geq 1/2$ , only one firm enters and locates at any point inside the line segment.*



(ii) When  $0 \leq \beta < 1/2$ , the first entrant locates at the center, while the second locates at  $x_b^* = 1/2 + \beta$ .

The market outcome is somewhat similar between simultaneous entry and sequential entry. First, when the intensity of competition  $\beta$  is strong enough, the profit  $\pi_B^*(ab)$  is negative, so that “natural monopoly” arises. Second, when both firms achieve positive profits, the locations of firms are always inside the line segment. Third, when  $\beta$  approaches 0, both firms locate at the center of the segment.

However, there are some differences between simultaneous entry and sequential entry. The continuum of equilibria disappears in the case of sequential entry. For  $1/2 \leq \beta < 1$ , the first entrant can monopolize the market in the sequential entry game, whereas this is not the case in the simultaneous entry game. Put differently, natural monopoly is more easily realized in sequential entry.

Furthermore, the locations of the two firms are asymmetric: while the first entrant always chooses the center, the second entrant selects a periphery. As a result, the profits are also asymmetric: the first entrant earns more profit than the second entrant. Such a *first-mover advantage* also prevails in location-then-price competition for two firms (Tabuchi and Thisse, 1995) and for more than two firms (Neven, 1987). We see in the next section that these findings are also true when firms are allowed to open multiple stores.

## 4 Multi-store duopoly

We now explore the case in which each firm can establish multiple stores. For analytical tractability, we assume (i) that two firms enter sequentially, (ii) that firms can establish two stores at most ( $n_R \leq 2$ ), and (iii) that the store locations of the first entrant are symmetric ( $x_{a1} + x_{a2} = 1$ ), but the store locations of the second entrant can be asymmetric. The first assumption is to refine the continuum of equilibria that appears for simultaneous entry of firms, as observed in the previous section. The second and third assumptions are for analytical simplicity. Relaxing these assumptions is possible, but the analysis becomes cumbersome without obtaining more meaningful results. We instead focus on the implications and intuitions of location-then-variety competition.

For notational convenience, we write  $(x_r, x_r)$  for  $n_R = 1$ , and  $(x_{r1}, x_{r2})$  with  $x_{r1} \neq x_{r2}$  for  $n_R = 2$ . The game in this section is as follows. Firm  $A$  selects the number of stores  $n_A$  and their locations  $(x_{a1}, 1 - x_{a1})$  in the first stage, firm  $B$  selects the number of stores  $n_B$  and locations

$(x_{b1}, x_{b2})$  in the second stage, and both firms simultaneously choose the number of varieties  $(v_A, v_B)$  in the third stage. As before, we seek an SPNE by backward induction.

For example, if there are three stores  $a_1, a_2$  and  $b$  located such that  $x_{a1} \leq x_{a2} \leq x_b$ , we denote this configuration by  $(aab)$  and its profit by  $\pi_R(aab)$ . Excluding axisymmetric configurations, there are nine spatial arrangements:

$$(ab), (bab), (abb), (aab), (aba), (aabb), (baab), (abba), (abab). \quad (9)$$

#### 4.1 The third and second stages

There exists a unique equilibrium in the third stage of variety competition for any configuration in (9), as shown in Appendix A1. Since this is easily computed, we analyze the third and second stages together in this subsection given  $A$ 's store locations  $(x_{a1}, 1 - x_{a1})$ . By solving the two stages in reverse, the profits  $\pi_R(\bullet)$  of the nine configurations can be expressed as  $x_{a1}$  and  $\beta$ .

**Single store (ab).** We have already solved the profits in subsection 3.2 as

$$\pi_A(ab) = x_a \quad \pi_B(ab) = x_a - \beta.$$

**Sandwich by B (bab).** When firm  $A$  establishes one store  $a$  at  $x = x_a$  and firm  $B$  two stores  $b1$  and  $b2$  at  $x = x_{b1}, x_{b2}$  with  $x_{b1} \leq x_a \leq x_{b2}$ , the equilibrium numbers of varieties are computed as:

$$v_a^* = 2v_b^* = \frac{\beta^2}{2f} \left( \frac{1}{x_{b2} - x_a} + \frac{1}{x_a - x_{b1}} \right).$$

As before, the number of varieties is determined by the distance from rival stores. Although single-store firm  $A$  offers double of varieties, the total number of varieties is the same between firms  $A$  and  $B$ . Straightforward computation yields that the best locational replies of  $B$  are, respectively, given by:

$$x_{b1} = x_a - \beta\sqrt{1 + \log 2} \quad x_{b2} = x_a + \beta\sqrt{1 + \log 2}. \quad (10)$$

Substituting these  $B$  reactions into the profits, we obtain:

$$\pi_A(bab) = \frac{2\beta \log 2}{\sqrt{1 + \log 2}} \quad \pi_B(bab) = 1 - 2\beta\sqrt{1 + \log 2}.$$

Note that these profits are not functions of  $x_a$ , and that there exists a continuum of equilibria for all  $x_{b1} \in [0, 1 - 2\beta\sqrt{1 + \log 2}]$  with Eq. (10).

**Sandwich by A (aba).** Similarly, the equilibrium numbers of varieties are

$$2v_a^* = v_b^* = \frac{\beta^2}{2f} \left( \frac{1}{1 - x_{a1} - x_b} + \frac{1}{x_b - x_{a1}} \right)$$

and the best locational reply of  $B$  is  $x_b = 1/2$ . Given this  $B$  reaction, the profits are given by:

$$\pi_A(aba) = x_{a1} + \frac{1}{2} - \frac{2\beta^2(1 + \log 2)}{1 - 2x_{a1}} \quad \pi_B(aba) = x_{a1} - \frac{1}{2} + \frac{2\beta^2(1 - \log 2)}{1 - 2x_{a1}}.$$

**Segmentation (abb).** This is never chosen by firm  $B$  because the peripheral store  $b_2$  is immaterial. That is, the presence of  $b_2$  does not raise  $B$ 's revenue, but increases the costs of providing another set of varieties.

**Segmentation (aab).** When the intensity of competition is relaxed, firm  $A$  has an incentive to proliferate stores. The equilibrium numbers of varieties in this configuration are

$$2v_a^* = v_b^* = \frac{\beta^2}{2f(x_b - 1 + x_{a1})}$$

and the best locational reply of  $B$  is given by:

$$x_b = 1 - x_{a1} + \beta\sqrt{1 - \log 2}. \quad (11)$$

Given this  $B$  reaction, the profits are expressed as:

$$\pi_A(aab) = 1 - x_{a1} - \frac{\beta \log 2}{\sqrt{1 - \log 2}} \quad \pi_B(aab) = x_{a1} - \beta\sqrt{1 - \log 2}.$$

**Segmentation (aabb).** As in case  $(abb)$ , firm  $B$  never chooses this configuration.

**Enclosure by B (baab).** The equilibrium numbers of varieties are computed as

$$v_a^* = v_b^* = \frac{\beta^2}{4f} \left( \frac{1}{x_{b2} - 1 + x_{a1}} + \frac{1}{x_{a1} - x_{b1}} \right)$$

and the best locational replies for stores  $b_1$  and  $b_2$  are given by

$$x_{b1} = x_{a1} - \beta \quad x_{b2} = 1 - x_{a1} + \beta.$$

Given these  $B$  reactions, the profits are expressed as:

$$\pi_A(baab) = 1 - 2x_{a1} \quad \pi_B(baab) = x_{a1} - \beta.$$

**Enclosure by A (abba).** The equilibrium numbers of varieties are computed as

$$v_a^* = v_b^* = \frac{\beta^2}{4f} \left( \frac{1}{1 - x_{a1} - x_{b2}} + \frac{1}{x_{b1} - x_{a1}} \right)$$

and the best locational replies are given by:

$$x_{b1} = x_{a1} + \beta \quad x_{b2} = 1 - x_{a1} - \beta.$$

Given these  $B$  reactions, the profits are:

$$\pi_A(abba) = 2x_{a1} \quad \pi_B(abba) = 1 - 2x_{a1} - 2\beta.$$

**Interlacing (abab).** The equilibrium numbers of varieties are

$$v_a^* = v_b^* = \frac{\beta^2}{4f} \left( \frac{1}{x_{b2} - 1 + x_{a1}} + \frac{1}{1 - x_{a1} - x_{b1}} + \frac{1}{x_{b1} - x_{a1}} \right)$$

and the best locational replies are

$$x_{b1} = \frac{1}{2} \quad x_{b2} = 1 - x_{a1} + \beta.$$

Given these  $B$  reactions, the profits are:

$$\pi_A(abab) = \frac{1}{2} - \frac{2\beta^2}{1 - 2x_{a1}} \quad \pi_B(abab) = \frac{1}{2} - \beta - \frac{2\beta^2}{1 - 2x_{a1}}.$$

The above reaction functions emphasize that the location decisions of multi-store firms are dependent on each other in our model, while they are independent in the works by Pal and Sarkar (2002) and Janssen *et al.* (2005) due to the different types of spatial competition.

## 4.2 The first stage

So far, we have shown that there are seven possible SPNE configurations. We now move to investigate the first-stage location of the first entrant  $A$  as follows.

**Single store (ab).** We already know that given firm  $B$ 's reaction, firm  $A$  necessarily chooses a central location in subsection 3.2. The profit of firm  $B$  is computed as  $\pi_B^*(ab) = \frac{1}{2} - \beta$ . However, for this choice strategy to be feasible, firm  $B$  should have no incentive to open the second store  $\pi_B(ab) \geq \pi_B(bab)$ , or equivalently,  $\beta \geq (4\sqrt{1 + \log 2} - 2)^{-1} \simeq 0.31$ . Moreover, firm  $B$  should have a positive profit  $\pi_B(ab) > 0$ , or  $\beta < 1/2$ . Hence, a candidate for SPNE is:

$$x_a^* = 1/2 \quad \pi_A^*(ab) = 1/2 \quad \text{if } 0.31 \leq \beta < 1/2. \quad (12)$$

**Sandwich by B (bab).** When firm  $A$  establishes one store at  $x = x_a$ , firm  $B$  locates two stores at  $x_{b1} = x_a - \beta\sqrt{1 + \log 2}$  and  $x_{b2} = x_a + \beta\sqrt{1 + \log 2}$ . For this choice to be feasible, it is necessary that  $\pi_B(bab) \geq \pi_B(ab)$  and  $\pi_B(bab) > 0$ . Hence, a candidate for SPNE is:

$$x_a^* \in \left( \beta\sqrt{1 + \log 2}, 1 - \beta\sqrt{1 + \log 2} \right) \quad \pi_A^*(ab) = \frac{2\beta \log 2}{\sqrt{1 + \log 2}} \quad \text{if } \beta < 0.31. \quad (13)$$

**Segmentation (aab).** When firm  $A$  locates two stores at  $x = x_{a1}, 1 - x_{a1}$ , firm  $B$  locates one store at  $x_b = 1 - x_{a1} + \beta\sqrt{1 - \log 2}$ , from Eq. (11). For this choice to be feasible, it is necessary that

$$\pi_B(aab) \geq \max \{ \pi_B(aba), \pi_B(baab), \pi_B(abba), \pi_B(abab) \} \quad \pi_B(aab) > 0. \quad (14)$$

It can be readily confirmed that there exists a non-empty domain that satisfies the inequalities for the  $(\beta, x_{a1})$  coordinates. Firm  $A$  selects the best location within the domain, which leads to an SPNE candidate:

$$\begin{aligned} x_{a1}^* &= \frac{1}{8} \left[ 3 - \sqrt{1 - 4\beta\sqrt{1 - \log 2} - 36\beta^2(1 - \log 2)} + 2\beta\sqrt{1 - \log 2} \right] \\ \pi_A^*(aab) &= 1 - x_{a1}^* - \frac{\beta \log 2}{\sqrt{1 - \log 2}} \quad \text{if } 0.19 < \beta < 0.45. \end{aligned} \quad (15)$$

**Sandwich by A (aba).** Calculations similar to Eq. (14) yield the following SPNE candidate:

$$\begin{aligned} x_{a1}^* &= \begin{cases} \frac{1}{2} - \beta\sqrt{1 + \log 2} & \text{if } 0.18 < \beta < 0.38 \\ \frac{1}{4} \left[ 1 + 2\beta - \sqrt{1 - 4\beta + 4(1 - 4\log 2)\beta^2} \right] & \text{if } 0.16 < \beta < 0.18 \end{cases} \\ \pi_A^*(aba) &= x_{a1}^* + \frac{1}{2} - \frac{2\beta^2(1 + \log 2)}{1 - 2x_{a1}^*}. \end{aligned} \quad (16)$$

**Enclosure by B (baab).** Similarly, an SPNE candidate is given by:

$$\begin{aligned} x_{a1}^* &= \begin{cases} \beta(2 - \sqrt{1 - \log 2}) & \text{if } 0.19 < \beta < 0.35 \\ \frac{1}{6} \left[ 2 + 2\beta - \sqrt{1 - 4\beta + 4(4 - 3\log 2)\beta^2} \right] & \text{if } 0.18 < \beta < 0.19 \\ \frac{1}{8} \left[ 3 + 2\beta - \sqrt{1 - 4\beta + 36\beta^2} \right] & \text{if } 0 < \beta < 0.18 \end{cases} \\ \pi_A^*(baab) &= 1 - 2x_{a1}^*. \end{aligned} \quad (17)$$

**Enclosure by A (abba).** Likewise, an SPNE candidate is:

$$\begin{aligned} x_{a1}^* &= \begin{cases} \frac{1}{2} - (1 + \sqrt{\log 2})\beta & \text{if } 0.16 < \beta < 0.27 \\ \frac{1}{8} \left[ 3 - 2\beta - \sqrt{1 + 4\beta - 28\beta^2} \right] & \text{if } 0 < \beta < 0.16 \end{cases} \\ \pi_A^*(abba) &= 2x_{a1}^*. \end{aligned} \quad (18)$$

**Interlacing (abab).** Similarly, an SPNE candidate is computed as:

$$\begin{aligned} x_{a1}^* &= \begin{cases} \frac{1}{2} \left[ 1 + 2\beta - \sqrt{1 - 4\beta + 4(1 - 4\log 2)\beta^2} \right] & \text{if } 0.16 < \beta < 0.18 \\ \frac{1}{8} \left[ 3 - 2\beta - \sqrt{1 + 4\beta - 28\beta^2} \right] & \text{if } 0 < \beta < 0.16 \end{cases} \\ \pi_A^*(abab) &= \frac{1}{2} - \frac{2\beta^2}{1 - 2x_{a1}^*}. \end{aligned} \quad (19)$$

Based on comparison of the seven profits  $\pi_A^*(ab)$ ,  $\pi_A^*(bab)$ ,  $\pi_A^*(aab)$ ,  $\pi_A^*(aba)$ ,  $\pi_A^*(baab)$ ,  $\pi_A^*(abba)$  and  $\pi_A^*(abab)$  as given by Eqs. (12) (13), (15), (16), (17), (18) and (19), respectively, firm  $A$  selects the best number of stores and their locations. Tedious but straightforward computations revealed that configurations  $bab$  and  $abba$  are not selected as an SPNE for any  $\beta$ , while the other five configurations are selected as an SPNE, depending on  $\beta$ . In summary, we establish the following.

**Proposition 3** *For sequential entry of duopolists, five cases may arise.*

(i) *When  $0.31 < \beta < 1/2$ , firm A establishes one store at the center  $x_a = 1/2$  and firm B one store at  $x_b = 1/2 + \beta \in (0.81, 1)$ .*

(ii) *When  $0.21 < \beta \leq 0.31$ , firm A establishes two stores at  $x_{a1} \in (0.27, 0.28)$  and  $x_{a2} \in (0.72, 0.73)$ , and firm B one store at  $x_b = x_{a2} + \beta\sqrt{1 - \log 2} \in (0.84, 0.90)$ .*

(iii) *When  $0.16 < \beta \leq 0.21$ , firm A establishes two stores at  $x_{a1} \in (0.22, 0.27)$  and  $x_{a2} \in (0.73, 0.78)$ , and firm B one store at the center  $x_b = 1/2$ .*

(iv) *When  $1/8 < \beta \leq 0.16$ , firm A establishes two stores at  $x_{a1} \in (0.27, 0.28)$  and  $x_{a2} \in (0.72, 0.73)$ , and firm B two stores at  $x_{b1} = x_{a1} - \beta$  and  $x_{b2} = x_{a2} + \beta$ .*

(v) *When  $0 < \beta \leq 1/8$ , firm A establishes two stores at  $x_{a1} \in (0.21, 0.25)$  and  $x_{a2} \in (0.75, 0.79)$ , and firm B two stores at  $x_{b1} = 1/2$  and  $x_{b2} = x_{a2} + \beta$ .*

Proposition 3 is illustrated in Figure 1. There are three remarks. First, observe that the first entrant opens one store at  $x_a = 1/2$  or two stores at  $(x_{a1}, x_{a2}) \approx (1/4, 3/4)$ , which are the socially optimum locations. Since more than half of consumers go to the stores of the first entrant, welfare losses due to the non-cooperative behavior of firms may not be as large.

Second, we might consider whether or not the first entrant  $A$  can preempt the the second entrant by opening multiple stores. It can be readily verified that such a multi-store monopoly is not possible for any  $\beta < 0.5$ . For  $\beta \geq 0.5$ , spatial monopoly is possible, but only by a single store, as shown in Proposition 2. Hence, multi-store spatial monopoly is never realized as an equilibrium outcome in the setting of location-then-variety competition.

Third, the first entrant always opens a number of stores greater than or equal to the number opened by the second entrant. For example, in the segmented case (ii), while the first entrant establishes two stores near one and three quarters of the segment, the second entrant can locate only at a periphery. This implies that *spatial preemption is an effective strategy* for chain-store firms. Whereas such spatial preemption rarely appears as an equilibrium outcome in the literature on spatial competition, it is observed in many retail markets, which may vindicate our spatial variety competition between chain-store firms.

The profits of the two firms are illustrated in Figure 2. Both profits are not monotonic with respect to the intensity of competition  $\beta$ . However, we can roughly state that as the intensity of competition increases, the profit of the second entrant tends to decrease, while that of the first entrant does not. We can also observe that *the first entrant always earns higher profit than the second entrant*. Thus, what is true for the single-store duopoly in the previous section is also true for the multi-store duopoly.

When competition is not intense ( $\beta$  small), both firms open multiple stores. The profits are not low compared to the case with large  $\beta$  because the intensity of competition is relaxed. Hence, *proliferating stores do not harm each other*, i.e., the so-called prisoners' dilemma does not occur in variety competition. It should finally be noted that multi-store configurations never arise in the location-then-price competition of Martinez-Giralt and Neven (1988).

## 5 Conclusion

We have examined the location-then-variety competition of a multi-product and multi-store oligopoly, in which the number of firms, the number and location of stores, and the number of varieties are endogenously determined. It was revealed that location-then-variety competition with multi-stores can better describe the spatial configurations of the retail sector in the real world, such as market segmentation, interlacing, sandwich and enclosure.

Furthermore, we have shown that any store locates inside the market segment whenever firms achieve positive profits. We have also shown that when competition is keen ( $\beta$  large), market globalization leads to a natural monopoly, i.e., the first entrant conducts spatial preemption. These results are in sharp contrast to spatial price competition. On the other hand, when competition is weak ( $\beta$  small), firms establish multiple stores at a certain distance from rival stores. This is in contrast to spatial Cournot competition, as well as spatial price competition.

## Appendix

### A1. Existence of a unique Nash equilibrium in variety competition

Suppose firms  $A$  and  $B$  locate at  $n_a$  and  $n_b$  respectively. When store  $s$  is sandwiched between stores  $r$  and  $t$  such that  $x_r < x_s < x_t$ , the profit of store  $s$  is:

$$\begin{aligned} \pi_s &= \sum_{v=1}^{v_s} pq_{sv}(\hat{x}_{st} - \hat{x}_{rs}) - fv_s \\ &= \hat{x}_{st} - \hat{x}_{rs} - fv_s \\ &= \frac{x_s + x_t}{2} + \frac{\beta \log(v_s/v_t)}{2(x_t - x_s)} - \frac{x_r + x_s}{2} - \frac{\beta \log(v_r/v_s)}{2(x_s - x_r)} - fv_s \\ &= g_{rst} \log(v_s) + h_{rst}(v_s), \end{aligned}$$

where  $g_{rst} \equiv \frac{\beta(x_t - x_r)}{2(x_t - x_s)(x_s - x_r)}$  is a positive constant and  $h_{rst}(v_s)$  is linear in  $v_s$ . Because  $v_{ai} = v_a$

for all  $i$ , the total profit of firm  $A$  is given by:

$$\begin{aligned}
\pi_A &= \sum_{i=1}^{n_a} \pi_{ai} \\
&= \sum_{i=1}^{n_a} g_{ra_i t} \log(v_{a_i}) + h_{rst}(v_{a_i}) \\
&= \left( \sum_{i=1}^{n_a} g_{ra_i t} \right) \log(v_a) + h_{rst}(v_a).
\end{aligned}$$

Since this is concave in  $v_a$ , a unique Nash equilibrium exists.

## A2. Endogenous price model

The prices of differentiated goods are endogenously determined if each good is produced and sold by a tenant firm in a monopolistically competitive market. Building on Henkel, Stahl and Walz (2000), assume that there are a few developers each owning a shopping mall (or a department store)  $r$  at location  $x_r$ , where there are many tenant firms. Each tenant firm pays rent to developer  $r$ , and sells a differentiated good that is produced with a fixed input requirement  $f$  and a marginal input requirement  $c$ .

The profit of a representative tenant  $v$  at mall  $r$  is given by:

$$\pi_{rv} = (p_{rv} - c) q_{rv} (\hat{x}_{rs} - \hat{x}_{tr}) - f - P_r, \quad (\text{A-1})$$

where  $s$  and  $t$  are neighboring malls,  $P_r$  is the rent at mall  $r$ , and the demand for variety  $v$  by a consumer who visits mall  $r$  is

$$q_{rv} = \frac{p_{rv}^{-\sigma}}{\sum_{u=1}^{v_r} p_{ru}^{1-\sigma}}.$$

We add the last stage of price competition to the games in the text without changing the earlier stages. For example, the simultaneous (sequential) entry game is now as follows. Developers simultaneously determine the number of malls  $n_r$  and the locations of malls  $r_1, r_2, \dots, r_{n_r}$  at  $x = x_{r_1}, x_{r_2}, \dots, x_{r_{n_r}}$  in the first stage(s); developers simultaneously choose the number of tenant firms  $(v_{r_1}, v_{r_2}, \dots, v_{r_{n_r}})$  and set the rent  $(P_{r_1}, P_{r_2}, \dots, P_{r_{n_r}})$  such that they absorb all the profits of tenant firms in the next stage, and each tenant firm simultaneously selects the price of a differentiated good in the last stage. Seeking SPNE by backward induction, we only need to compute the last-stage price game.

Since the number of tenant firms is large enough in each mall, the effect of the price  $p_{rv}$  of tenant  $v$  in mall  $r$  on  $\hat{x}_{rs}$  and  $\hat{x}_{tr}$  is negligible. Maximization of profits (A-1) with respect to  $p_{rv}$  yields the equilibrium price

$$p_{rv}^* = \frac{\sigma c}{\sigma - 1} \quad (\text{A-2})$$



for all  $r$  and  $v$ . Because the price in Eq. (A-2) is constant, the endogenous price model is reduced to the exogenous price model in the text.

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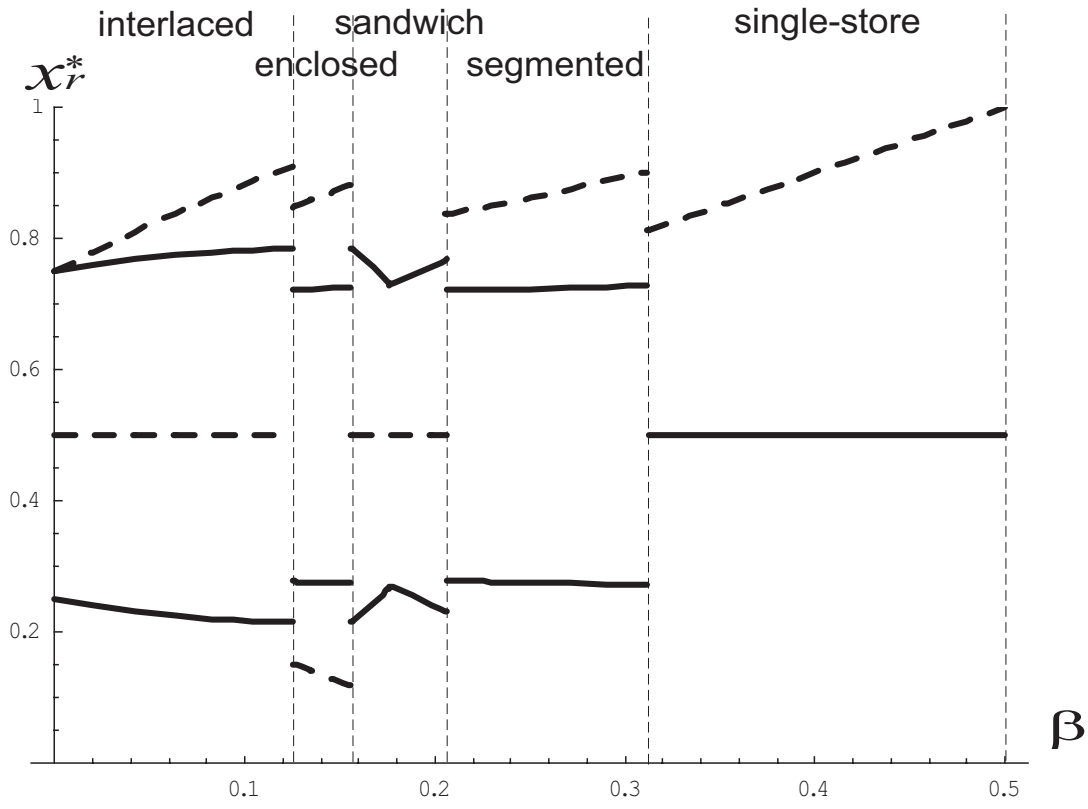


Figure 1: Locations of the first entrant (solid) and the second entrant (broken)

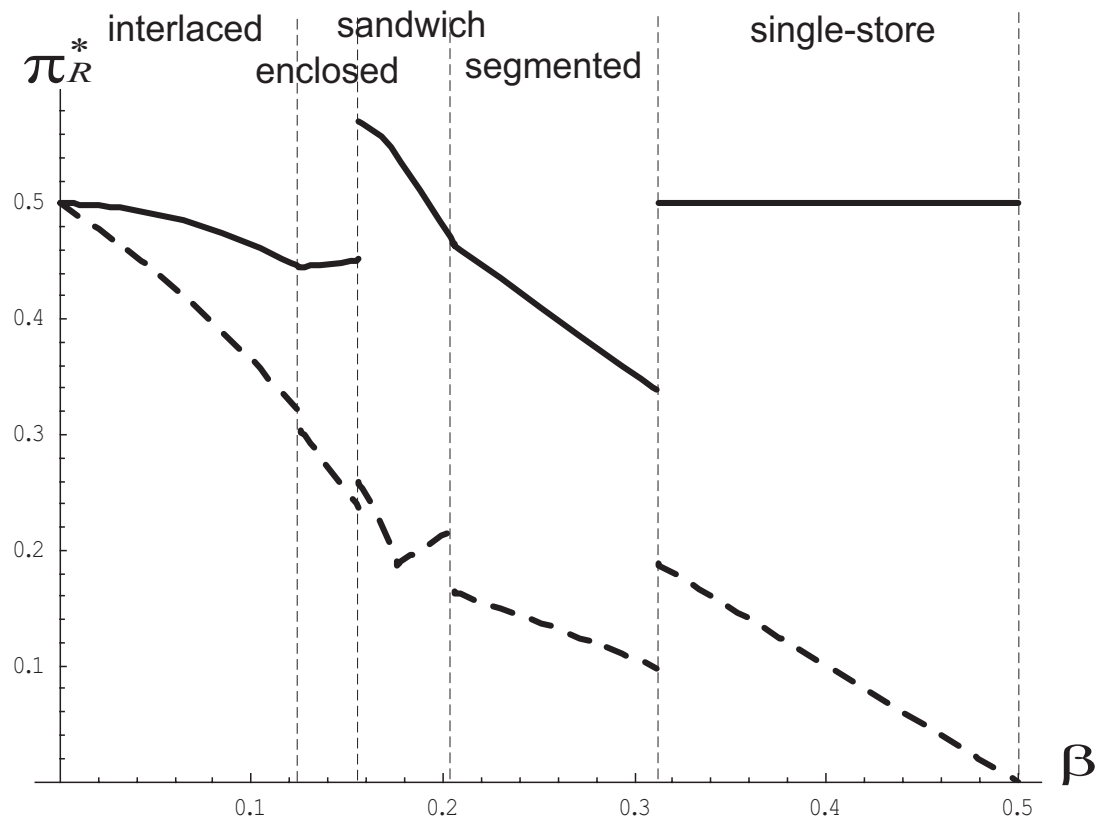


Figure 2: Profits of the first entrant (solid) and the second entrant (broken)