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Does it Pay to be First? Sequential Locational Choice and Foreclosure*

by

Nicholas Economides,** Jamie Howell, and Sergio Meza**

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Abstract

We analyze the *sequential* choices of locations in the Hotelling [0, 1] space of variety-differentiated products. n firms locate in sequence, one at a time. In stage n+1, all firms choose prices simultaneously. Firms anticipate correctly the decisions of subsequent entrants, as well as the equilibrium prices, so we analyze subgame-perfect equilibria. We analyze two games. In the first, the number of firms is fixed. In the second, the number of firms is determined by free entry, *i.e.*, entry continues until the last entrant makes non-negative profits. When the number of firms is fixed, the ordering of profits follows the order of action. When the number of firms is determined by free entry, for a range of fixed costs, early entrants choose their positions strategically so as to keep out potential entrants. For a range of fixed costs, early actors reduce the distances among them to foreclose entry even though these actions reduce their profits given the number of active firms. For low enough fixed costs, entry cannot be prevented any more and a new firm enters resulting in a complete disruption of the locational pattern. In the game with a fixed number of firms, we find that the order of the profits of the firms is the same as the order of action, so that it pays to be first. In contrast, in the free entry game it does not always pay to be first. We also note that entry of a new firm significantly reduces the pre-entry profits of incumbents. Thus, if a technology is available that would increase the costs of both incumbents and entrants ("raising both rivals and own costs"), it will be used to deter entry.

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** Stern School of Business, New York University, 44 West 4th Street, New York, New York 10012, tel. (212) 998-0864, fax (212) 995-4218. e-mail: neconomi@stern.nyu.edu, smeza@stern.nyu.edu. www: http://www.stern.nyu.edu/networks/

Does it Pay to be First? Sequential Locational Choice and Foreclosure

1. Introduction

Although there exist numerous models of *symmetric* locational product differentiation, not enough modeling has been done of asymmetric locational settings.[1] Nevertheless, there are many market situations where firms choose variety specifications sequentially. In this paper, we analyze a variation of Hotelling's (1929) model of differentiated products where firms locate sequentially in the product space and subsequently all choose prices simultaneously. This is a model of Stackelberg leadership in the choice of locations, followed by a stage of simultaneous price choice. Because pricing and production decisions are taken simultaneously, a firm that locates first does not have the possibility to sell first or capture consumers. However, such a firm can choose to position itself in the product space most advantageously.

The main focus of the paper is the strategic asymmetry of the participants and the resulting asymmetric locational equilibrium. Since firms locate sequentially, the locational choices of firms that act earlier influence the locational choices of subsequent actors. Taking this into consideration, firms that locate early in the game carve their locational niche anticipating the subsequent choices of locations. Thus, we expect significant differences in this model's equilibrium in comparison with the traditional models of simultaneous choice of locations.[2] Although our analysis is of *variety*-differentiated products, our results can also be applied to *quality*-differentiated products using the equivalence established by Shaked and Sutton (1982).

We are interested in the game where firms can use their positioning to deter the entry of subsequent firms. As a preliminary tool for this analysis, we first analyze the game where the number of firms is fixed. In this game, with knowledge of the number n of active firms, firms choose locations, one at each of n stages.[3] In stage n + 1, firms choose prices simultaneously.

We then examine the game where the number of firms is endogenously determined. In this game, firms enter and locate, one at each stage. At the end of this process, they choose prices simultaneously. Entry occurs as long as a firm can realize non-negative post-entry profits. We seek subgame-perfect equilibria. In this game, each firm has a limited ability to deter future entrants through its location choice.

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[1] Among the exceptions are Prescott and Visscher (1977), Lane (1980), Eaton and Wooders (1985) and Rothschild (1976). Our model is in the spirit of Lane (1980), but uses a locational framework as in Hotelling (1929). After the first version of our paper was circulating, we discovered that Neven (1987) has analyzed part of the same problem independently.

[2] For example, Salop, (1979), Economides (1989, 1993a).

[3] In stage i, firm i (i = 1, ..., n) locates in the space of characteristics, C. In choosing a location, firm i anticipates correctly the location of firms of higher index that locate in later stages. Thus, firm i acts as a (location) leader with respect to firms i + 1, ..., n, and as a (location) follower with respect to firms 1, ..., i - 1.

These games differ in the extent that firms can make commitments in locating and in entering. By separating the price choice to a later stage, we assume that prices are more flexible than entry and location. The sequential entry game assumes that entry and product specification choice are equally flexible, while the fixed number of firms sequential location game assumes that the entry choice is less flexible than the product specification choice.

The equilibrium locations imply a *potential market area* for each firm, which would be its market share if all prices were equal. Because price competition in general leads to unequal equilibrium prices, the equilibrium market shares will differ from the potential market areas. Thus, a market can be look more (or less) concentrated at equilibrium than its locational structure implies.

Given the locations, the equilibrium in prices is straightforward. However, the problem of searching for the equilibrium locations structure in the earlier stages of the game is computationally quite hard. Each firm has to take into account the effects of its locational decision on the decisions of all firms that locate after it. For example, firm 1 has to take into account a number of effects. First, the *direct effects* of its location choice, y_1, on the locational decision of firm 2, y_2, on the locational decision of firm 3, y_3, etc. Second, firm 1 has to take into account the *indirect effects*. There is a second round indirect effect of y_1 on y_3 and y_4 through y_2. There is also a third round indirect effect of y_1 on y_4 through y_3 *and* y_2; that is, y_4 is influenced by y_3, as y_3 is influenced by y_2, which is itself influenced by y_1. It is evident that the level of complexity of the calculation increases dramatically with the number of stages in the decision process, which here coincides with the number of firms. Because of the absence of closed-form solutions for these effects, we used numerical techniques. We chose locations y_i on a grid of coarseness 0.01.[4] Computing power limitations restricted us to a maximum of five competing firms (brands). We therefore report results for two, three, four, and five brands.

The rest of the paper is organized as follows: Section 2 sets up the basic model. Section 2.1 discusses the equilibrium of the price (last) stage of the game. Section 2.2 discusses the setup of the stage of sequential locations choice, both for a fixed and an endogenously-determined number of firms. Section 3 reports the results for the sequential location game with a fixed number of firms. Section 4 presents the results for the sequential location game with an endogenously-determined number of firms. Section 5 presents concluding remarks.

2. Model Set-up

Let C be the line interval [0, 1]. Consumer of type z, $z \in C$, receives utility[5]

$$U_z(z, x, m, p_x) = m - p_x + k - \lambda(x - z)^2$$

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[4] For n = 5 firms we used a grid of coarseness 0.02. Use of a finer grid proved infeasible even with maximum computing power.

[5] The homogeneous outside good can be thought of as a Hicksian composite commodity.

from the consumption of one unit of differentiated good of type x sold at price p_x. With this utility specification, consumer "z" has single-peaked preferences in the space of characteristics, which peak at $x = z$, when the specification of the offered product x coincides with the consumer's ideal product specification z. If consumer of type z (who prefers most variety "z") buys a product of specification x other than z, he incurs a utility cost (loss) of $\lambda(x - z)^2$. Parameter k represents the reservation price for the most preferred variety. We assume that k is large enough so that all consumers buy one unit of the differentiated product. Consumers are distributed uniformly according to their type on C. There are no variable production costs, although the extension to constant marginal costs is straightforward.[6]

We begin by analyzing the last stage where firms choose prices. In the earlier stages of the game, firms i = 1, …, n have chosen locations $(y_1, ..., y_n)$. These locations are, in general, not ordered *a priori* in any way. To analyze the price stage, we order the locations y_i and assign them one to one to locations x_j such that $x_j \geq x_{j-1}$. If two (or more) firms have located at the same position, then the equilibrium price (and profits) for these firms in the second stage subgame will be zero.[7] Thus, no two firms will choose the same location, and we assume that n firms are at distinct locations $(x_1, ..., x_n) \equiv \mathbf{x}$, where $x_{j+1} > x_j$, for $j = 1, ..., n - 1$. The demand faced by a typical firm j (other than the first or last firms) is generated by consumers in the interval $[z_{j-1}, z_j]$, where z_j (respectively z_{j-1}) represents the marginal consumer who is indifferent between buying from firm j and j+1 (respectively j and j-1). Since the marginal consumer is

$$z_j = [(p_{j+1} - p_j)/(x_{j+1} - x_j) + \lambda(x_{j+1} + x_j)]/(2\lambda),$$

the demand facing firm $j \neq 1, j \neq n$ is

$$D_j = \int_{z_{j-1}}^{z_j} dz = [(p_{j+1} - p_j)/(x_{j+1} - x_j) - (p_j - p_{j-1})/(x_j - x_{j-1}) + \lambda(x_{j+1} - x_{j-1})]/(2\lambda).$$

For the first and the last firms, demand is:

$$D_1 = \int_0^{z_1} dz = [(p_2 - p_1)/(x_2 - x_1) + \lambda(x_1 + x_2])/(2\lambda),$$

$$D_n = \int_{z_{n-1}}^{1} dz = 1 - [(p_n - p_{n-1})/(x_n - x_{n-1}) + \lambda(x_n + x_{n-1})]/(2\lambda).$$

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[6] In a model with constant marginal cost c, a price p of this model is interpreted as the increment of price above marginal cost. Thus, in the positive marginal cost model, prices are $P = p + c$.

[7] Price-setting firms drive price to marginal cost when their specifications are identical.

2.1 Equilibrium In The Price (Last) Stage

Letting $\mathbf{p} \equiv (p_1, ..., p_n)$ denote the vector of prices and assuming no costs, the profit function of firm j is

$$\Pi_j(\mathbf{p}, \mathbf{x}) = p_j D_j(\mathbf{p}, \mathbf{x}).$$

In the last stage of the game, all firms choose prices simultaneously. The non-cooperative equilibrium of a price subgame played for fixed locations is characterized by the following first order conditions for firms 2 to n-1:

$$2p_j[1/(x_{j+1} - x_j) + 1/(x_j - x_{j-1})] - p_{j-1}/(x_j - x_{j-1}) - p_{j+1}/(x_{j+1} - x_j) = \lambda(x_{j+1} - x_{j-1}),$$

$$j = 2, ..., n - 1.$$

For the first and the last firms, first order conditions are:

$$2p_1/(x_2 - x_1) - p_2/(x_2 - x_1) = \lambda(x_1 + x_2),$$

$$2p_n/(x_n - x_{n-1}) - p_{n-1}/(x_n - x_{n-1}) = \lambda[2 - (x_n + x_{n-1})].$$

All maximization conditions can be summarized as

$$\mathbf{B}.\mathbf{p}^* = \mathbf{w}, \tag{1}$$

where

$$w_j = \lambda(x_{j+1} - x_{j-1}),\ \mathbf{B}_j = (0, ..., 0, -1/(x_j - x_{j-1}), 2[1/(x_{j+1} - x_j) + 1/(x_j - x_{j-1})], -1/(x_{j+1} - x_j), 0, ..., 0),$$

$$\text{for } j \neq 1, j \neq n, \text{ and}$$

$$w_1 = \lambda(x_1 + x_2),\ \ w_n = \lambda[2 - (x_n + x_{n-1})],$$

$$\mathbf{B}_1 = (2/(x_2 - x_1), -1/(x_2 - x_1), ..., 0),\ \ \mathbf{B}_n = (0, ..., -1/(x_n - x_{n-1}), 2/(x_n - x_{n-1})).$$ [8]

The profit functions in the subgame of price choice (stage n+1) are concave since demand functions are linear.[9] Therefore second order conditions are also satisfied, and the subgame has a non-cooperative equilibrium. Moreover, for each location vector $\mathbf{x}$, the equilibrium prices vector $\mathbf{p}^*(\mathbf{x}) = (p_1(\mathbf{x}), ..., p_j(\mathbf{x}), ..., p_n(\mathbf{x}))$ is unique. Uniqueness of the equilibrium is guaranteed from the fact that the best reply mapping is a contraction since

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[8] $\mathbf{B}_j$ is the jth row of matrix **B.**

[9] This is a consequence of the quadratic transportation costs in distance, as observed by D'Aspremont *et al*. (1979) and Economides (1989).

$$\partial^2\Pi_j/\partial p_j^2 + \sum_{i \neq j} \partial^2\Pi_j/\partial p_j\partial p_i < 0.$$

Using numerical techniques we solve the system (1) and derive the equilibrium prices as functions of locations,

$$\mathbf{p}^*(\mathbf{x}) = (p_1^*(\mathbf{x}), ..., p_n^*(\mathbf{x})) \tag{2}$$

Equilibrium profits of firm j, $j \neq 1$, $j \neq n$, are:

$$\Pi_j^*(\mathbf{x}) \equiv \Pi_j(\mathbf{p}^*(\mathbf{x}), \mathbf{x}) = p_j^* D_j^* = (p_j^*(\mathbf{x}))^2[1/(x_{j+1} - x_j) + 1/(x_j - x_{j-1})]/(2\lambda). \tag{3a}$$

For the first and last firms equilibrium profits are:

$$\Pi_1^*(\mathbf{x}) \equiv \Pi_1(\mathbf{p}^*(\mathbf{x}), \mathbf{x}) = p_1^* D_1^* = (p_1^*(\mathbf{x}))^2/[2\lambda(x_2 - x_1)], \tag{3b}$$

$$\Pi_n^*(\mathbf{x}) \equiv \Pi_n(\mathbf{p}^*(\mathbf{x}), \mathbf{x}) = p_n^* D_n^* = (p_n^*(\mathbf{x}))^2/[2\lambda(x_n - x_{n-1})]. \tag{3c}$$

2.2 Setup of The Sequential Locations Choice Stage

The equilibrium profits of the price subgame are the objective functions of the first n stages, where firms choose locations. Firm i acts as a location-choice leader with respect to firms i + 1, ..., n, and as a location-choice follower with respect to firms 1, ..., i - 1. Thus, firm i recognizes the influence of its location choice x_i on firms i + k, k > 0, but considers location choices y_{i-k}, k > 0, as fixed. We will consider two sequential location games. In the first game, the number of firms is fixed. Thus, a firm that acts first has the ability to influence the market area that will be under the control of firms that choose location later, but cannot influence the number of active firms. In the second game, the number of active firms is determined by a zero profit condition. Thus, by locating appropriately, an early locator can limit the profits of firms that locate later, and, for some range of fixed costs, make the profits of a potential entrant negative so that it does not enter the market. Therefore, when the number of firms is variable and determined by zero profit condition, firms can use their locational choice strategically to limit the number of competitors.

Let the equilibrium locations be

$$\mathbf{y}^* = (y_1^*, ..., y_i^* ..., y_n^*),$$

corresponding to

$$\mathbf{x}^* = (x_1^*, ..., x_j^*, ..., x_n^*).$$

Subgame-perfect equilibrium prices are found by substitution in equation (2) as

$$\mathbf{p}^*(\mathbf{x}^*) = (\mathbf{p_1}^*(\mathbf{x}^*), ..., \mathbf{p_n}^*(\mathbf{x}^*)).$$

In discussing the equilibrium locations of firms, a few definitions are necessary. We define the *potential market area* for a firm located at x_j as half the distance between the immediate firm to the right and the immediate firm to the left, $m_j = (x_{j+1} - x_{j-1})/2$, where for the firm closest to 0 and the firm closest to 1 we interpret $x_0 = 0$ and $x_{n+1} = 1$. The potential market area would be the realized equilibrium demand if all prices were equal.

We also define the *locational asymmetry index* ("LAI") as

$$\mathrm{LAI} = \Sigma_{j=1}^{n} (m_j)^2 = \Sigma_{j=1}^{n} [(x_{j+1} - x_{j-1})/2]^2. \quad (4)$$

This index has similar properties to the Herfindahl-Hirschman index of market concentration ("HHI"), defined as the sum of the squared market shares, $\mathrm{HHI} = \Sigma_{i=1}^{n} s_i^2$, where s_i is the share of sales of firm i. LAI decreases as the locations become more symmetric. By its definition, the locational asymmetry index, LAI, takes the same value as the Herfindahl index for a market with shares m_j. Thus, when prices are equal, the index of locational asymmetry collapses to the Herfindahl index. Index LAI also tends to decrease as the number of brands increases. By comparing the locational asymmetry index, LAI, with the Herfindahl index, HHI, we can indirectly measure the extent to which locational asymmetries are translated into differences in equilibrium market shares.

In general, we expect that the sequential location equilibria will be asymmetric, and this will reduce surplus. We also expect that total surplus will be lower in the game of sequential location because the asymmetric distribution of locations forces consumers to travel longer distances on the average, and transportation costs are convex in distance. To assess the extent of the distortion of total surplus, we calculate the surplus loss due to transportation costs in our asymmetric model and we compare it with its counterpart for symmetric locations. The surplus loss due to "transportation costs" of consumers who buy from the firm located at x_j is

$$\mathrm{CSL}_j = \int_0^{z_j - x_j} \lambda s^2\, ds + \int_0^{x_j - z_{j-1}} \lambda s^2\, ds = \lambda[(z_j - x_j)^3 + (x_j - z_{j-1})^3]/3, \quad (5)$$

where z_j, z_{j-1} are the marginal consumers of firm j. Industry-wide consumers' surplus loss due to "transportation costs" (*i.e.*, because consumers are not offered their ideal varieties) is $\mathrm{CSL}(n) = \Sigma^{n}_{j=1} \mathrm{CSL}_j$. As a reference point for surplus comparisons, we note that the optimal locational structure is symmetric with consecutive firms located 1/n apart, and the first and last firms located at 1/2n from the boundaries. The minimal (given the number of varieties) consumers' surplus loss from "transportation costs" at the optimal surplus structure is $\mathrm{CSL}^o(n) = 1/(12n^2)$. We will also refer to the consumers' surplus of the game of simultaneous location choice as $\mathrm{CSL}^s(n)$.[10]

[10] In the comparisons with the simultaneous-location game (with subsequent simultaneous choice of prices) we use the results of Jingbin Cao (1991).

3. Results for the Sequential Location Game With a Fixed Number of Firms

We first analyze the sequential location game when the number of firms is fixed. The equilibrium locations for 2, 3, 4, and 5 firms are shown in Figure 1. In the tables below we note the equilibrium locations with a fixed number of firms, and we compare the equilibrium surplus loss, CSL(n), with the surplus loss of the simultaneous locations choice game, $CSL^s(n)$, and the minimum surplus loss of the optimal locational structure, $CSL^o(n)$.

Figure 1: Sequential Location Choices With a Fixed Number of Firms

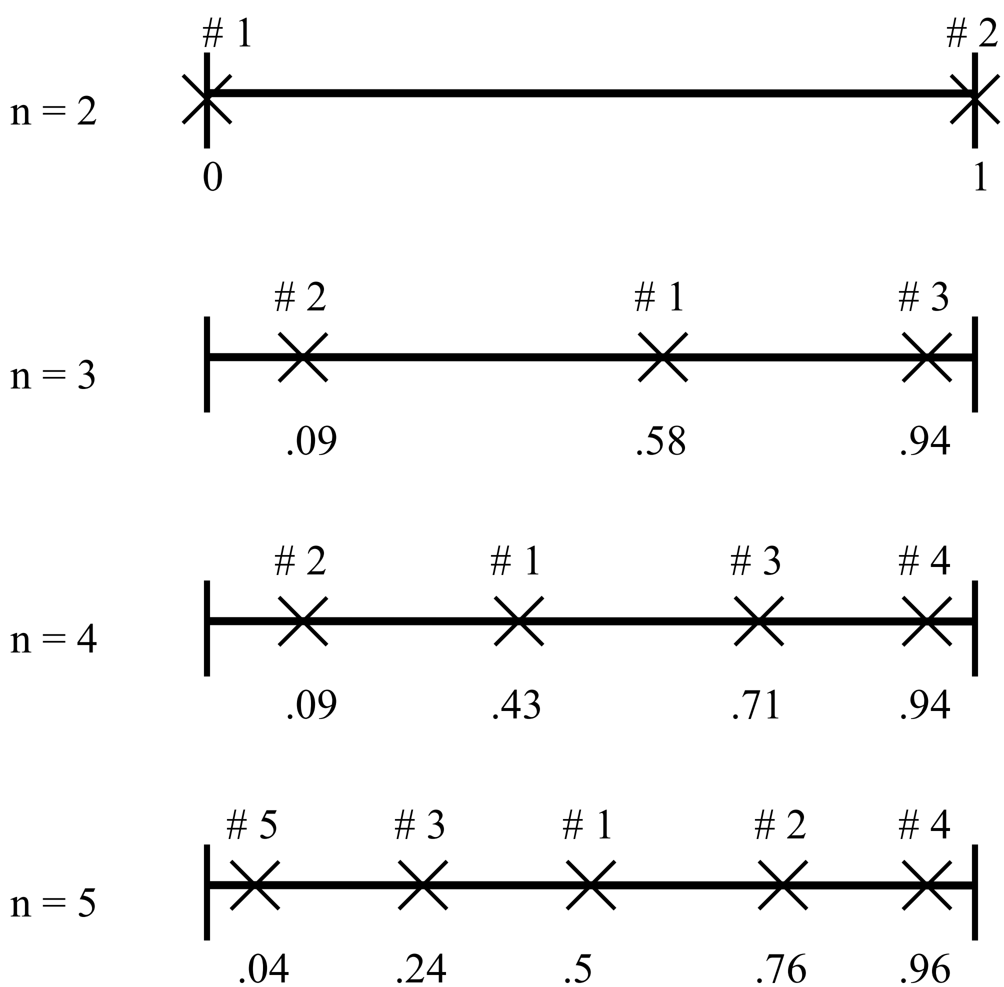


Table 1
Equilibrium locations and prices in sequential choice with two competing firms

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area	
1	0	1	0.5	0.5	0.5	*
2	1	1	0.5	0.5	0.5	*

$CSL(2) = 0.0833331$, $CSL^s(2) = 0.083333$, $CSL^o(2) = 0.020833$,
$CSL(2)/CSL^s(2) = 1$, $CSL(2)/CSL^o(2) = 4$,
$HHI(2) = 0.5$, $LAI(2) = 0.5$.

Asterisks (*) indicate the firms that locate closest to the endpoints of the market at 0 and 1. In duopoly, firms choose to locate at the endpoints. This is exactly the same equilibrium as in the game of *simultaneous choice* described by D'Aspremont *et al.* (1979).[11] Thus, prices and profits are equal, $p_1 = p_2 = 1$ and $\Pi_1 = \Pi_2 = 0.5$. The Herfindahl index and locational asymmetry indexes are equal, $HHI(2) = LAI = 0.5$. Despite equality in market shares, there are significant losses because the firms are located far apart. These losses are indicated by the high ratio of actual surplus loss CSL(2) compared to minimal surplus loss $CSL^o(2)$ of the optimal (surplus maximizing) locational structure.

Table 2
Equilibrium locations and prices in sequential choice with three competing firms

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area	
1	0.58	0.197153	0.093647	0.475000	0.425	
2	0.09	0.262726	0.070433	0.268088	0.335	*
3	0.94	0.184976	0.047522	0.256912	0.24	*

$CSL(3) = 0.016304$, $CSL^s(3) = 0.011393$, $CSL^o(3) = 0.009259$,
$CSL(3)/CSL^s(3) = 1.43$, $CSL(3)/CSL^o(3) = 1.76$,
$HHI(3) = 0.3635$, $LAI(3) = 0.3504$.

The first firm locates near the center of the market, but not exactly at the center. Firm 1 anticipates the positioning of firms 2 and 3 on its left and right. By creating an asymmetric situation for the other firms, firm 1 gets a larger potential market share than if the situation was symmetric with firm 1 locating at 0.5 and firms 2 and 3 locating at 0.5 - d and 0.5 + d. Further, firm 1 expands output beyond its potential market share. Firm 1 accomplishes this result by choosing a price that is only slightly above the price of firm 3, $p_2 > p_1 > p_3$. The order of equilibrium profits follows the order of action, $\Pi_1 > \Pi_2 > \Pi_3$. The variance of the potential market areas is smaller than the variance of the equilibrium market

[11] From D'Aspremont *et al.* (1979) we know that if firm 1 locates at any $x_1 \in [0, .5)$, firm 2 chooses $x_2^*(x_1) = 1$ because $\partial\Pi_2^{**}/\partial x_2 > 0$ for all $x_2 \in (x_1, 1]$. Firm 1 maximizes $\Pi_1^{**}(x_1, x_2^*(x_1)) = \Pi_1^{**}(x_1, 1)$ with respect to x_1. Since $\partial\Pi_1^{**}(x_1, 1)/\partial x_1 < 0$ for all $x_1 < 1$, firm 1 chooses $x_1 = 0$. Therefore the equilibrium is $x_1^* = 0$, $x_2^* = 1$, and it coincides with the equilibrium of the simultaneous location choices game.

shares; the index of locational inequality is smaller than the Herfindahl index, LAI(3) < HHI(3). This shows that firms convert their locational advantages into higher market shares than their potential market areas. The surplus loss because of transportation costs is CSL(3) = 0.016304. This is 43% larger than the surplus loss in the case of simultaneously locating firms, $CSL^s(3)$ = 0.011393. Compared to optimality, CSL(3) is 76% larger than the minimum surplus loss.

Table 3
Equilibrium locations and prices in sequential choice with four competing firms

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area
1	0.43	0.099709	0.032374	0.324685	0.31
2	0.09	0.138255	0.028109	0.203316	0.26 *
3	0.71	0.076190	0.022985	0.301684	0.255
4	0.94	0.078345	0.013343	0.170315	0.175 *

CSL(4) = .008025, $CSL^s(4)$ = 0.007626, $CSL^o(4)$ = 0.005208,
$CSL(4)/CSL^s(4)$ = 1.05, $CSL(4)/CSL^o(4)$ = 1.54,
HHI(4) = 0.2668, LAI(4) = .2593.

The general locational pattern of firms 1, 2, and 3 in the four-brand case is very similar to their locational pattern in the three-brand case. Firms 1 and 3 are squeezed to the right of their positions in the three-brand case. The last (fourth) firm finds four open intervals that are ordered in terms of length as [0.09, 0.43], [0.71, 1], [0.43, 0.71], and [0, 0.09]. It locates at 0.94, which is in the second largest interval, [0.71, 1], and has the advantage of no competition from the right. Anticipating the location of the fourth firm to its right, the third firm locates in the largest interval available to it after firms 1 and 2 have located. Firm 3 chooses a location slightly to the right of the midpoint of the interval [0.43, 1], and thus can significantly squeeze firm 4, which is left with a relatively small potential market area.

Looking at the overall picture, we note that the second and the fourth firms choose locations nearest to the boundaries of the product space. The sequence of choices is leapfrogging, $x_1 = 0.43$, $x_2 = 0.09$, $x_3 = 0.71$, $x_4 = 0.94$. The ordering of profits still follows the order of actions, $\Pi_1 > \Pi_2 > \Pi_3 > \Pi_4$. The first firm is able to take advantage of acting first by securing the largest potential market area. Since its price is not the highest, $p_2 > p_1 > p_4 > p_3$, it has an even larger market share. The second firm has a higher price than both of its neighbors (firms 1 and 3). Its profits are smaller than those of firm 1, whose potential market area is larger than firm 2's but are greater than the profits of firm 3, whose potential market area is slightly smaller than that of firm 2. The surplus loss because of transportation costs is CSL(4) = 0.008025, which is 5% larger than the surplus loss of the case of simultaneously locating firms, $CSL^s(4)$ = 0.007626. Compared to optimality, CSL(4) is 54% larger than the minimum surplus loss.

Table 4
Equilibrium locations and prices in sequential choice with five competing firms

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area	
1	0.50	0.0613	0.014456	0.2358	0.26	
2	0.76	0.055014	0.0133868	0.2434	0.23	
3	0.24	0.055014	0.0133868	0.2434	0.23	
4	0.96	0.055507	0.007702	0.1388	0.14	*
5	0.04	0.055507	0.007702	0.1388	0.14	*

$CSL(5) = 0.0043823$, $CSL^s(5) = 0.005209$, $CSL^o(5) = 0.003333$,
$CSL(5)/CSL^s(5) = 0.8413$, $CSL(5)/CSL^o(5) = 1.3147$,
$HHI(5) = 0.2125$, $LAI(5) = 0.2126$.

As in the cases discussed earlier, each firm locates in the largest remaining interval at the time of its choice. The sequence of locational moves again leapfrogs. Like the case of three brands, and unlike the case of four brands, the last two firms locate very close to the boundaries. Different from previous cases, here we observe a certain level of symmetry. The first firm locates in the middle of the interval, firm 3 follows the same strategy of firm 2 but at the opposite side of firm 1, and firm 5 locates symmetrically to firm 4. The first firm does not manage to carve out a significant market area for itself and can secure a potential market area that is slightly larger to the second and third firm's potential market area. Further, its price is significantly higher than the price of the second and third firms which are its two neighbors. Thus, the first firm realizes a market share that is lower than its potential market area. In contrast, the second and third firms, with smaller potential market share to that of the first firm, capture the highest market share because they face high prices on both sides (firms 1, 4 and 5). As in previous cases, profits follow the order of action. The complete comparisons of prices and profits are $p_1 > p_4 = p_5 > p_2 = p_3$ and $\Pi_1 > \Pi_2 = \Pi_3 > \Pi_4 = \Pi_5$. The surplus loss because of transportation costs is $CSL(5) = 0.0043823$, which is 15.9% smaller than the surplus loss of the case of simultaneously locating firms, $CSL^s(5) = 0.005209$. This shows a more favorable positioning of the firms from the welfare point of view than in the simultaneous game. Of course, compared to optimality the surplus loss is larger -- CSL(5) is 29.9% larger than the minimum surplus loss.

The main features of the sequential location equilibria with a fixed number of firms can be summarized as follows:

(1) In the case of two brands the equilibrium of the sequential location game coincides with the equilibrium in the simultaneous location choice game.

(2) For three or more brands we have the following results. The order of action is preserved in the order of equilibrium potential market areas, and profits. In the case of three and four firms, the second firm is the one with the highest price. But in the case of five firms the first firm exhibits the highest price.

(3) The equilibrium market shares exhibit more variance than the potential market areas of the firms. The locational asymmetry index, LAI, is lower than the Herfindahl index, HHI. Firms with an advantage in potential market share are able to accentuate their advantage and achieve an even higher market share at equilibrium. Still, prices and profits vary more across firms, than equilibrium market shares.

(4) The surplus loss due to transportation costs ranges from 43% above (for the case of three firms) to 16% below (for the case of five firms) the surplus loss of the model of simultaneous location. The ratio of the surplus loss in the sequential game to the surplus loss in the simultaneous game, $CSL(n)/CSL^s(n)$ decreases in the number of firms $n \geq 3$ (and so do both $CSL(n)$ and $CSL^s(n)$. The ratio of the surplus loss in the sequential game to the minimum surplus loss of the optimal positioning, $CSL(n)/CSL^o(n)$ also decreases in the number of firms.

4. Results for the Sequential Location Game With an Endogenously-Determined Number of Firms

In this game, the number of active firms is endogenously determined by the requirement that the last active firm makes positive or zero profits. The crucial feature of this game is the possibility that location and product positioning can be used strategically to deter entry. We use Π to denote "short run profits", i.e., revenues minus variable costs. Profits in the usual definition are $\Pi - F$, where F is the fixed cost. Thus, the number of active firms n fulfills $\Pi(n) \geq F$, and $\Pi(n + 1) < F$.

For example, suppose that there is one firm in the market, and that the fixed cost is so high that only a second firm could enter the market. We first compute $y_2^*(y_1)$, the optimal location of firm 2 for any location of firm 1 by maximizing duopoly profits of firm 2, $\Pi_2(y_1, y_2)$. Let the maximized equilibrium short run profits of firm 2 be $\Pi_2^*(y_1) \equiv \Pi_2(y_1, y_2^*(y_1))$. If $\Pi_2^*(y_1) > F$, then firm 2 enters the market. Given F, we collect points y_1 that fulfill $\Pi_2^*(y_1) > F$ into set E_2, $E_2 = \{y_1 \mid \Pi_2^*(y_1) > F\}$. For low F, firm 2 enters irrespective of the location of firm 1, so that $E_2 = C$. As F increases, the set E_2 of the locations of firms 1 such that firm 2 can enter profitably shrinks. Firm 1 finds its maximum profits by maximizing $\Pi_1(y_1, y_2^*(y_1))$ with respect to y_1, subject to $\Pi_2^*(y_1) > F$, i.e., subject to $y_1 \in E_2$. Let the solution of this maximization be y_1^*, and the corresponding profits be $\Pi_1^* = \Pi_1(y_1^*, y_2^*(y_1^*))$. The choice of location y_1^* is the *optimal accommodating strategy of firm 1*.

If $\Pi_2^*(y_1) < F$, then firm 2 does not enter the market. This condition holds for all $y_1 \notin E_2$. Firm 1 finds its maximum profits by maximizing the *monopoly* profits $\Pi_1(y_1)$ subject to $\Pi_2^*(y_1) < F$, i.e., for all $y_1 \notin E_2$. Let the solution of this maximization be y_1^{**} and the corresponding profits be $\Pi_1^{**} = \Pi_1(y_1^{**})$. The choice of location y_1^{**} is the *optimal deterrence strategy of firm 1*. In choosing whether to deter or accept entry, firm 1 chooses between the optimal accommodating strategy y_1^* and the optimal deterrence strategy y_1^{**} by comparing the corresponding profits Π_1^* and Π_1^{**}.

Now consider the situation for lower fixed costs, when there may be three firms in the market. We first compute $y_3^*(y_1, y_2)$, the optimal location of firm 3 for any pairs of locations of firms 1 and 2. We find the maximized equilibrium short run profits of firm 3, $\Pi_3^*(y_1, y_2) = \Pi_3(y_1, y_2, y_3^*(y_1, y_2))$.

If $\Pi_3^*(y_1, y_2) > F$, then firm 3 enters the market. We collect pairs (y_1, y_2) that fulfill $\Pi_3^*(y_1, y_2) > F$ into set E_3, $E_3 = \{(y_1, y_2) \mid \Pi_3^*(y_1, y_2) > F\}$. Firm 2 maximizes $\Pi_2(y_1, y_2, y_3^*(y_1, y_2))$ with respect to y_2 subject to $\Pi_3^*(y_1, y_2) > F$, i.e., subject to $(y_1, y_2) \in E_3$. Let the solution of this maximization be $y_2^a(y_1)$. This is the *optimal accommodating strategy of firm 2*. The corresponding profits are $\Pi_2^a(y_1) = \Pi_2(y_1, x_2^a(y_1), y_3^*(y_1, y_2^a(y_1)))$.

If $\Pi_3^*(y_1, y_2) < F$, then firm 3 does not enter the market. This condition holds for all $(y_1, y_2) \notin E_3$. Firm 2 then maximizes the *duopoly* profits $\Pi_1(y_1, y_2)$ subject to $\Pi_3^*(y_1, y_2) < F$, i.e., for all $(y_1, y_2) \notin E_3$. Let the optimal choice for firm 2 be $y_2^d(y_1)$. This is the *optimal deterrence strategy of firm 2*. The corresponding profits are $\Pi_2^d(y_1) = \Pi_2(y_1, y_2^d(y_1))$. Firm 2 will choose to let firm 3 enter if its profits with (optimal) deterrence are lower than with (optimal) acceptance of firm 3, i.e.,

$$\Pi_2^d(y_1) < \Pi_2^a(y_1) \tag{5}$$

Let E_{32} be the collection of all locations y_1 such that firm 2 prefers to see firm 3 enter, i.e., where (5) holds.

Firm 1 has to choose either its best location that will lead to entry by firm 3, or the best location that will lead to deterrence of firm 3. Assuming that firm 3 will enter, and that firm 2 prefers that firm 3 enters, firm 1 chooses its best location by maximizing the accommodation profits. Formally, for $y_1 \in E_{32}$ and $(y_1, y_2^a(y_1)) \in E_3$, firm 1 maximizes triopoly profits $\Pi_1^a(y_1) = \Pi_1(y_1, y_2^a(y_1), y_3^*(y_1, y_2^a(y_1)))$ with respect to y_1. Let firm 1's optimal accommodation strategy be y_1^a and the corresponding profits be $\Pi_1^a = \Pi_1^a(y_1^a)$.

In contrast, assuming that firm 3 does not enter, and that firm 2 prefers that firm 3 does not enter, firm 1 chooses its best location by maximizing the deterrence profits. Formally, for $y_1 \notin E_{32}$ and $(y_1, y_2^d(y_1)) \notin E_3$, firm 1 maximizes duopoly profits $\Pi_1(y_1, y_2^d(y_1))$ by choosing the optimal deterrence strategy y_1^d. The implied location for firm 2 is $y_2^d(y_1^d)$. Firm 1 realizes profits $\Pi_1^d = \Pi_1(y_1^d), y_2^d(y_1^d))$, and firm 2 realizes profits $\Pi_2^d = \Pi_2((y_1^d), y_2^d(y_1^d))$. Finally, firm 1 compares the profits Π_1^{**} it makes when it deters firm 2 (if that is possible) and it compares them with Π_1^d and Π_1^a.

Since, in general, profits with a larger number of active firms are lower, early actors try to position themselves so as to deter entry. For a range of fixed costs F, n active firms do not face a serious threat of entry by firm n+1, since, for these fixed costs, the profits of firm n + 1 are very negative. As F decreases, the threat of entry of firm n + 1 becomes viable and the n active firms position themselves in sequence so that the potential entrant would makes small negative profits if it were to enter. As the fixed cost is lowered, active firms have to adjust their position to make sure that the potential entrant stays out. They do so purely to deter entry and even though it decreases their profits. It is just that the incumbents' profits would have been further reduced if they had not adjusted their positions and the potential entrant had entered. As F is lowered further, entry of firm n + 1 is profitable irrespective of the actions of the n incumbents. That is, even the optimal deterrence strategy of the n incumbents cannot stop the entrant from making positive profits once it enters, and entry occurs.

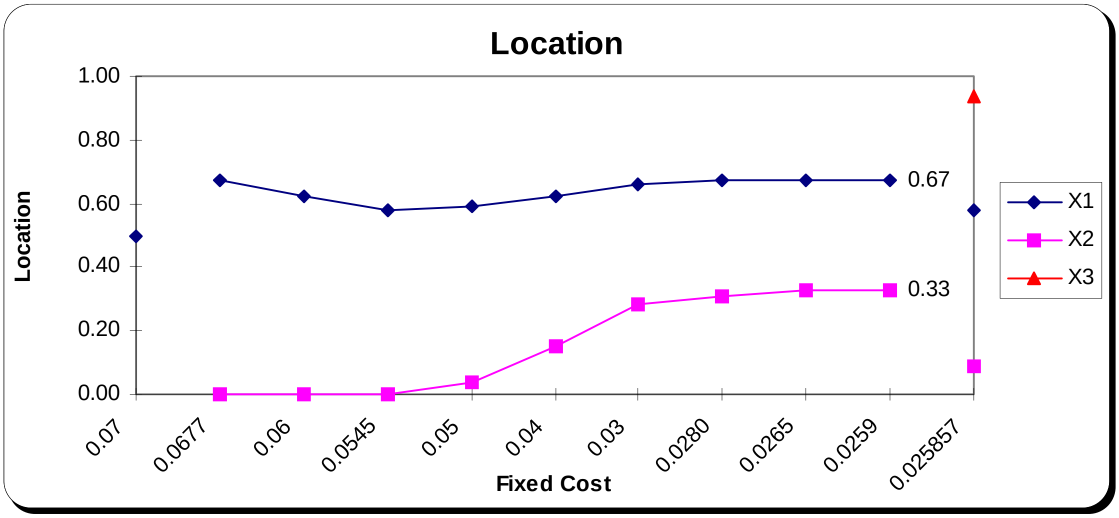
4.1 Specific Results

4.1.1 One And Two Active Firms

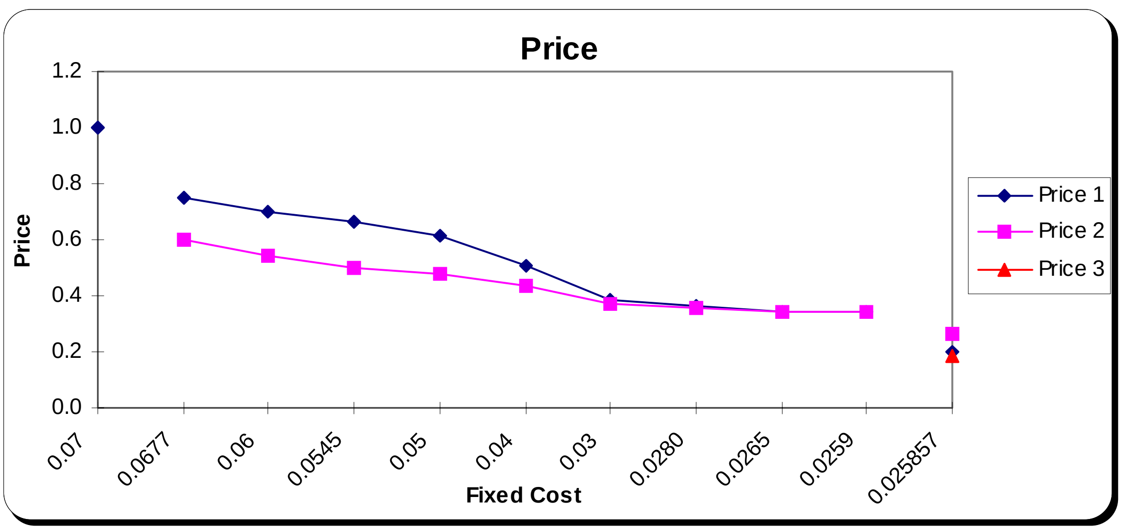
Our specific results follow. We report on the locational pattern, prices, market shares, potential market shares, profits, surplus loss, and on the locational asymmetry and Herfindahl indices. For very high fixed cost F > 0.0677, only one firm can survive. It locates at $y_1 = 0.5$, since this is both the profit maximizing monopoly position and the best position for deterrence of entry of a second firm. For F < 0.0677, firm 2 enters. Firms locate at $y_1 = 0.669$ and $y_2 = 0$ to deter entry. If there was no entry deterrence issue, the firms would have located at the interval endpoints, $y_1 = 1$, $y_2 = 0$, and would have realized higher profits. As F decreases, firms 1 and 2 locate closer to deter entry. At F = 0.025857, they cannot deter entry anymore, and firm 3 enters. See Figure 2.

As fixed cost decreases from 0.0677 to 0.025857 and the two incumbent firms locate closer to deter entry, their prices and profits decrease, as shown in Figures 3 and 4. Market share and potential market share differences eventually decrease as F decreases, as seen in Figures 5 and 6. It is worth noting that potential market share differences are larger than actual market share differences. This implies that the index of locational asymmetry is larger than the Herfindahl index, as seen in Figure 7. This means that the market has less asymmetric production than would result if firms produced according to their potential market areas.

It is important to note that entry of a third firm and the discontinuous change in the locations of incumbent firms significantly reduces the pre-entry profits of the two incumbents. Thus, if a technology is available that would increase the (fixed) costs of both incumbents and potential entrants ("raising both rivals and own costs"), it will be used to deter entry. The entry-induced disruption of the locational pattern resulting in significant profit changes and the fact that it can be "prevented" by a very small "ε" increase in fixed cost of all firms, guarantees that, if available, such "raising both rivals and own costs" strategy will be used in this case and in the cases of three, four and five firms.



<u>Figure 2</u>: Equilibrium locations in sequential choice with free entry, 2 firms



<u>Figure 3</u>: Equilibrium prices in sequential choice with free entry, 2 firms

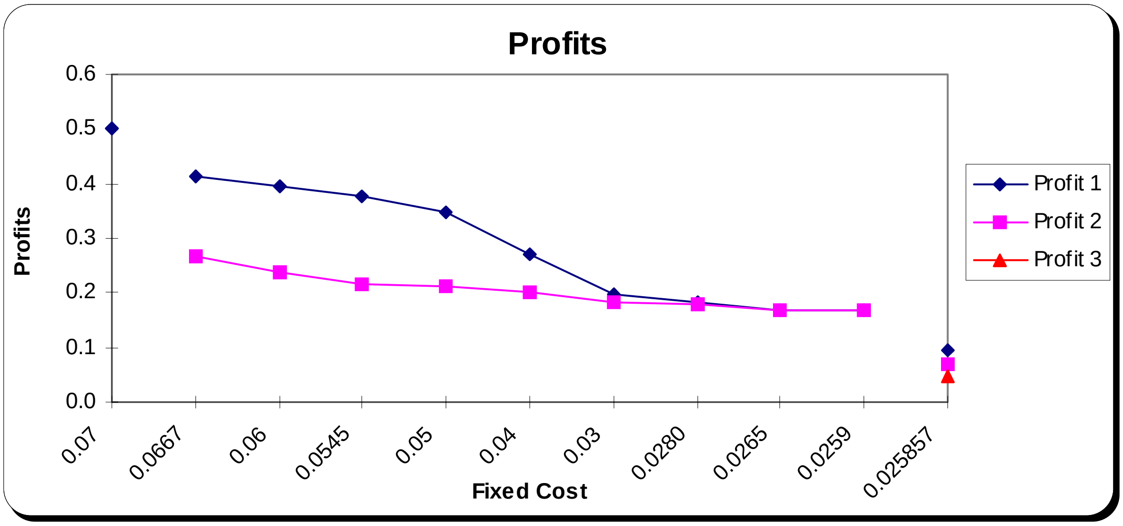


Figure 4: **Equilibrium profits in sequential choice with free entry, 2 firms**

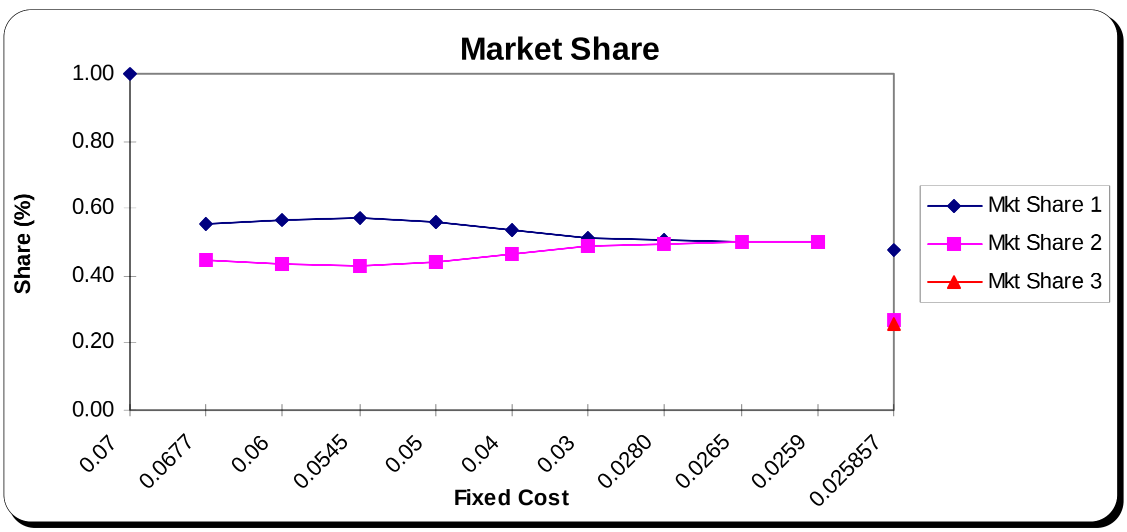


Figure 5: **Equilibrium market share in sequential choice with free entry, 2 firms**

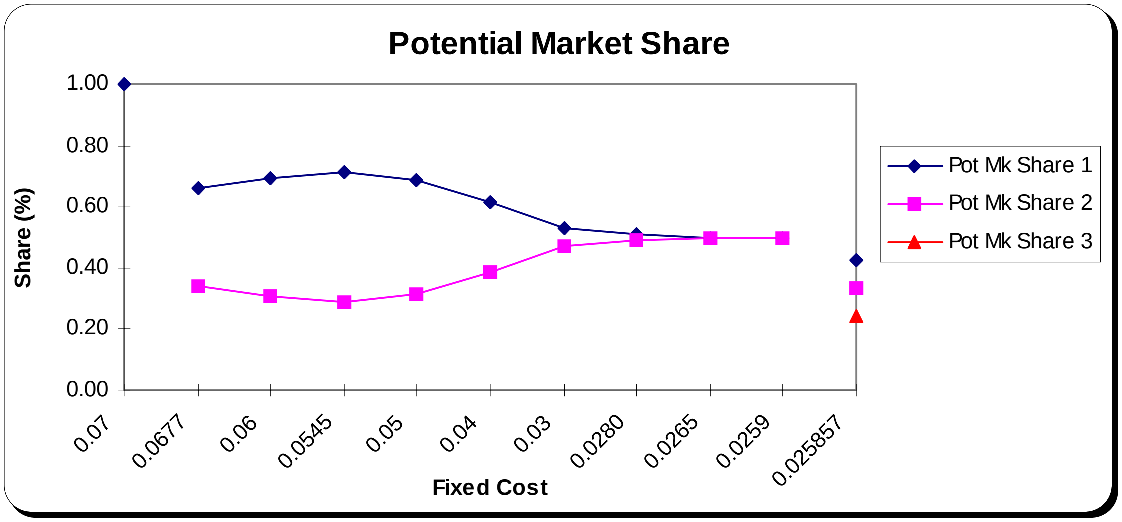


Figure 6: **Equilibrium potential market share in sequential choice with free entry, 2 firms**

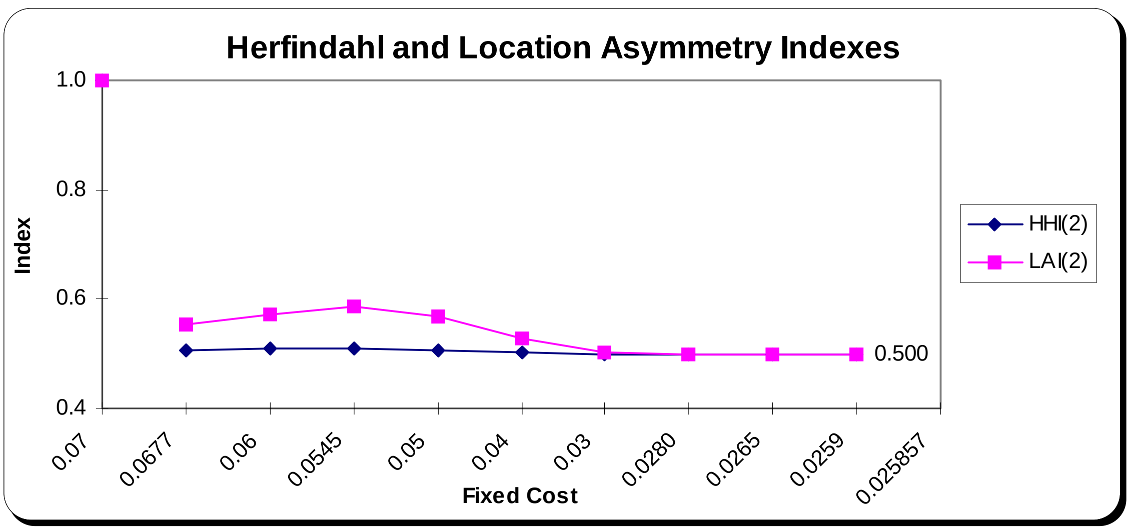


Figure 7: **Comparison of Herfindahl Index and Locational Asymmetry Index in sequential choice with free entry, 2 firms**

Table 5, below, shows the locations, prices, profits, etc. for the lowest fixed cost for which the entry of the fourth firm is prevented. In terms of figures 2 to 7, table 5 shows the data of the one before the last observation on the right. We next compare the data on table 5 with table 1, which shows the data of no-threat-of entry sequential equilibrium.

Table 5
Equilibrium locations and prices in sequential choice with two competing firms and free entry for F = 0.0259

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area
1	0.67	0.34	0.17	0.50	0.50
2	0.33	0.34	0.17	0.50	0.50

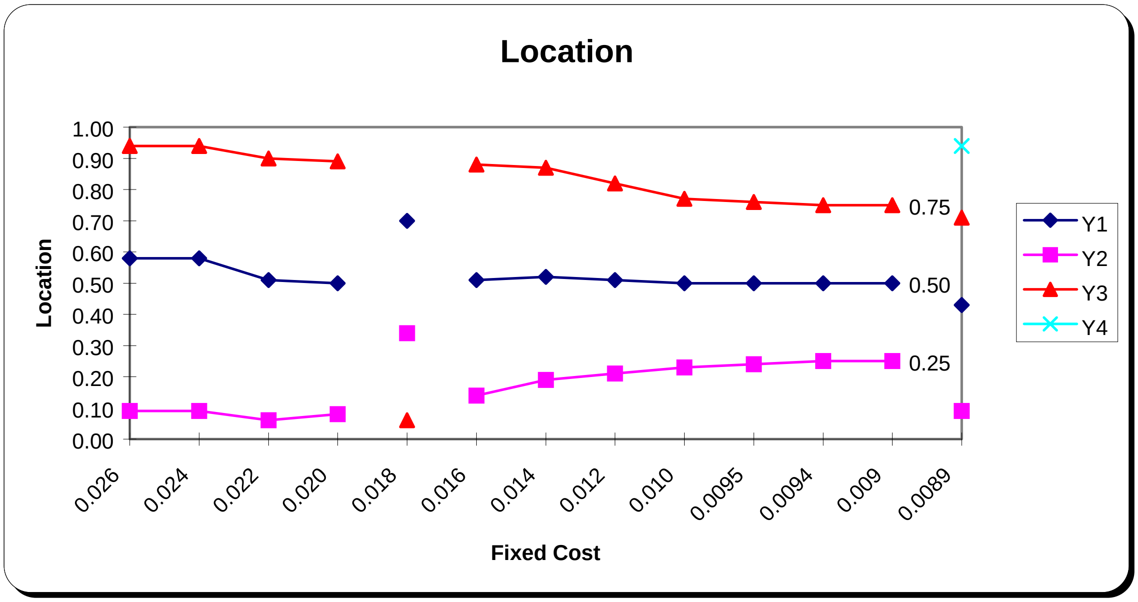
$CSL^{FE}(2) = 0.02723$,[12] $CSL^{s}(2) = 0.083333$, $CSL^{o}(2) = 0.020833$,
$CSL^{FE}(2)/CSL^{s}(2) = 0.3268$, $CSL^{FE}(2)/CSL^{o}(2) = 1.31$,
$HHI^{FE}(2) = 0.50$, $LAI^{FE}(3) = 0.50$.

When we compare the outcome of table 5 with that of table 1, we see that, as expected, firms make large sacrifices to deter entry. Prices and profits in the last point of entry deterrence are about 1/3 of their values in the no-threat-of entry sequential equilibrium. Although both firms end up with identical profits in the last point of entry deterrence, at all fixed costs except the lowest one, firm 1 realizes higher profits and prices than firm 2, as seen in figures 3 and 4. Similarly, market share and potential market share are higher for firm 1 at all fixed costs except the lowest, as seen in figures 5 and 6. For the intermediate values of fixed cost, the divergence in potential market shares between firms 1 and 2 is larger than the divergence in actual market shares. Thus, for intermediate values of fixed cost, the locational asymmetry index is larger than the Herfindahl index, as seen in Figure 7. In terms of surplus loss, the free entry game has about 1/3 of the surplus loss of the game with fixed number of firms.

4.1.2 Three Active Firms

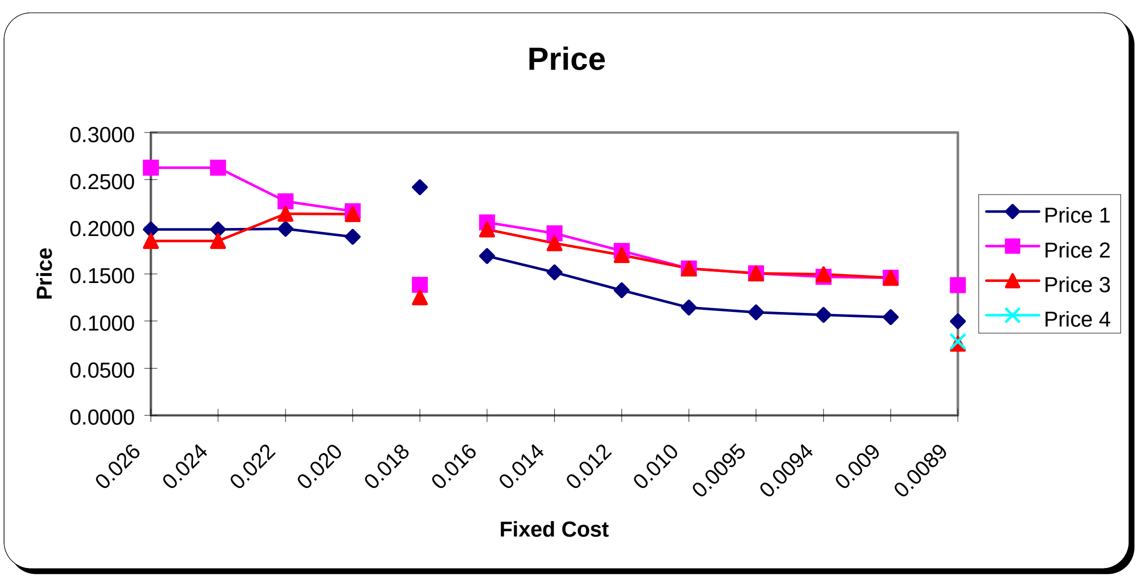
For fixed cost values $F \in [0.009, 0.025857]$ we have three active firms. For $F > 0.022$, a fourth firm does not pose a threat of entry because its profits are very small, so the three active firms do not attempt foreclosure strategies. For $F < 0.022$, the three active firms try to reduce the gaps between them to foreclose entry of a fourth firm. We also observe a discontinuity in the locations of the three firms around $F = 0.018$. After the discontinuity all players seem to follow the continuation of the position strategy previous to the discontinuity. They continue reducing the gaps between them until ending with $y_1 = 0.5$, $y_2 = 0.25$, $y_3 = 0.75$, for $F = 0.009$. At $F = 0.0089$ a fourth firm enters and all firms adjust their positions to $y_1 = 0.43$, $y_2 = 0.09$, $y_3 = 0.71$, $y_4 = 0.94$. The equilibrium locations of three active firms as fixed costs are decreasing are shown in figure 8.

[12] The superscript "FE" means "final equilibrium" indicates that the measurement corresponds to the lowest fixed cost with 3 active firms.



<u>Figure 8</u>: Equilibrium locations in sequential choice with free entry, 3 firms

As the fixed cost decreases, the three firms come closer to each other to prevent the entry of a fourth firm, and the prices and profits of firms 1 and 2 fall. See figures 9 and 10. The price and profits of the third firm generally decrease, but, for a region of fixed costs, they increase as firm 3 finds itself in a better position because of the impact of the entry prevention on the location choices of firms 1 and 2.



<u>Figure 9</u>: Equilibrium prices in sequential choice with free entry, 3 firms

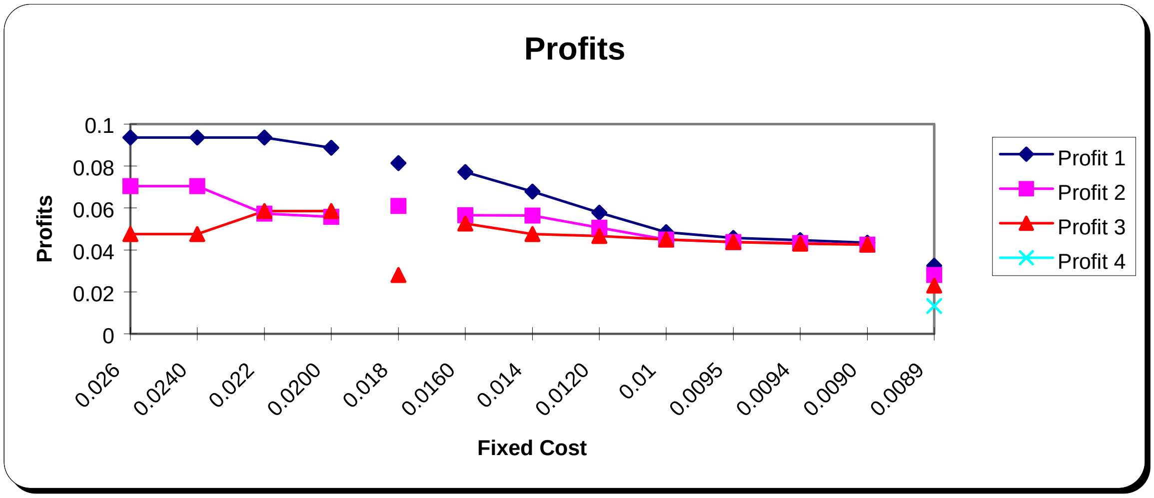


Figure 10: **Equilibrium profits in sequential choice with free entry, 3 firms**

Figures 11 and 12 show the equilibrium market shares and the potential market share as the fixed cost decreases. We see that the market share of the first entrant decreases as fixed costs decrease and entry deterrence becomes more pressing. As the same time, firms 2 and 3 get higher market shares for lower fixed costs. Except for the discontinuity discussed earlier, the order of the equilibrium market shares sizes of all firms remains the same as the order of entry for the range of fixed costs with three active firms. This is despite the fact that potential market share sizes vary considerable and the order of potential market shares is reversed more than once as fixed costs decrease.

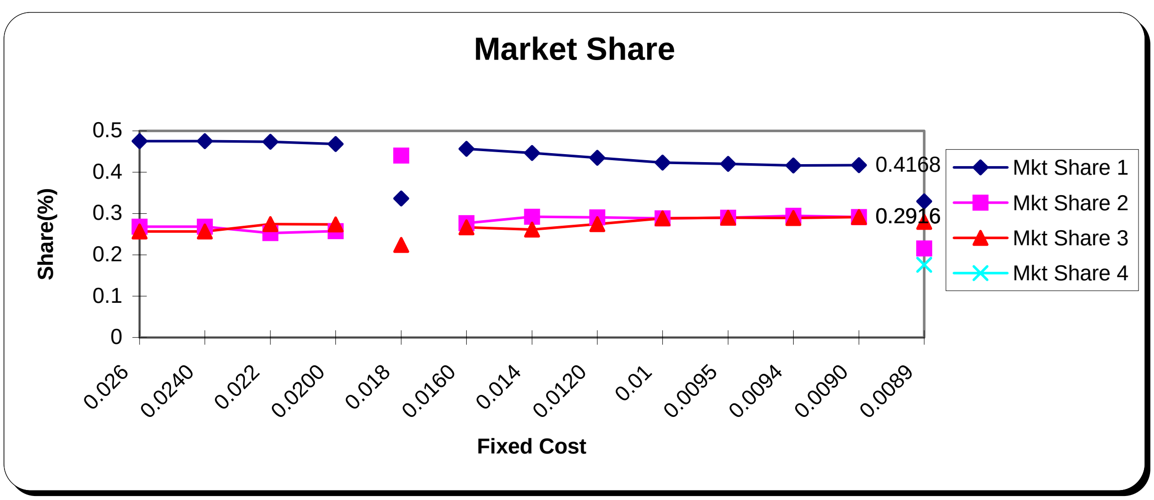
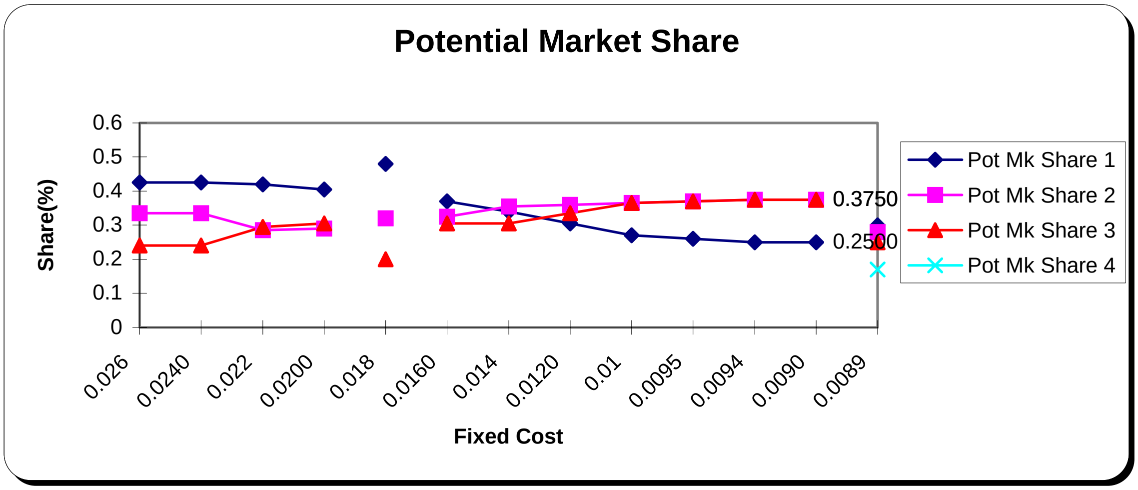
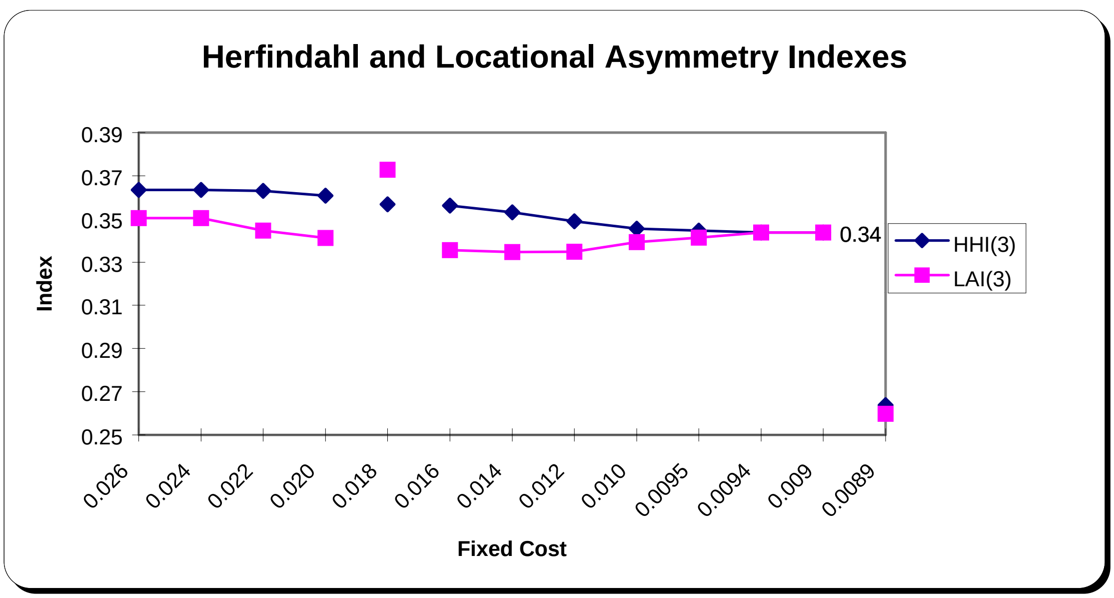


Figure 11: **Equilibrium market share in sequential choice with free entry, 3 firms**



<u>Figure 12</u>: Equilibrium potential market share in sequential choice with free entry, 3 firms

Figure 13 shows the comparison of the Herfindahl and locational asymmetry indexes as fixed costs decrease. Locational asymmetry is smaller than the Herfindahl index, except for the discontinuous choice at F = 0.018. This means that the market has more asymmetric production than would result if firms produced according to their potential market areas. Therefore, firms are able to convert locational asymmetries to even larger market share asymmetries.



<u>Figure 13</u>: Comparison of Herfindahl Index and Locational Asymmetry Index in sequential choice with free entry, 3 firms

The following table shows the locations, prices, profits, etc. for the lowest fixed cost for which the entry of the fourth firm is prevented. In terms of figures 8 to 13, table 6 shows the data of the one before the last observation on the right. We next compare the data on table 6 with table 2, which also shows the data of the first point on the left of figures 8 to 13.

Table 6
Equilibrium locations and prices in sequential choice with three competing firms and free entry for F = 0.009

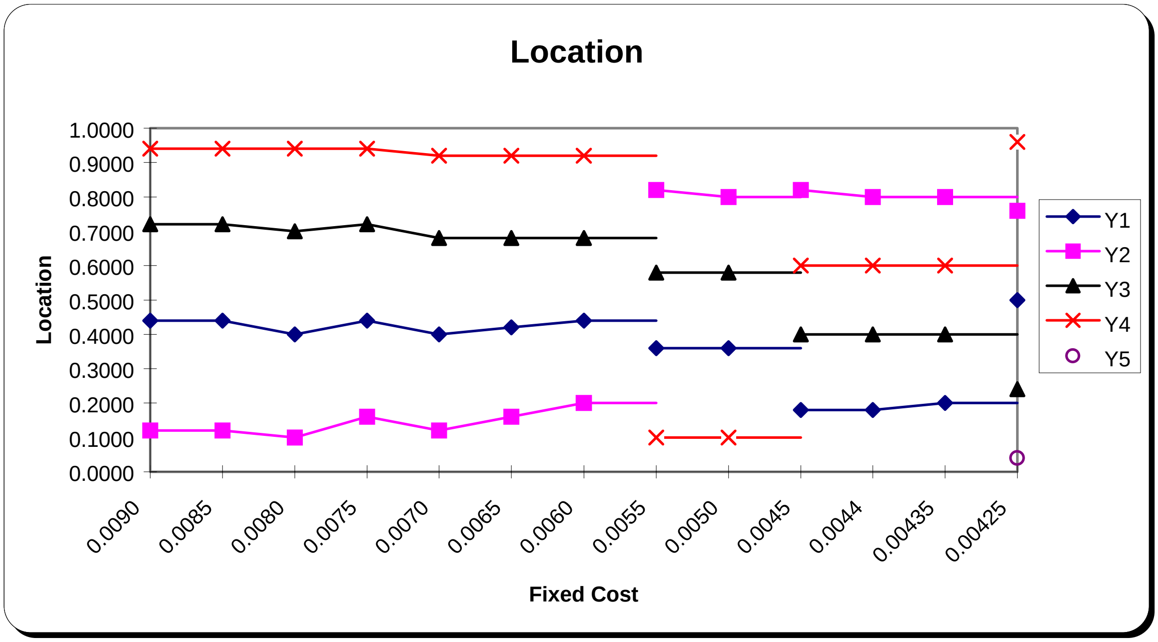
Firm Number	Location	Price	Profits	Market Share	Pot. Market Area	
1	0.50	0.1041	0.0434	0.42	0.25	
2	0.25	0.1458	0.0425	0.29	0.38	*
3	0.75	0.1458	0.0425	0.29	0.38	*

$CSL^{FE}(3) = 0.01659$, $CSL^{s}(3) = 0.011393$, $CSL^{o}(3) = 0.009259$,
$CSL^{FE}(3)/CSL^{s}(3) = 1.46$, $CSL^{FE}(3)/CSL^{o}(3) = 1.79$,
$HHI^{FE}(3) = 0.34$, $LAI^{FE}(3) = 0.34$.

A comparison between tables 2 and 6 shows very significant reductions in prices and profits (excluding fixed costs) of all three firms under free entry in their attempt to thwart entry of a fourth firm. The biggest loss of profits occurs for the first firm, which had the highest profits when the number of firms was fixed at three, and makes less than half of these under free entry. Also, prices fall as a result of the increased competition among the three firms, which have located closer to each other to prevent entry. We also note that market share and potential market share inequalities is significant under free entry but lower than when the number of firms was fixed. This is also shown by the lower HHI and LAI indices in the free entry case, $HHI^{FE}(3) < HHI(3)$, and $LAI^{FE}(3) < LAI(3)$. Notice that, in contrast with the two-firm case, for three active firms, consumers' surplus loss is larger in the free entry case than in the no-entry-threat case.

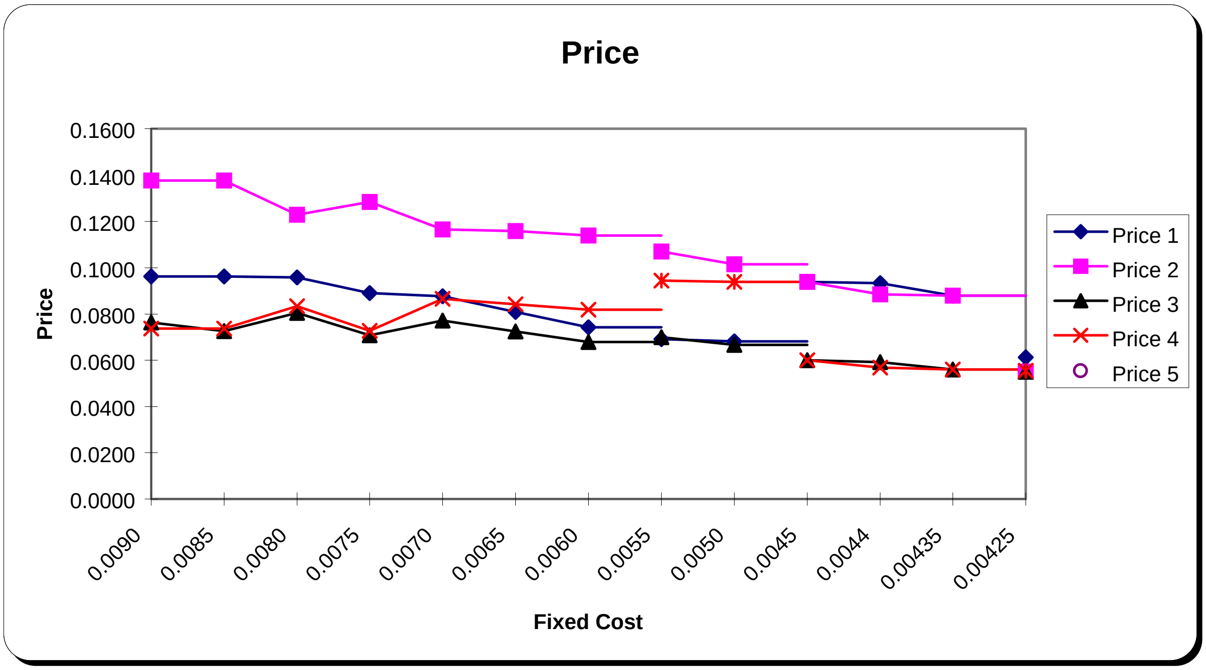
4.1.3 Four Active Firms

For fixed cost values $F \in (0.00425, 0.0089]$, at equilibrium there are four active firms. For $F \in [0.0085, 0.0089]$ there is no fifth firm entry threat. For $F < 0.0085$, the entry threat of the fifth firm appears and the four active firms close the gaps between them to foreclose entry of the fifth firm. We also observe discontinuities in positioning both at F = 0.0055 and at F = 0.0045. In the first discontinuity, as F is lowered below 0.0055, firm 2 switches order in [0, 1] with firm 4, and firm 2 becomes the one with the outer location closer to 1. In the second discontinuity, as F is lowered below 0.0045, firm 1 switches order in [0, 1] with firm 3. As we will see, both of these switches have significant consequences for equilibrium prices and profits. At F = 0.00425, a fifth player enters, and firms take positions $y_1 = 0.5$, $y_2 = 0.76$, $y_3 = 0.24$, $y_4 = 0.96$, $y_5 = 0.04$.

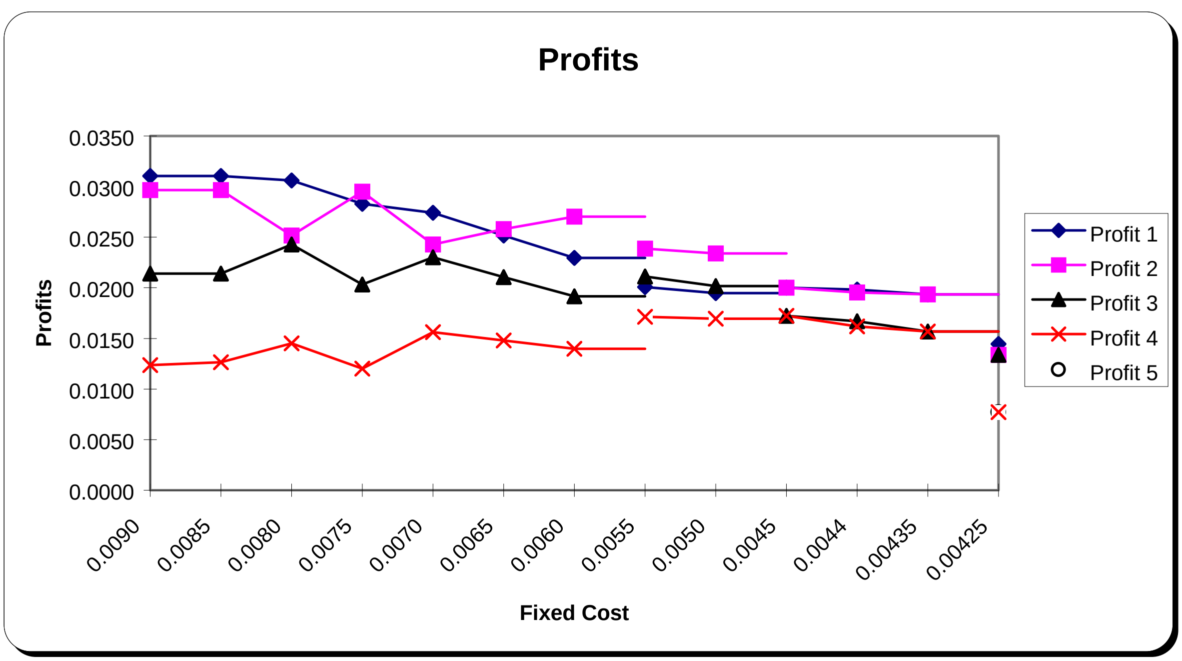


<u>Figure 14</u>: Equilibrium locations in sequential choice with free entry, 4 firms

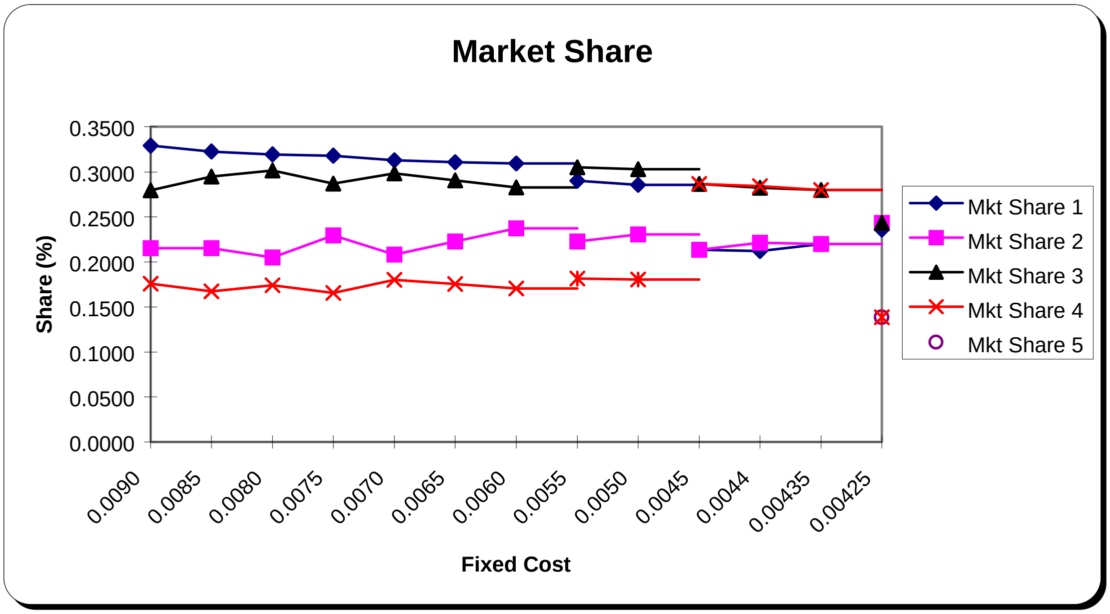
As the four active firms come closer to each other to prevent the entry of a fifth firm, the prices of the four active firms are generally non-monotonic. Only the second firm's price is non-increasing throughout the fixed cost region of four active firms. See figure 15. Similarly, there are significant upheavals in the ordering of profits as fixed costs decrease, as seen in figure 16. Only the first firm's profits are decreasing throughout the region as fixed costs decrease. Similarly, there are a number of re-orderings of market shares and potential market shares as fixed costs vary, as seen in figures 17 and 18. Only the first firm's market share and potential market share are decreasing throughout the region as fixed costs decrease. Moreover, the Herfindahl and the locational asymmetry indexes reverse their order as fixed costs vary, as seen in figure 19.



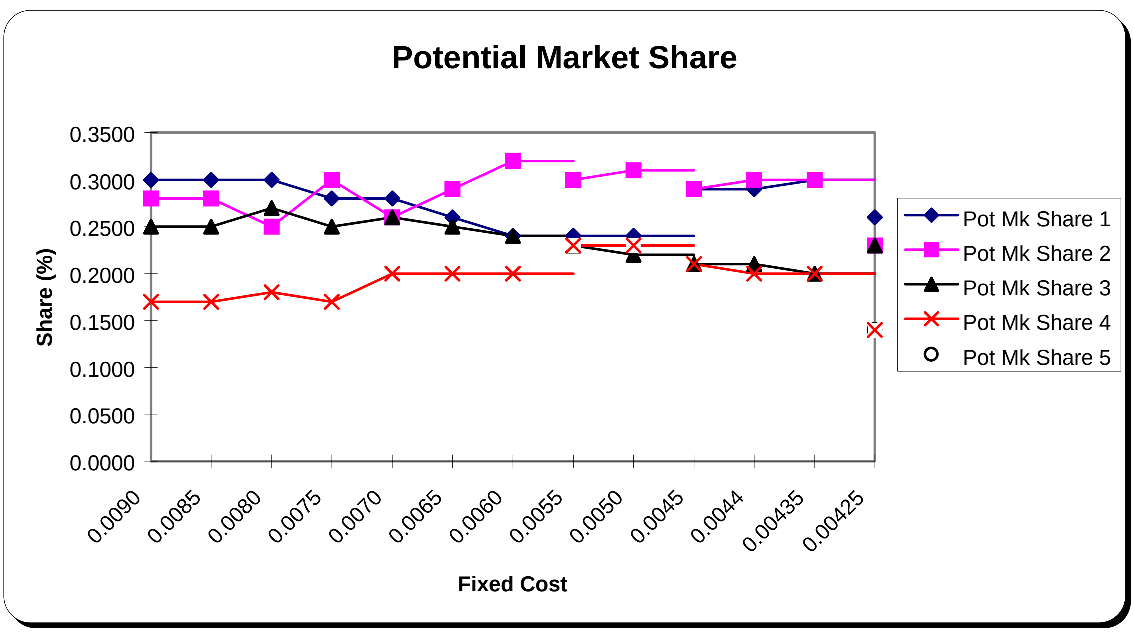
<u>Figure 15</u>: Equilibrium prices in sequential choice with free entry, 4 firms



<u>Figure 16</u>: Equilibrium profits in sequential choice with free entry, 4 firms



<u>Figure 17</u>: Equilibrium market share in sequential choice with free entry, 4 firms



<u>Figure 18</u>: Equilibrium potential market share in sequential choice with free entry, 4 firms

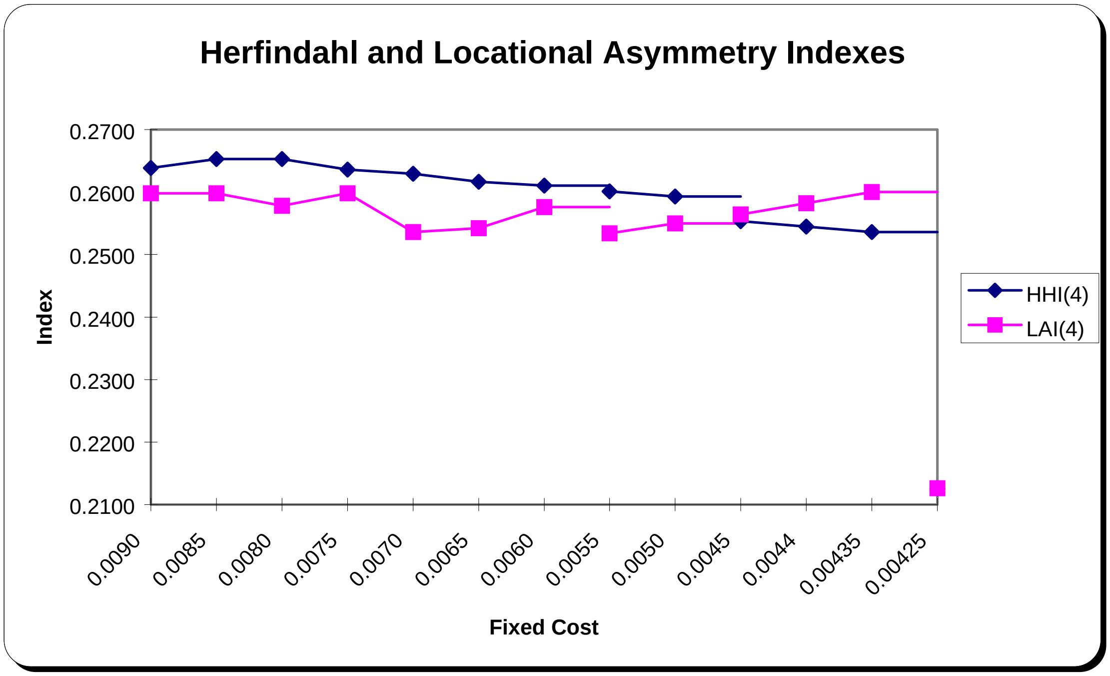


Figure 19: Comparison of Herfindahl Index and Locational Asymmetry Index in sequential choice with free entry, 4 firms

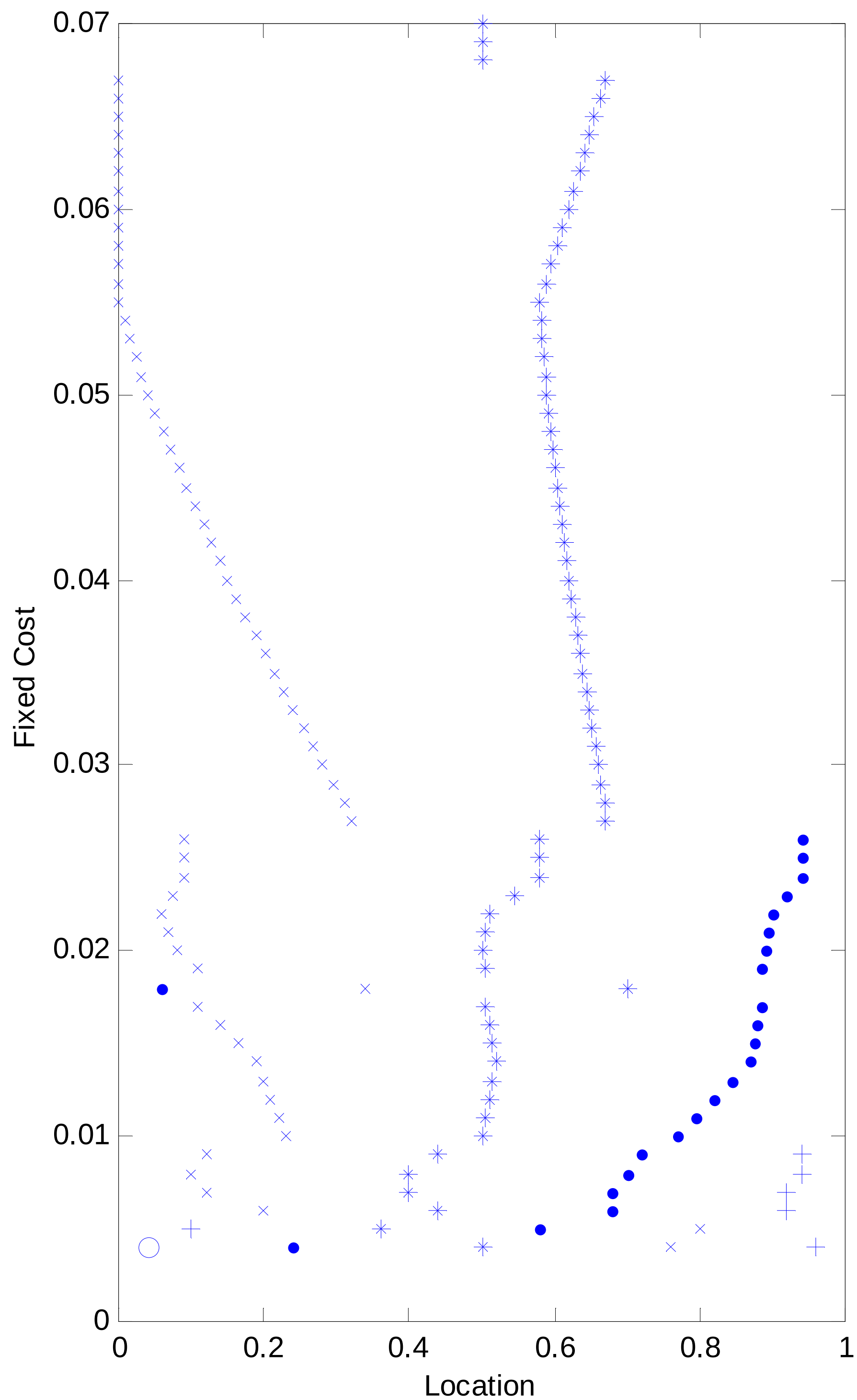
The following table shows the locations, prices, profits, etc. for the lowest fixed cost for which the entry of the fifth firm is prevented. In terms of figures 14 to 19, table 7 shows the data of the one before the last observation on the right. We next compare the data on table 7 with table 3, which also shows the data of the first point on the left of figures 14 to 19.

Table 7
Equilibrium locations and prices in sequential choice with four competing firms and free entry for F = 0.00435

Firm Number	Location	Price	Profits	Market Share	Pot. Market Area	
1	0.20	0.0880	0.0194	0.22	0.30	*
2	0.80	0.0880	0.0194	0.22	0.30	*
3	0.40	0.0560	0.0157	0.28	0.20	
4	0.60	0.0560	0.0157	0.28	0.20	

$CSL^{FE}(4) = 0.00989$, $CSL^{s}(4) = 0.007626$, $CSL^{o}(4) = 0.005208$,
$CSL^{FE}(4)/CSL^{s}(4) = 1.36$, $CSL^{FE}(4)/CSL^{o}(4) = 1.90$,
$HHI^{FE}(4) = 0.2536$, $LAI^{FE}(4) = 0.2600$.

Figure 20 shows the equilibrium locations of firms in the game of sequential locations choice with free entry as the fixed cost varies.



<u>Figure 20</u>: Equilibrium locations in sequential choice with free entry

5. Concluding Remarks

We analyzed two games of sequential location with subsequent simultaneous price choice. In the first game, the number of active firms is fixed. In the second one, there is free entry. We find significant differences between the game of sequential choice of locations and the traditional game of simultaneous choices of locations. In locating sequentially, some firms are able to create locational asymmetries and take advantage of them. Moreover, we find significant differences in the equilibria of the sequential location game with a fixed number of firms from the sequential location game with free entry.

In the sequential location game with a fixed number of competitors, the order of profits is identical to the order of action of the active firms, so that it always pays to locate first. A striking result is the fact that, in the free entry game, it does not always pay to be first.[13] For example, in the three firm equilibrium, although for most values of fixed cost F the order of entry is identical to the ranking of the profits (*i.e.,* the first entrant is the one with the highest profit, the second entrant has the second higher profit, and so on), for several values of F, the profits of incumbent #2 are higher than those of #1. For some values of F, even the profits of incumbent #3 are higher than the profits of player #1.

Market concentration in the free entry game varies with how low the fixed cost is and therefore how big the threat of further entry is and how much the active firms need to change their positions to thwart entry. When the threat of entry increases, firms come to almost symmetric positions in their attempt to minimize any open interval where a potential entrant may enter. The almost symmetric positions also result in very similar prices, which are generally significantly lower than in the game with a fixed number of firms. Thus, when the threat of entry is great, both market concentration and locational asymmetry are low compared to the game of sequential entry with a fixed number of firms. Similarly, consumers' surplus loss varies with fixed cost. As the threat of entry increases, the resulting almost symmetric positioning results in smaller consumers' surplus loss compared to the case of a fixed number of firms.

As fixed costs decrease, the locational pattern is typically continuous as firms adjust their positions to thwart entry. The continuity of the pattern is disrupted as eventually the entry deterrence strategy fails and a new firm enters. This is followed by a continuous variation of locational choices as fixed cost decreases and firms adjust locations to thwart further entry, to be eventually disrupted again when entry deterrence fails and a new firm enters. As a new firm enters, the discontinuous change in the locations of incumbent firms reduces significantly their pre-entry profits. This also implies that if incumbents have a technology (say advertising) that can raise the costs of potential entrants (as well as of incumbents) ("raising both rivals and own costs"), they will use it to deter entry.

[13] These results contrast to the results in Cournot competition (quantity leadership), where the first-acting firm always has a distinct advantage (see Economides (1993b)) and with the price leadership game where the leader is always at a disadvantage.

References

Cao, Jingbin (1991), "Spatial Oligopolistic Competition," mimeo.

Eaton, B. Curtis and Myrna Wooders (1985), "Sophisticated Entry in a Model of Spatial Competition," *Rand Journal of Economics*, vol. 16, pp. 282-297.

Economides, Nicholas (1989), "Symmetric Equilibrium Existence and Optimality in Differentiated Products Markets," *Journal of Economic Theory*, vol. 47, no.1, pp. 178-194.

Economides, Nicholas (1993a), "Hotelling's Main Street with More Than Two Competitors," *Journal of Regional Science*, vol. 33, no. 3, pp. 303-319.

Economides, Nicholas, (1993b), "Quantity Leadership and Social Inefficiency," *International Journal of Industrial Organization*, vol. 11, no. 2, pp. 219-237.

Gabszewicz, Jean Jaskold and Jacques-Francois Thisse (1986), "Spatial Competition and the Location of Firms," *Fundamentals of Pure and Applied Economics*, vol. 5, pp. 1-71.

Hotelling, Harold, (1929), "Stability in Competition," *Economic Journal*, vol. 39, pp. 41-57.

Lane, W. J., (1980), "Product Differentiation in a Market with Endogenous Sequential Entry," *Bell Journal of Economics*, vol. 11 (1), pp. 237-260.

Neven, Damien, (1987), "Endogenous Sequential Entry in a Spatial Model," *International Journal of Industrial Organization*, vol. 5, pp. 419-434.

Prescott, Edward. and M. Visscher (1977), "Sequential Location Among Firms with Foresight," *Bell Journal of Economics*.

Rothschild, R. (1976), "A Note on the Effect of Sequential Entry on Choice of Location," *Journal of Industrial Economics*, vol. 24, pp. 313-320.

Salop, Steven, C., (1979), "Monopolistic Competition with Outside Goods," *Bell Journal of Economics*, vol. 10, pp.141-156.

Shaked, Avner and John Sutton, (1982), "Product Differentiation and Industrial Structure," ICERD Discussion Paper, London School of Economics.