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Heterogeneous Preferences and Location Choice with Multi-Product Firms[1]

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Abstract

This paper investigates whether the principle of minimum differentiation extends to the location choices of multi-product firms of different sizes supplying differentiated goods to consumers with heterogeneous tastes. Our analysis explicitly allows for the possibility that the resulting location equilibria will be asymmetric, and we compare the multiproduct equilibria with the location configurations that would arise if each outlet were operated by a single-product firm. We show that multi-product firms disperse their products if consumer heterogeneity is low or distance between markets is high. They adopt more dispersed locations than single product firms to limit business stealing from their own outlets. Asymmetry is shown to characterize location configurations of both multi-product and single-product firms.

JEL Classification: D43, L13, R30

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1. Introduction

Hotelling's seminal (1929) analysis of stability in competition has given rise to a considerable literature on location choice in spatial markets and, more generally, in differentiated product markets. The primary aim of this literature has been to examine Hotelling's claim that we should expect to see an "excessive sameness" in product specifications or in location choices: what has subsequently been referred to as the principle of minimum differentiation. A significant limitation of the available analysis, as noted by Borenstein and Netz (1999), is that with few exceptions attention has been confined to the location choices of single-product firms. This is potentially important in that a single-product analysis of location choice ignores the ability of multi-product firms to coordinate the location/design choices of the various products that they bring to the market.

In this paper we focus on the location choices of multi-product firms supplying differentiated goods to consumers with heterogeneous preferences, indexed by a parameter μ. When $\mu \to 0$ consumers view the products as increasingly identical, whereas as $\mu \to \infty$ consumers consider the products to be increasingly differentiated.[2] We investigate the possibility that the resulting equilibrium spatial structure will be characterized by "partial agglomeration". Firms spread their own products over the market but agglomerate individual products, at least partially, with respect to those of their rivals. In addition, we explicitly allow for the possibility that the final location configurations that firms adopt will not necessarily be symmetric.

[2] See De Palma *et al.* (1985) and Anderson, De Palma and Thisse (1992) for an extensive discussion of this type of demand structure.

The primary motivation for our analysis is that, while such partially agglomerated structures appear to be precisely what we observe in a whole series of markets, they are not particularly well explained by current theory. Two examples suffice to illustrate the empirical motivation for our analysis. Figures 1 and 2 detail the locations in 2000 of first-run multiplex cinema theatres within the Boston MSA and in South Florida.[3] Figure 3 illustrates the locations of McDonalds, Burger King and Wendy's fast-food outlets for 2001 within the I-95 loop around Boston.[4]

(Figures 1-3 near here)

In each case, the location configurations exhibit a common empirical regularity. First, we observe a large firm with widespread locations throughout the relevant market. Second, we observe a group of other smaller firms with fewer locations that are, in the language of Brander and Eaton (1984), partially interleaved.

As we have noted, the available literature, building primarily on Hotelling's initial insight, does not effectively account for the observed spatial structures. d'Aspremont, Gabszewicz and Thisse (1979) were the first to identify a formal flaw in Hotelling's analysis but the correction that they suggested – quadratic rather than linear transport costs – leads to an equilibrium with maximum rather than minimum differentiation. Subsequent analysis by De Palma *et al.* (1985) shows that, with parametric prices, the principle of minimum differentiation holds provided that products are sufficiently differentiated in a dimension additional to their spatial differentiation.[5] Anderson, De

[3] Full documentation on the movie-theatre location data can be found in Chisholm and Norman (2001).
[4] Fast-food outlet location data were taken from the company websites: www.Wendys.com, www.Mcdonalds.com and www.BurgerKing.com.
[5] They also show that there is an agglomerated equilibrium with endogenous prices provided that the degree of heterogeneity is great enough. De Fraja and Norman (1993) obtain a similar result with a different demand specification and non-parametric prices.

Palma and Thisse (1992) extend this analysis to show that at intermediate levels of product differentiation, and again with parametric prices, we might see symmetric groupings of independent firms. However, their analysis predicts that an agglomeration will never contain more than two firms and that, as in their earlier work, when the degree of heterogeneity is great enough, firms will perfectly agglomerate at the market center.[6]

Hamilton, Thisse and Weskamp (1989) and Anderson and Neven (1990, 1991) take a different approach, assuming that the non-cooperative firms producing identical products are Cournot competitors. Both show that perfect agglomeration at the market center is a Cournot-Nash equilibrium.

The feature that all these analyses have in common is that the market center appears as a dominant location choice. Where equilibrium is characterized by some degree of dispersion of firms, the equilibria that are identified are symmetric, with the agglomerations containing no more than two firms.[7] Yet, as the empirical illustrations above and many other similar examples indicate, a more complete theory of location choice would predict partial agglomeration at best, with no particular requirement that each non-central agglomeration contain a small number of firms.

Braid (1988) is almost alone in generating this type of outcome, identifying equilibria in which non-central locations can contain the greatest agglomerations of firms. However, as in the location literature cited above, Braid confines attention to single-product firms and identifies only symmetric equilibria.[8]

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[6] Eaton and Lipsey (1975) find the same result with a different specification of demand and location choice.

[7] See also Eaton and Lipsey (1975).

[8] We return to the Braid analysis in more detail below.

The literature on location choice by multi-product firms is limited. Brander and Eaton (1984) were the first explicitly to consider product line rivalry and show that both segmented and interleaved product line choices are Nash equilibria. They do not explicitly consider spatial choice, but their analysis can be extended to include a spatial dimension. Martinez-Giralt and Neven (1988) consider the spatial dimension and find that when two Bertrand firms can each locate two outlets, neither firm will actually choose to do so. Rather, they will agglomerate their own outlets, effectively eliminating one of the products, while being maximally differentiated from their rival. One problem with this analysis, however, is that the equilibrium is very sensitive to the assumptions. Bensaid and De Palma (1993) show that if we extend the analysis to three Bertrand firms, each locating up to two outlets, almost any outcome can be an equilibrium.

One can easily show also that if the two-product firms are Cournot duopolists operating in a line market of unit length, then both firms locating their products at ¼ and ¾ is a Nash equilibrium. Pal and Sarkar (2002) extend this result to provide the most extensive and detailed analysis of location choice by Cournot firms currently available. They show, for example, that if the duopolists each operate m outlets, the Nash equilibrium has m agglomerations each containing two firms. One limitation of their analysis, however, is that because they assume homogeneous products there is no market overlap by outlets of a single firm so that the size of any agglomeration is limited to the number of firms in the market. More generally, again because of the lack of market overlap by outlets operated by the same firm, there is an underlying tendency in their analysis for a firm to spread its own outlets.[9]

[9] See also Norman and Pepall (2001) for a similar result in a different context.

Gabszewicz and Thisse (1986) allow two firms to locate any number of outlets. They show that with parametric prices and unit demand, an equilibrium exists in which the outlets of each firm are pairwise located and equally spaced. This is very like the equilibrium identified by Eaton and Lipsey (1975) for single-product firms, suggesting that competing firms with different ownership structures might make similar location choices. However, the relationship between ownership and location choice has not been explicitly investigated. At best, the literature compares the generally single-product, non-cooperative equilibrium with the choices that would be made by a monopolist. This is very different from asking whether the location choices of, for example, three firms operating multiple outlets will be the same as would be chosen if each of the outlets were operated by an independent firm, or by independent, profit-maximizing divisions of the three firms. Moreover, as Borenstein and Netz (1999) note, "none of the models studies asymmetric markets where firms locate different numbers of outlets." (1999, p. 618)[10]

The contributions of this paper are, then, threefold. First, we consider location choices by multi-product firms of different sizes. Second, we explicitly allow for the possibility that the resulting spatial equilibria will be asymmetric. Finally, we compare the multi-product equilibria with the location configurations that would arise if each outlet were operated by a single-product firm.

The remainder of the paper is structured as follows. In section 2, we detail the theoretical model that underpins our analysis. Section 3 identifies the single-product equilibrium location configurations and the corresponding equilibria for multiproduct firms. The final section contains some concluding remarks.

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[10] Pal and Sarkar (2002) is the one exception but they meet considerable difficulties in characterizing equilibria even for duopolists operating different numbers of outlets. Those that they identify exhibit a

2. The Model

The framework that we adopt is the simplest possible consistent with the questions that we wish to investigate. Following Braid (1988), we assume that the market consists of five equally sized submarkets, or towns, evenly distributed on a line market.[11] Each town is assumed to have S consumers. Consumers and firms are constrained to locate in only these towns, but consumers can purchase from, and firms can sell in, any of the five towns. All firms adopt f.o.b. pricing and the round-trip transportation costs between any pair of neighboring towns is d per unit. It follows that the transportation costs between any pair of towns i and j is $d|i-j|$.

We assume that there are three multi-product firms. Firm 1, the market leader, operates five outlets, while firms 2 and 3 each operate three outlets. In order to focus on location choice, we assume that all outlets have identical, constant marginal costs that we can normalize, without loss of generality, to zero. Again following Braid (see also Anderson, De Palma and Thisse, 1992), we assume that the firms charge the same parametric price p at each of their outlets. This considerably eases computations while not being an unreasonable characterization of price setting in the types of examples presented above.[12] We consider a two-stage location game in which firm 1 chooses the location configuration of its outlets in the first stage, and firms 2 and 3 simultaneously

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reasonable degree of symmetry.

[11] Throughout the analysis we use a spatial analogy. The extension of our analysis to more general issues of product specification is obvious. Discreteness of the product space follows the recent tradition in modern economic geography (see, for example, Fujita, Krugman and Venables, 2000). The choice of five submarkets is large enough to allow consideration of the strategic issues in which we are interested while being small enough to be analytically tractable. Norman (2002) also uses this spatial specification in a different context.

[12] We might think of these prices as being those that the firms consider to be sustainable as equilibria in a repeated price game.

choose their location configurations in the second stage. We look for subgame-perfect location equilibria to this game.

The outlets operated by a firm (cinemas, fast-food outlets) each sell a variant of a differentiated product and each consumer purchases exactly one unit of the product variant that gives her the greatest utility. Consumer choice is characterized by heterogeneity and uncertainty in that a consumer *s* located in town *i* purchasing from outlet *k* located in town *j* obtains conditional indirect utility of

$$\tilde{v}_{ijk} = y - p - d\left|i - j\right| + \varepsilon_s \qquad (i, j, k = 1,\ldots,5) \tag{1}$$

where the ε_s are i.i.d., following a double exponential distribution with mean zero and variance $\mu^2\pi^2/6$.[13] This implies, in particular, that consumers distinguish between the products being offered but do not treat the products offered by any one firm as being distinctly different from those offered by another firm.[14] The consumer reservation price is assumed to be sufficiently great with respect to *p* and *d* as to impose no constraints on consumer choice. With this demand structure and our parametric price assumption we can identify the probability that a consumer located in town *i* will buy from an outlet located in town *j* from the standard multinomial logit model.

Suppose that town *j* contains n_j outlets, with $N = \sum_{j=1}^{n} n_j$ being the total number of outlets in the market. Then the probability that a consumer located in town *i* will purchase from an outlet located in town *j* is:

$$pr_{ij} = \frac{e^{-d|i-j|/\mu}}{\sum_{m=1}^{5} n_m . e^{-d|i-m|/\mu}} \qquad (i, j = 1,\ldots,5) \tag{2}$$

[13] See Anderson, De Palma and Thisse (1992) p. 40 for a more extensive discussion.

The market share of an outlet located in town j is then

$$ms_j = \sum_{i=1}^{5} pr_{ij} \qquad (j = 1,\ldots 5) \tag{3}$$

Let m = $(ms_1, ms_2, ms_3, ms_4, ms_5)$ and denote the location configuration of firm n as $c_n = (c_{n1}, c_{n2}, c_{n3}, c_{n4}, c_{n5})$ where c_{nj} is the number of outlets that firm n has in town j. Given our assumptions, the set of feasible location configurations for firm 1 is C_1 and for firms 2 and 3 is C_h (h = 2, 3) such that the c_{ni} (n = 1,2,3; i = 1,…,5) are non-negative integers with $\sum_{i=1}^{5} c_{1i} = 5$ and $\sum_{i=1}^{5} c_{hi} = 3$ (h = 2, 3). The profit of firm n from location configuration c_n is:

$$\pi_n(c_1, c_2, c_3) = Sm.c_n \quad (n = 1, 2, 3) \tag{4}$$

Given any location configuration c_1 for firm 1, equilibrium for firm 2 is defined as a location configuration $c_2^*(c_1) \in C_2$ such that

$$\pi_2\left(c_1, c_2^*(c_1), c_3^*(c_1)\right) \geq \pi_2\left(c_1, c_2, c_3^*(c_1)\right) \; \forall \, c_2 \in C_2 \tag{5}$$

with a similar definition for firm 3. Equilibrium for firm 1 is defined as a location configuration $c_1^* \in C_1$ such that

$$\pi_1\left(c_1^*, c_2^*(c_1^*), c_3^*(c_1^*)\right) \geq \pi_1\left(c_1, c_2^*(c_1), c_3^*(c_1)\right) \; \forall \, c_1 \in C_1 \tag{6}$$

Note that since the towns are of equal size and prices are parametric, maximizing profit for each firm is equivalent to maximizing that firm's aggregate market share.

Given our demand specification, consumer choice of which product to purchase and the resulting equilibrium location configurations of the three firms are determined by the ratio d/μ. As d increases or μ decreases a consumer's shopping choice becomes more

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[14] Introducing such heterogeneity across firms would require that we adopt a nested logit formulation: Anderson *et al (1992).*

concentrated on outlets in her own town and thus should encourage dispersion of a firms' outlets in order to be closer to the individual submarkets. By contrast, as d falls or μ increases, shopping choices become more dispersed, encouraging more agglomeration of a firms' outlets closer to the market center.

3. Location Equilibrium

3.1 Single-Product Firms

We first extend Braid's (1988) analysis to examine the impact of d/μ on the location equilibria that apply if the eleven outlets choose their locations independently and simultaneously. In this situation, the definition of an equilibrium location configuration is straightforward: no firm wishes to change its location (choice of town) given the locations of the other ten firms.

Table 1 summarizes our results.[15] First, as we expect, an increase in d/μ leads to increased dispersion. The fully agglomerated configuration (0,0,11,0,0) is an equilibrium for $d/\mu \leq 0.498$ while, for example, the more dispersed equilibrium (0,2,7,2,0) holds for $0.474 \leq d/\mu \leq 0.592$. Locations are concentrated on towns 2, 3 and 4 for $d/\mu \leq 0.892$ while the fully dispersed equilibrium (2,2,3,2,2) holds for $1.253 \leq d/\mu \leq 2.101$.

Second, and much more surprisingly, no symmetric equilibrium exists for $1.084 \leq d/\mu \leq 1.253$ and for $d/\mu \geq 2.102$. In the former interval, the obvious candidate symmetric equilibrium is (1,3,3,3,1), but for this range of values of d/μ, at least one firm can increase its market share by moving. We find that (1,4,2,3,1) is an equilibrium for $1.084 \leq d/\mu \leq 1.227$, with a firm in town 3 in the configuration (1,3,3,3,1) preferring to move to town 2 (or 4) and (1,3,3,2,2) for $1.222 \leq d/\mu \leq 1.253$, now with a firm in town 4 (or 2) preferring to locate in town 5 (or 1). In both cases, the common feature is that a centrally located firm finds that it can do better by moving to a more peripheral location. For $d/\mu \geq 2.102$ we find much the same. Now the obvious candidate symmetric equilibrium is (2,2,3,2,2) but we find that with this configuration one of the centrally located firms can increase its market share by moving to town 2 (or 4), with the result that (2,3,2,2,2) is an equilibrium configuration.[16] More generally, our analysis indicates that Braid's conclusion that towns 2, 3 and 4 will contain the majority of outlets turns out to be particularly sensitive to his chosen value of $d/\mu = 0.693$.[17]

(Table 1 near here)

3.2 Multi-Product Firms

Now consider the location equilibrium when three firms operate the eleven outlets - firm 1 with five outlets, firms 2 and 3 each with three outlets each - and competition between these firms is the two-stage location game specified above with the subgame-perfect equilibrium defined by (5) and (6).

We must allow for the possibility that there will be asymmetric location choices by the three firms. Ignoring "mirror images," firm 1 chooses from among 66 possible location configurations, firms 2 and 3 choose from among 14 each. We present a selection of the payoff matrices for firms 2 and 3 in the Appendix.[18] Table 2 summarizes

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[15] This is one extension that Braid thought might be interesting to investigate. We report here only a selection of the equilibria. A full characterization can be obtained from the authors on request.

[16] We suspect from extensive searching, but have not proved, that this configuration and its symmetric partner (2,2,2,3,2) are the only equilibria for $d/\mu \geq 2.101$.

[17] One further result of extending Braid's analysis is even more surprising. If $N = 5$ we find *no* pure strategy equilibrium location configuration exists for $d/\mu \geq 2.267$. We leave to further analysis a more extensive examination of whether such non-existence extends to other values of N.

[18] Evaluation of this and the Braid cases were performed using Mathematica®. The notebook can be obtained from the authors on request.

the resulting subgame-perfect location configurations for a range of values of d/μ. The market share of firm 1 is illustrated in Figure 4.[19]

(Table 2 and Figure 4 near here)

Several points emerge very clearly from these results. First, while the aggregate distribution exhibits increased dispersion with increased d/μ as we would expect, this hides a considerable degree of non-monotonicity in the individual firms' equilibrium location configurations. It should be emphasized that, in contrast to Martinez-Giralt and Neven (1988), agglomeration of a firm's own products does not imply elimination of any of these products, since consumers have heterogeneous preferences with respect to the products of a given firm as well as across different firms.

As can be seen from Table 2, there is no simple relationship between d/μ and the degree of dispersal exhibited by the location configurations of the lead firm. There are several cycles of dispersal and concentration as d/μ is raised until, for $d/\mu \in (1.530, 2.138)$ the lead firm has more outlets in the most peripheral towns than it has in any other town, encouraging as a result a partial concentration of the outlets of firms 2 and 3. It is only for d/μ greater than approximately 2.139 that we can be confident that firm 1 will adopt a fully dispersed, uniform distribution of its outlets, causing firms 2 and 3 to reject overlapped location configurations dispersed over the central three towns in favor of the interleaved pair of configurations (1,0,1,1,0) and (0,1,1,0,1) respectively.

A similar pattern can be discerned in the location choices of firms 2 and 3: initially increasingly dispersed locations at higher values of d/μ, then a reversion to more central locations, dispersal again, and finally adoption of the interleaved location

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[19] Note that the aggregate market share of firms 2 and 3 is just 5 minus the market share of firm 1.

configurations (1,0,1,1,0) and (0,1,1,0,1) respectively. We find no cases in which firms 2 and 3 segment their location configurations, reflecting Hotelling's insight that for these firms the desire to agglomerate outweighs the desire to separate.

Intuition would suggest that firm 1 enjoys a first-mover advantage so that, with the exception of the fully agglomerated configuration (0,0,11,0,0), firm 1's market share should exceed 5/11 = 2.2727. While generally true, Figure 4 demonstrates that for $d/\mu \in (0.530, 0.622)$ this is not the case. For $d/\mu < 0.555$ the desire to concentrate outlets on the central market is greater for the lead firm than for the two followers, with the result that firms 2 and 3 adopt more dispersed patterns than does firm 1 gaining market share for these firms. If $d/\mu \in (0.555, 0.624)$ firm 1 adopts the more dispersed configuration (0,2,1,2,0) which gives it the potential to offset the power of firms 2 and 3, but it is only for $d/\mu \geq 0.625$ that firm 1's market share is greater than 2.2727. This result suggests that, while firm 1's first-mover advantage allows it to manipulate the choices of firms 2 and 3, this power is limited. The pressure on the "follower" firms to disperse at higher values of d/μ is sufficiently strong in some cases to offset the reduced market share that higher values of d/μ generally impose on these firms.

Figure 4 also shows that the lack of monotonicity in location choices with respect to d/μ is reflected in a non-monotonicity of both market shares and profits. What appears to be the case is that the relationship between d/μ and market shares and profits is actually determined by the *relative* agglomeration of the large and small firms. When firm 1 chooses a more dispersed location configuration than firms 2 and 3, higher values of d/μ increase firm 1's market share. We observe this result in three cases: for $d/\mu \in (0.555, 0.833)$, when the location configurations are {(0,2,1,2,0), (0,1,1,1,0), (0,1,1,1,)};

for $d/\mu \in$ (1.530, 2.138), when the location configurations are {(2,0,1,0,2), (0,1,1,1,0), (0,1,1,1,0)}; and for d/μ >2.139, when the location configurations are {(1,1,1,1,1), (1,0,1,1,0), (0,1,1,0,1)}. By contrast, for $d/\mu \in$ (1.069, 1.529), the location configurations are {(0,2,1,2,0), (1,0,1,0,1), (1,0,1,0,1)}. Firms 2 and 3 are the more dispersed firms and firm 1's market share declines as d/μ increases.

The aggregate location configurations generated by our three multi-product firms and the location configurations of the eleven single outlet firms (Table 1) share a degree of similarity. This is not surprising given that location choices under both ownership structures are affected in similar ways by increases in d/μ. A notable difference, however, is that the adoption of more dispersed location configurations occurs at lower values of d/μ with the multi-product ownership structure. The fully concentrated configuration (0,0,11,0,0) breaks down for $d/\mu > 0.434$ and the fully dispersed structure (2,2,3,2,2) appears for $d/\mu > 1.069$. It is equally important to note that the same aggregate location configuration can be generated by a number of very different individual equilibrium configurations. For example, Table 5 shows that the fully dispersed configuration (2,2,3,2,2) is generated by three different configurations of the individual firms.

The difference in location choices between the two ownership structures reflects a trade-off that influences the location choices of multi-product firms but not single-product firms. On the one hand, both types of firms face the same pressure to agglomerate in the attempt to steal customers from their rivals. On the other hand, the multi-product firm has an incentive to disperse its products in order better to coordinate that firm's coverage of the different consumer markets or towns and to limit business stealing from its own outlets.

Finally, let us return to the empirical regularities with which we started. The parameter region for d/μ that generates location configurations that most closely reflect those of our examples is $d/\mu > 2.139$. When this condition holds, the large lead firm distributes its outlets evenly over the market while the small firms adopt an interleaved structure that gives them reasonable coverage of the entire market rather than a fully overlapped structure in which they concentrate their outlets on parts of the market.[20] This implies that, for the types of good that we have used to motivate our analysis, consumer tastes are relatively homogeneous and/or the consumer valuation of distance costs is high. It seems reasonable to suggest that the goods in these markets (films and fast food) are not highly differentiated in their product characteristics (other than location) but they are such that consumers strongly prefer outlets (cinemas and fast-food restaurants) that are close to their own "locations".[21]

4. Conclusions

A large, and still growing, literature is attempting to refine Hotelling's original insight that the location, and more generally, the product design decisions of competing firms will be characterized by an "excessive sameness", with firms being driven to imitate each other rather than to seek out individual market niches. A major shortcoming of the current literature, however, is that it is largely confined to the analysis of location choices by single-product firms. This severely limits our ability to comment sensibly on whether excessive sameness should be expected to apply to multi-product firms, given

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[20] As we have noted, we have found no cases in which firms 2 and 3 adopt a segmented structure.

that these firms have the countervailing incentive to disperse their individual products in order to limit business stealing from their own outlets rather than from those of their competitors.[22] By the same argument, the available literature is of limited usefulness as a guide to empirical work trying to relate competition, consumer choice and location.

In this paper we have presented the beginnings of a theory of location choice by multiproduct firms of different sizes, in a market containing consumers with heterogeneous tastes. As in the single product case, we find that the location patterns adopted by multi-product firms are more dispersed when heterogeneity in consumer tastes is lower, since then it is important for firms to locate their products close to individual consumer markets. However, we have also shown that this aggregate pattern hides considerable lack of monotonicity in the location configurations adopted by individual firms. Strategic interaction between the firms can actually lead to one or other of them adopting a more concentrated location configuration at lower levels of consumer heterogeneity or when the distance between markets is greater.

We have also shown that a similar lack of monotonicity characterizes the market shares won by firms of different sizes. It might be expected that a "large" firm should gain when heterogeneity in tastes is lower, or distance between markets is greater, since such a firm is better able to place its products close to individual consumer markets. Our analysis shows, however, that this will be the case only if the large firm adopts an equilibrium location configuration that is more dispersed than its smaller competitors.

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[21] This is consistent with other work, Chisholm and Norman (2001), in which we find that revenues per screen for first-run cinemas increase significantly with distance from a cinema's nearest competitor.

[22] Greenhut, Norman and Hung (1987) do something along these lines but in a very intuitive and informal manner.

Symmetry in location choices generally characterizes the equilibrium configurations of our multi-product firms, although we have identified some parameter regions in which there is considerable asymmetry in these choices. Somewhat surprisingly, it turns out that asymmetry is actually more characteristic of location configurations adopted by single-product firms.

As a guide to empirical work, our analysis shows that consumer tastes matter as determinants of location choice and do so in a reasonably determinate manner. When consumer heterogeneity is high or distance between individual markets is low, we typically find that the large firm disperses its outlets, concentrating on the less central markets, while the smaller firms locate in the more central markets. By contrast, when consumer heterogeneity is low or distance between markets high, the larger firm adopts a more uniform distribution of its outlets while the smaller firms adopt more separated, but interleaved location configurations.

Much more remains to be done in this important area. Introducing explicit price competition presents formidable technical challenges and, we feel, is not a particularly fruitful route to take. The types of markets that provided the initial motivation for our analysis, for example, are not characterized by any great degree of price competition. This is not actually all that surprising. Multi-product firms are involved in multi-market contact, with the result that they might well be expected to arrive at a tacitly cooperative set of prices that will apply across their markets, competing instead on dimensions such as product design (location choice).

A more fruitful and interesting extension is to relax our assumption that each firm chooses to locate a *given* number of outlets, in order to investigate whether this is the number of outlets that it would actually choose. We leave detailed analysis of this question to later research. However, we can give an outline of what we are likely to find. We can show that in every equilibrium configuration we have identified a firm loses market share by reducing its number of outlets, and that its increase in market share as it adds outlets decreases with the number of outlets. This implies that, if adding an outlet imposes set-up costs, there is a range of set-up costs for which our chosen configuration is, indeed, an equilibrium. More generally, we should find that there is an identifiable relationship between consumer heterogeneity, set-up costs and product proliferation by multi-product firms. In addition, of course, this analysis is likely to find even more asymmetry in firms' equilibrium choices than we have identified in the current analysis.

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Table 1: Location Equilibria for Single-Outlet Firms

d/μ	Location Equilibria
0-0.439	(0,0,11,0,0)
0.440-0.473	(0,0,11,0,0), (0,1,9,1,0)
0.474-0.498	(0,0,11,0,0), (0,1,9,1,0), (0,2,7,2,0)
0.499-0.520	(0,1,9,1,0), (0,2,7,2,0)
0.521-0.539	(0,1,9,1,0), (0,2,7,2,0), (0,3,5,3,0)
0.540-0.592	(0,2,7,2,0), (0,3,5,3,0)
0.593	(0,3,5,3,0)
0.594-0.675	(0,3,5,3,0), (0,4,3,4,0)
0.676-0.753	(0,4,3,4,0)
0.754-0.849	(0,4,3,4,0), (0,5,1,5,0)
0.850-0.891	(0,5,1,5,0)
0.892-0.937	(0,5,1,5,0), (1,3,3,3,1)
0.938-1.083	(1,3,3,3,1)
1.084-1.221	(1,4,2,3,1)**
1.222-1.227	(1,4,2,3,1), (1,3,3,2,2)**
1.228-1.253	(1,3,3,2,2)**
1.254-2.101	(2,2,3,2,2)
2.102-	(2,3,2,2,2)**

Notes: ** indicates an asymmetric equilibrium.

Table 2: Location Equilibria for Multi-Outlet Firms

d/μ	Location Configuration			Aggregate Configuration
	Firm 1	Firm 2	Firm 3	
0-0.434	(0,0,5,0,0)	(0,0,3,0,0	(0,0,3,0,0)	(0,0,11,0,0)
0.435-0.456	(0,1,3,1,0)	(0,0,3,0,0)	(0,0,3,0,0)	(0,1,9,1,0)
0.456-0.471	(0,0,5,0,0)	(0,1,1,1,0)	(0,1,1,1,0)	(0,2,7,2,0)
0.472-0.485	(0,2,1,2,0)	(0,0,3,0,0)	(0,0,3,0,0)	(0,2,7,2,0)
0.486-0.554	(0,1,3,1,0))	(0,1,1,1,0)	(0,1,1,1,0)	(0,3,5,3,0)
0.555-0.833	(0,2,1,2,0)	(0,1,1,1,0)	(0,1,1,1,0)	(0,4,3,4,0)
0.834-0.839	(0,2,1,2,0)	(0,1,1,1,0)	(1,0,1,0,1)	(1,3,3,3,1)
0.839-1.026	(1,1,1,1,1)	(0,1,1,1,0)	(0,1,1,1,0)	(1,3,3,3,1)
1.027-1.032	(1,2,0,1,1)	(0,1,1,1,0)	(0,1,1,1,0)	(1,4,2,3,1)
1.033-1.057	(1,0,3,0,1)	(0,2,0,1,0)	(0,1,0,2,0)	(1,3,3,3,1)
1.058-1.064	(1,1,2,0,1)	(1,0,1,1,0)	(0,1,0,2,0)	(2,2,3,3,1)
1.065-1.068	(0,2,1,2,0)	(1,0,1,1,0)	(1,0,1,0,1)	(2,2,4,1,2)
1.069-1.529	(0,2,1,2,0)	(1,0,1,0,1)	(1,0,1,0,1)	(2,2,3,2,2)
1.530-2.138	(2,0,1,0,2)	(0,1,1,1,0)	(0,1,1,1,0)	(2,2,3,2,2)
2.139-	(1,1,1,1,1)	(1,0,1,1,0)	(0,1,1,0,1)	(2,2,3,2,2)

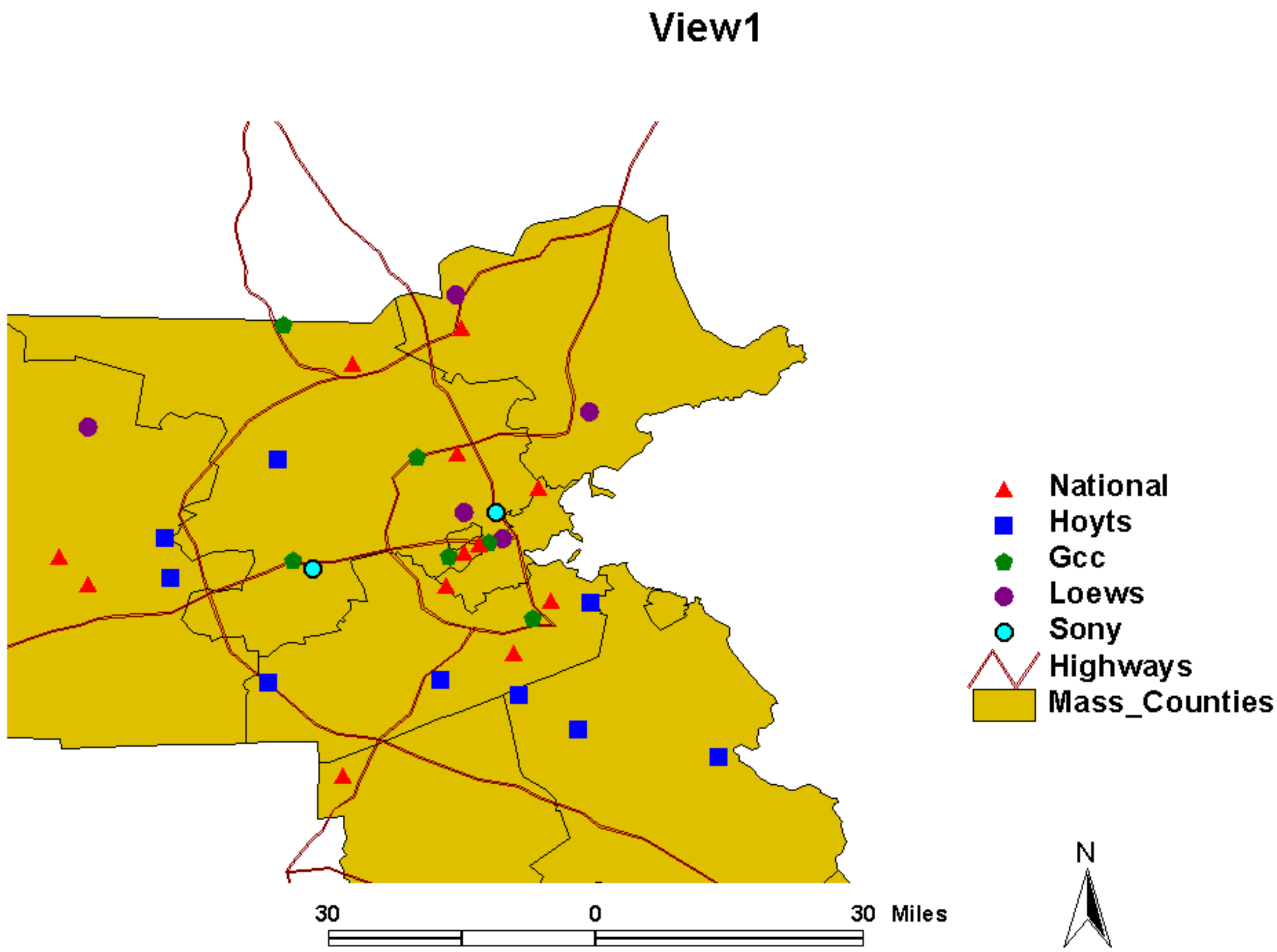


Figure 1: Locations of Multiplex Cinemas in Eastern Massachusetts

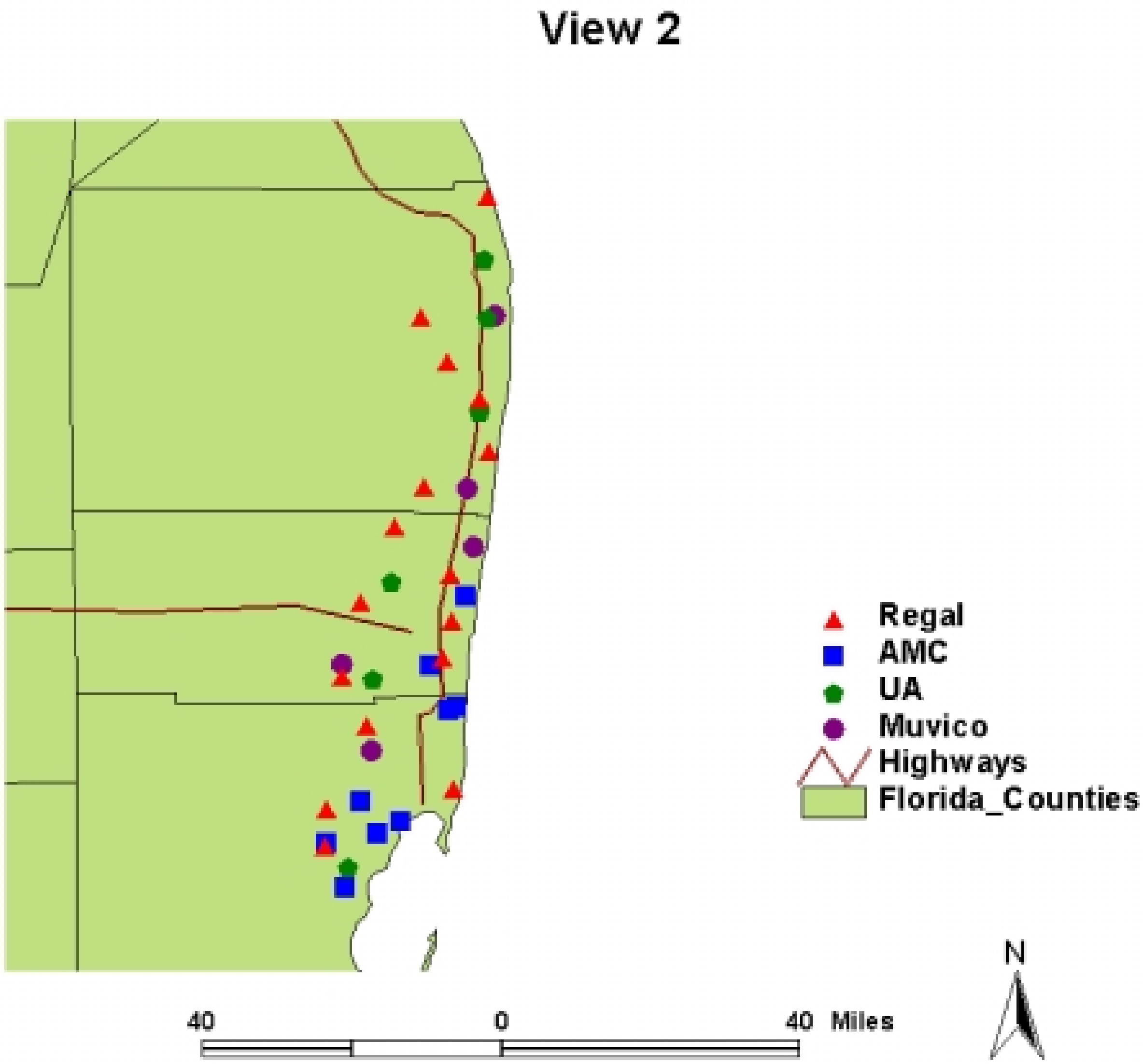
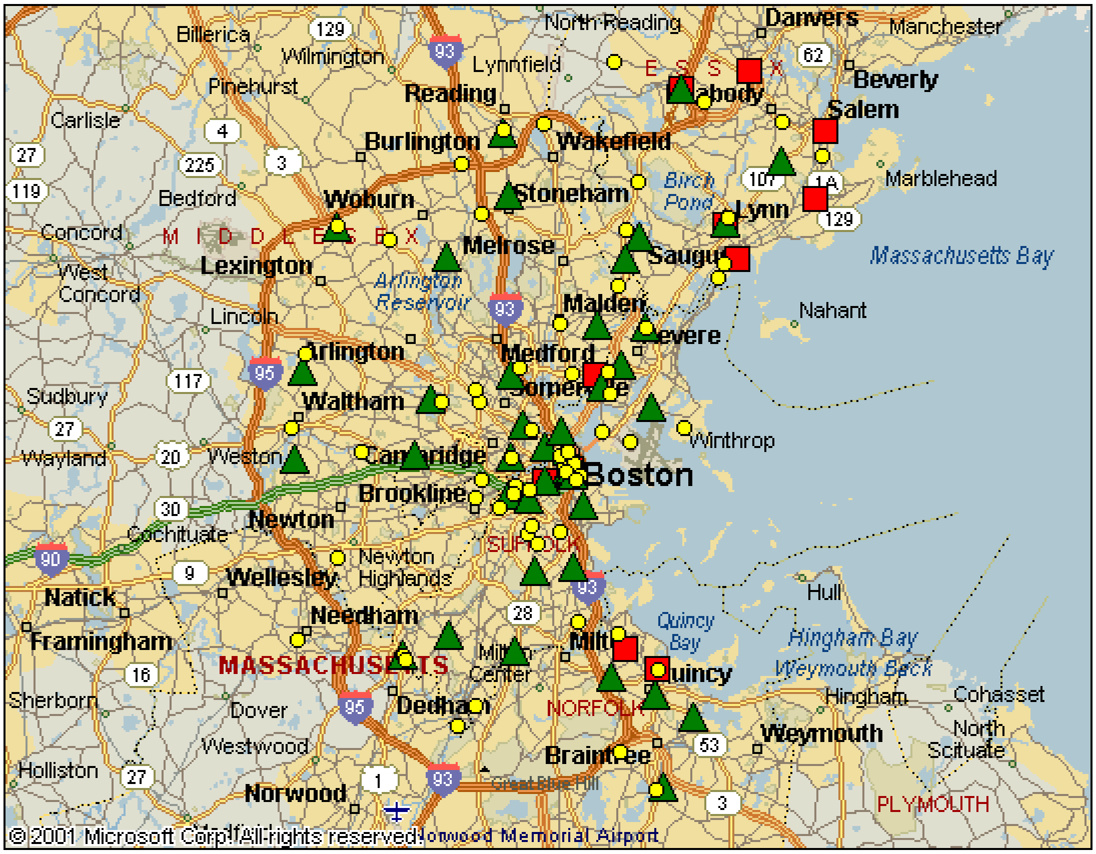


Figure 2: Locations of Multiplex Cinemas in South Florida



McDonald's

Burger King

Wendy's

Figure 3: Fast Food Outlets in the Boston MSA

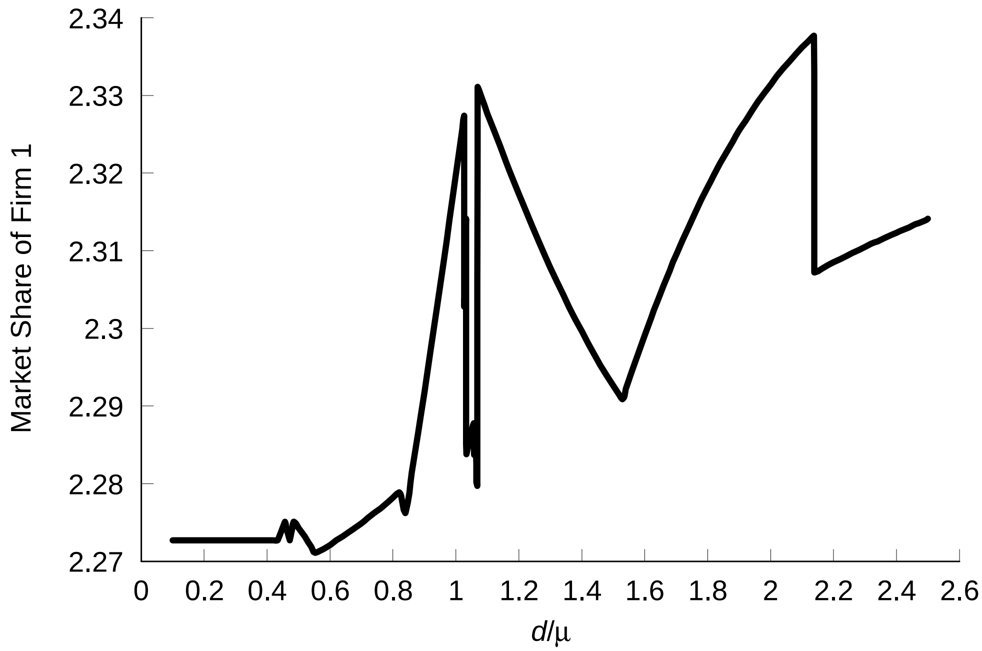


Figure 4: Market Share of Firm 1

Appendix Table 1: Payoff Matrix for Firms 2 and 3 – d/μ = 1; c_1 = (1,1,1,1,1)

Firm2	Firm 3															
	(0,0,3,0,0)		(0,0,2,1,0)		(0,0,1,2,0)		(0,.0,2,0,1)		(0,0,1,1,1)		(0,0,0,2,1)		(0,0,1,0,2)		(0,0,0,1,2)	
(0,0,3,0,0)	1.2501	1.2501	1.2539	1.2929	1.2770	1.2829	1.2812	1.2912	1.3040	1.2753	1.3481	1.2069	1.3489	1.2029	1.3921	1.1366
(0,1,2,0,0)	1.2929	1.2539	1.3060	1.3060	1.3377	1.3030	1.3350	1.3056	1.3666	1.2976	1.4193	1.2347	1.4116	1.2242	1.4641	1.1646
(0,2,1,0,0)	1.2829	1.2770	1.3030	1.3377	1.3401	1.3401	1.3315	1.3382	1.3688	1.3360	1.4261	1.2750	1.4112	1.2606	1.4691	1.2033
(1,0,2,0,0)	1.2912	1.2812	1.3056	1.3350	1.3382	1.3315	1.3342	1.3342	1.3668	1.3253	1.4204	1.2587	1.4107	1.2498	1.4644	1.1859
(1,1,1,0,0)	1.2753	1.3040	1.2976	1.3666	1.3360	1.3688	1.3253	1.3668	1.3642	1.3642	1.4226	1.2998	1.4050	1.2867	1.4644	1.2256
(1,2,0,0,0)	1.2069	1.3481	1.2347	1.4193	1.2750	1.4261	1.2587	1.4204	1.2998	1.4226	1.3568	1.3568	1.3334	1.3423	1.3923	1.2791
(2,0,1,0,0)	1.2029	1.3489	1.2242	1.4116	1.2606	1.4112	1.2498	1.4107	1.2867	1.4050	1.3423	1.3334	1.3242	1.3242	1.3812	1.2548
(2,1,0,0,0)	1.1366	1.3921	1.1646	1.4641	1.2033	1.4691	1.1859	1.4644	1.2256	1.4644	1.2791	1.3923	1.2548	1.3812	1.3105	1.3105
(0,1,1,1,0)	1.3585	1.2534	1.3517	1.2889	1.3654	1.2732	1.3764	1.2877	1.3902	1.2638	1.4271	1.1855	1.4352	1.1935	1.4716	1.1126
(1,0,1,1,0)	1.3571	1.2835	1.3490	1.3207	1.3611	1.3044	1.3731	1.3190	1.3851	1.2940	1.4200	1.2111	1.4289	1.2214	1.4633	1.1348
(1,1,0,1,0)	1.3600	1.3042	1.3540	1.3509	1.3665	1.3415	1.3779	1.3505	1.3899	1.3326	1.4231	1.2522	1.4315	1.2585	1.4640	1.1736
(1,0,1,0,1)	1.3517	1.3166	1.3433	1.3488	1.3537	1.3254	1.3374	1.3230	1.3505	1.2999	1.3851	1.2131	1.3687	1.2151	1.4053	1.1294
(0,2,0,1,0)	1.3658	1.2749	1.3607	1.3195	1.3749	1.3101	1.3854	1.3195	1.3992	1.3020	1.4349	1.2254	1.4424	1.2299	1.4775	1.1501
(2,0,0,1,0)	1.2822	1.3536	1.2711	1.4007	1.2774	1.3887	1.2925	1.3992	1.2978	1.3779	1.3228	1.2893	1.3357	1.3003	1.3594	1.2055

Appendix Table 1 (cont.): Payoff Matrix for Firms 2 and 3 – d/μ = 1; c_1 = (1,1,1,1,1)

Firm 2	Firm 3											
	(0,1,1,1,0)		(0,1,1,0,1)		(0,1,0,1,1)		(1,0,1,0,1)		(0,1,0,2,0)		(0,1,0,0,2)	
(0,0,3,0,0)	1.2534	1.3585	1.2835	1.3571	1.3042	1.3600	1.3166	1.3517	1.2749	1.3658	1.3536	1.2822
(0,1,2,0,0)	1.2889	1.3517	1.3207	1.3490	1.3509	1.3540	1.3488	1.3433	1.3195	1.3607	1.4007	1.2711
(0,2,1,0,0)	1.2732	1.3654	1.3044	1.3611	1.3415	1.3665	1.3254	1.3537	1.3101	1.3749	1.3887	1.2774
(1,0,2,0,0)	1.2877	1.3764	1.3190	1.3731	1.3505	1.3779	1.3230	1.3374	1.3195	1.3854	1.3992	1.2925
(1,1,1,0,0)	1.2638	1.3902	1.2940	1.3851	1.3326	1.3899	1.2999	1.3505	1.3020	1.3992	1.3779	1.2978
(1,2,0,0,0)	1.1855	1.4271	1.2111	1.4200	1.2522	1.4231	1.2131	1.3851	1.2254	1.4349	1.2893	1.3228
(2,0,1,0,0)	1.1935	1.4352	1.2214	1.4289	1.2585	1.4315	1.2151	1.3687	1.2299	1.4424	1.3003	1.3357
(2,1,0,0,0)	1.1126	1.4716	1.1348	1.4633	1.1736	1.4640	1.1294	1.4053	1.1501	1.4775	1.2055	1.3594
(0,1,1,1,0)	**1.3401**	**1.3401**	1.3675	1.3374	1.3796	1.3216	1.3978	1.3306	1.3522	1.3328	1.4297	1.2427
(1,0,1,1,0)	1.3374	1.3675	1.3642	1.3642	1.3748	1.3477	1.3654	1.3263	1.3480	1.3600	1.4238	1.2662
(1,1,0,1,0)	1.3216	1.3796	1.3477	1.3748	1.3568	1.3568	1.3518	1.3382	1.3314	1.3718	1.4033	1.2681
(1,0,1,0,1)	1.3306	1.3978	1.3263	1.3654	1.3382	1.3518	1.3242	1.3242	1.3398	1.3826	1.3607	1.2540
(0,2,0,1,0)	1.3328	1.3522	1.3600	1.3480	1.3718	1.3314	1.3826	1.3398	1.3450	1.3450	1.4202	1.2459
(2,0 ,0,1,0)	1.2427	1.4297	1.2662	1.4238	1.2681	1.4033	1.2540	1.3607	1.2459	1.4202	1.3105	1.3105

Appendix Table 2: Payoff Matrix for Firms 2 and 3 – d/μ = 1.06; c_1 = (1,1,2,0,1)

Firm 2	Firm 3															
	(0,0,3,0,0)		(0,0,2,1,0)		(0,0,1,2,0)		(0,.0,2,0,1)		(0,0,1,1,1)		(0,0,0,2,1)		(0,0,1,0,2)		(0,0,0,1,2)	
(0,0,3,0,0)	1.2499	1.2499	1.2278	1.3200	1.2313	1.3255	1.2627	1.3256	1.2599	1.3304	1.2834	1.2743	1.3152	1.2516	1.3302	1.2075
(0,1,2,0,0)	1.2893	1.2617	1.2784	1.3414	1.2920	1.3532	1.3146	1.3482	1.3220	1.3607	1.3550	1.3094	1.3763	1.2805	1.4016	1.2432
(0,2,1,0,0)	1.2716	1.2934	1.2708	1.3814	1.2918	1.3973	1.3054	1.3893	1.3210	1.4070	1.3600	1.3562	1.3707	1.3246	1.4032	1.2893
(1,0,2,0,0)	1.2924	1.2895	1.2835	1.3706	1.2982	1.3815	1.3189	1.3771	1.3277	1.3886	1.3616	1.3332	1.3803	1.3063	1.4069	1.2648
(1,1,1,0,0)	1.2684	1.3211	1.2710	1.4105	1.2942	1.4256	1.3043	1.4184	1.3224	1.4353	1.3631	1.3808	1.3696	1.3511	1.4046	1.3121
(1,2,0,0,0)	1.1869	1.3749	1.2007	1.4716	1.2295	1.4887	1.2277	1.4811	1.2532	1.5009	1.2956	1.4428	1.2895	1.4145	1.3287	1.3724
(2,0,1,0,0)	1.1944	1.3663	1.1973	1.4553	1.2193	1.4668	1.2278	1.4622	1.2451	1.4753	1.2835	1.4131	1.2880	1.3882	1.3214	1.3409
(2,1,0,0,0)	1.1154	1.4194	1.1318	1.5159	1.1606	1.5300	1.1549	1.5251	1.1813	1.5417	1.2219	1.4765	1.2118	1.4530	1.2503	1.4032
(0,1,1,1,0)	1.3884	1.2313	1.3532	1.2920	1.3446	1.2918	1.3845	1.2982	1.3702	1.2942	1.3834	1.2295	1.4256	1.2193	1.4308	1.1606
(1,0,1,1,0)	1.3942	1.2599	1.3577	1.3220	1.3474	1.3210	1.3886	1.3277	1.3724	1.3224	1.3834	1.2532	1.4266	1.2451	1.4294	1.1813
(1,1,0,1,0)	1.3982	1.2834	1.3648	1.3550	1.3561	1.3600	1.3961	1.3616	1.3808	1.3631	1.3910	1.2956	1.4332	1.2835	1.4346	1.2219
(1,0,1,0,1)	1.3921	1.3038	1.3578	1.3585	1.3479	1.3469	1.3508	1.3358	1.3385	1.3333	1.3515	1.2592	1.3606	1.2440	1.3686	1.1831
(0,2,0,1,0)	1.3962	1.2560	1.3633	1.3258	1.3558	1.3312	1.3952	1.3328	1.3813	1.3349	1.3937	1.2714	1.4351	1.2574	1.4389	1.2004
(2,0 ,0,1,0)	1.3224	1.3302	1.2844	1.4016	1.2700	1.4032	1.3136	1.4069	1.2920	1.4046	1.2945	1.3287	1.3409	1.3214	1.3341	1.2503

Appendix Table 2 (cont.): Payoff Matrix for Firms 2 and 3 – d/μ = 1.06; c_1 = (1,1,2,0,1)

	Firm 3											
Firm 2	(0,1,1,1,0)		(0,1,1,0,1)		(0,1,0,1,1)		(1,0,1,0,1)		(0,1,0,2,0)		(0,1,0,0,2)	
(0,0,3,0,0)	1.2313	1.3884	1.2716	1.3912	1.2626	1.4202	1.3038	1.3921	1.2308	1.4144	1.3252	1.3317
(0,1,2,0,0)	1.2634	1.3888	1.3048	1.3899	1.3064	1.4216	1.3318	1.3908	1.2731	1.4160	1.3679	1.3274
(0,2,1,0,0)	1.2413	1.4099	1.2809	1.4092	1.2916	1.4418	1.3001	1.4087	1.2593	1.4367	1.3481	1.3408
(1,0,2,0,0)	1.2677	1.4138	1.3083	1.4143	1.3117	1.4461	1.3079	1.3820	1.2790	1.4408	1.3714	1.3493
(1,1,1,0,0)	1.2373	1.4350	1.2752	1.4335	1.2886	1.4655	1.2770	1.4030	1.2574	1.4608	1.3422	1.3618
(1,2,0,0,0)	1.1498	1.4793	1.1799	1.4762	1.2014	1.5060	1.1777	1.4458	1.1759	1.5019	1.2423	1.3944
(2,0,1,0,0)	1.1675	1.4802	1.2023	1.4777	1.2154	1.5076	1.1904	1.4193	1.1868	1.5038	1.2643	1.4005
(2,1,0,0,0)	1.0786	1.5237	1.1038	1.5197	1.1259	1.5466	1.0933	1.4642	1.1041	1.5434	1.1597	1.4315
(0,1,1,1,0)	1.3446	1.3446	1.3806	1.3474	1.3601	1.3561	1.4098	1.3479	1.3312	1.3558	1.4226	1.2700
(1,0,1,1,0)	1.3495	1.3702	1.3854	1.3724	1.3631	1.3808	1.3820	1.3385	1.3348	1.3813	1.4246	1.2920
(1,1,0,1,0)	1.3348	1.3834	1.3707	1.3834	1.3474	1.3910	1.3715	1.3515	1.3200	1.3937	1.4066	1.2945
(1,0,1,0,1)	1.3479	1.4098	1.3448	1.3760	1.3265	1.3901	1.3381	1.3381	1.3339	1.4099	1.3550	1.2837
(0,2,0,1,0)	1.3375	1.3585	1.3741	1.3592	1.3531	1.3678	1.3955	1.3585	1.3246	1.3694	1.4140	1.2744
(2,0 ,0,1,0)	1.2598	1.4308	1.2936	1.4294	1.2638	1.4346	1.2769	1.3686	1.2392	1.4389	1.3194	1.3341

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