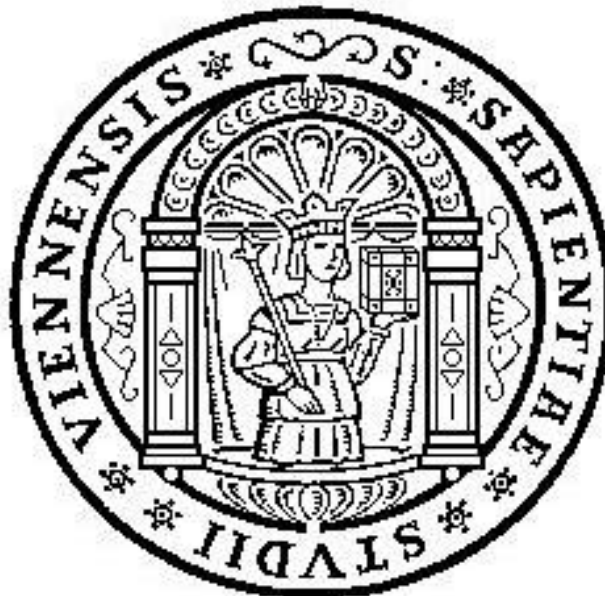# WORKING PAPERS

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Spatial Competition, Sequential Entry, and Technology Choice

April 2002

Working Paper No: 0215

DEPARTMENT OF ECONOMICS

UNIVERSITY OF VIENNA

Spatial Competition, Sequential Entry, and Technology Choice

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This draft: April 2002

Abstract: This article introduces technology choice into a Hotelling model of spatial competition. This yields two entry deterrence devices, as well as complex strategic choices for the firms and a rich picture of industry structure. Depending on cost parameters and market size, firms may choose to over-invest or to under-invest. Industry structure is typically asymmetric either in terms of the locations chosen or the technologies used or in both. I find excessive entry deterrence, second-mover advantage as well as delegation of entry deterrence. Both the number of firms and the equilibrium prices may be non-monotonic in market size. Larger markets may exhibit higher prices.

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1. Introduction

Strategic competition covers a wide range of business strategies. Among the most important devices to manipulate market positions in a favorable way are strategic investments and the strategic choice of product characteristics. These instruments are most important when there is an initial asymmetry among firms. Early movers have a first mover advantage in this case due to the ability to make commitments. By suitably choosing their strategic variables, incumbents affect market structure. They may be able to determine the number and types of their rivals. The degree by which incumbents can influence market structure depends on exogenous factors such as market size, preferences, and technology. Therefore, industry structure is the result of both exogenous variables and the strategic actions of early movers.

One of the main aims of the paper is a theory of industry structure based on fundamentals including market size and costs. The results are twofold. First, I obtain an endogenous explanation of the number of firms, their size distribution and the prices charged. Industry structure is often characterized by heterogeneity among the active firms. Second, as a by-product the determinants of the strategic behavior of the early movers become obvious. My model facilitates the evaluation of the firms' strategic actions from a social point of view. It turns out that both over-investment and under-investment by all active firms may be equilibrium outcomes.

To analyze strategic actions, I use a Hotelling model of spatial competition to which I add a stage with technology choice. I deal both with the question of strategic choice of product characteristics and with the question of strategic investment. Rather than the literature on entry deterrence by means of capacity choice, I follow McLean and Riordan (1989) in modeling strategic investment by the choice from a set of technologies which differ in terms

of fixed as well as marginal costs. Entry mode is sequential in my model.[1] This assumption implies the above mentioned asymmetry among firms.

The simple framework yields a rich picture of industry structure and allows for rather complex strategic actions of firms. The structure of the model also fits quite well to specific industries. An example is the airline industry. Competition on a specific route typically involves a small number of firms. The products, that is the flights, are differentiated by departure times. Technology choice enters the picture through the choice of the aircraft, which serves the route. Finally, the position of different airlines is usually asymmetric. If an airport is a hub for an airline, this carrier often has preferred access to slots.[2]

The model enables one to address the following questions. Why is a certain local route served by two competing airlines using small sized aircrafts and departing at 7.00am and 9.00am, respectively, rather than by a single airline using a medium-sized aircraft departing at 8.00am?[3] Is the choice of the aircraft, i.e., the technology choice, socially optimal? Although the model certainly does not capture the complex nature of competition among airlines completely, it provides insight into the determinants of the behavior of firms. The model also enables preliminary assessments of welfare properties of the emerging industry structure.

My article is related to and synthesizes two strands of the literature. The first one is the extensive literature on entry deterrence by means of capacity choice (Dixit 1980, Ware 1992). Questions of over-investment and under-investment typically arise in such models (Tirole 1988). The second one deals with the strategic choice of product characteristics (see Neven

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[1] With simultaneous entry, cost differences often lead to the non-existence of a location equilibrium, see Schulz and Stahl (1985), and Ziss (1993).

[2] Of course, the model captures only part of factors, which matter in the airline industry. The verdict of Borenstein and Netz (1999, p. 612) that "the airline industry is much more complicated than the assumptions of any of the models …" applies to my model as well.

[3] The connections between Vienna and Geneva exhibit this pattern, for instance.

1987, Pepall 1992, Donnenfeld and Weber 1995). Similar to my paper, at least part of the literature aims at a theory of industry structure that endogenously explains the number of firms, their size distribution and the prices. The fundamentals are demand and cost parameters as well as the structure of the entry game (see Eaton and Ware 1987, McLean and Riordan 1989). The contributions are interested in multi-firm competition that goes beyond the situation of one incumbent and one potential entrant.

My paper incorporates features which appear in different models of entry deterrence. As in Donnenfeld and Weber (1995), the noncooperative product and technology choice can lead to too much competition among incumbents and, therefore, excessive entry deterrence from the viewpoint of collusive location choice. Delegation of entry deterrence can also be an outcome of my model as in the Cournot models of McLean and Riordan (1989) and Church and Ware (1996). Delegation means that early entrants - rather than investing in entry deterrence themselves - induce later entrants to carry out the entry deterring investments. Similar to Eaton and Ware (1987), small parameter ranges exist for which my model exhibits a second-mover advantage.

I employ a standard Hotelling model with quadratic transportation costs (see, e.g., Tirole, 1988). Firms that are about to enter the market may choose from a set of technologies. For simplicity, it is assumed that only two different technologies are available, a small-scale and a large-scale technology. Both technologies require a fixed investment. Higher investments in fixed costs lower the variable production costs. There are no barriers to entry other than the fixed investments. As mentioned above, the main question of the paper is how the equilibrium industry structure will vary with changes in market size and cost parameters. I

examine this question in a simulation where I use parameter values Neven (1987) employs.[4] The paper corrects some of the conclusions drawn in Neven (1987). In the simulations I consider only parameter constellations for which at most three firms are active.

The remainder of the article is organized as follows. Section 2 describes the model. Section 3 examines the benchmark case in which only one technology matters. Section 4 derives industry structure as a function of fixed costs and market size when two technologies are available. With respect to the differences in marginal costs, two cases are treated. Section 5 concludes.

2. The model

In order to facilitate comparability, I use Neven's (1987) setup. There is a continuum of consumers distributed uniformly over the unit segment [0,1]. The density and the total population is N. As each consumer has a unit demand, N is a measure of market size. For a consumer whose location and most preferred variety is $\hat{x}$, the (indirect) utility from consuming a good which is sold at a price p_i at location x_i is

$$U_{\hat{x}} = a - t(x_i - \hat{x})^2 - p_i. \tag{1}$$

The (common) reservation price a is assumed to be large so that all consumers will always buy a product. I choose the indices of the firms in a way that firm i is located to the left of firm j, i.e. $x_i < x_j$, if $i < j$. With respect to the transport costs parameter t I assume: $t = 1$. Nevertheless, the model yields conclusions about the effects of changes in transport costs. In the case of one technology operating profits are proportional to t. Thus, a change in t has the same effect on operating profits as a change in market size N. In the case with two

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[4] The results of the simulation have been derived using Mathematica 3.0. They are available as both a compressed (zip) Mathematica notebook and a quite lengthy (>160 pages) PDF file at my home page at http://mailbox.univie.ac.at/Georg.Goetz

technologies, proportionality holds if the cost difference between the technologies is assumed to be proportional to t.[5] If the cost difference is independent of the transport costs, the difference becomes less important as the transport costs increase.

The consumer α who is indifferent between buying at i and j is defined by the condition

$$\alpha_{i,j} = \frac{p_j - p_i}{2(x_j - x_i)} + \frac{x_j + x_i}{2}. \tag{2}$$

Suppose n firms are active. Analogously to Neven (1987) I define the sets

$$L = \{0, \alpha_{1,i}, \ldots, \alpha_{i-1,i}\} \text{ and } R = \{\alpha_{i,i+1}, \ldots, \alpha_{i,n}, 1\} \tag{3}$$

The aggregate demand faced by firm i is given by

$$D_i = \max\{0, N(\min R - \max L)\}.$$

The profit function of firm i reads

$$\pi_i = (p_i - c_i)D_i - f_i,$$

where c_i and f_i denote firm i's marginal and fixed costs, respectively. As noted in the introduction, I consider two different technologies. The marginal production costs are assumed constant in both cases. f_S (f_L) and c_S (c_L) denote the fixed costs and the marginal costs associated with the small-scale (large-scale) technology. In slight abuse of terminology, I call firms employing the large-(small-)scale technology large (small) firms. With inelastic demand, this statement relates of course to the technology employed, not to actual size. I assume that $f_L > f_S$ and $c_L < c_S$. Therefore, higher investments in fixed costs lower the variable production costs. Without loss of generality, c_L can be set equal to 0. In this case c_S is interpreted as the cost difference between the two types of firms. Furthermore, I use $f_L = 25$. This does not restrict generality as the equilibrium depends only on the ratio of fixed costs to market size. The value of f_L is chosen because it yields nice numbers.

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[5] The effects of increasing N and t differ, however, if t is large compared to a. As t increases further, some consumers may start to buy the outside good rather than the differentiated products.

Neven (1987) shows that for any vector of products (i.e. locations) chosen by the firms a unique equilibrium of the second-stage price game exists. The arguments that ensure existence and uniqueness are concavity of the demand and the profit function as well as the linearity of the reaction functions in the rivals' prices. Neven considers only the case where firms have identical marginal costs. As the demand and profit functions are concave for the case of firms with different marginal costs, the existence and uniqueness result extends to this case. The only difference is that some (high marginal costs) firms may not be viable in equilibrium. In the simulations and results presented below the (unique) equilibria are calculated directly, therefore I will not spend more time on the question of existence and uniqueness here.

3.   The benchmark case: Only the large-scale technology is used

Before I turn to the cases in which small firms matter, I consider the case in which only large firms are active. This case applies in my setting if f_S is sufficiently large. The reasons for dealing with this case are twofold. First, this case provides the benchmark for the discussion of the situation with different firms. The discussion of this situation is more straightforward with this point of reference. Second, and more importantly, this section corrects some of the results derived in Neven (1987). Contrary to Neven, I will show that the pattern of locations is in general asymmetric in the case of a duopoly. The prices of the incumbents differ as well as the profits they make.

The equilibrium of the game is a function of market size N. The results are depicted in figures 1, 2 and 3.

[Insert figure 1 about here]

[Insert figure 2 about here]

[Insert figure 3 about here]

The diagrams show the equilibrium locations, the equilibrium profits, and the equilibrium prices as a function of market size. These relationships are not continuous. In what follows I depict the threshold values of market size for which changes in the type of competition takes place.

i)   For $N < 144$, a second firm cannot profitably enter. The monopolist locates in the center of the market and thus deters entry.

ii)   For $144 \leq N < 200$, we find a duopoly with maximum product differentiation.[6] Entry of a third firm is blockaded.

iii)   For $200 \leq N < 468.9$, entry is no longer blockaded. The first entrant deters further entry by unilaterally moving closer to the center as N grows.

        The above statement follows from figure 1. A formal proof can be found in the Appendix. The result is in contrast to Neven's claim that both firms will move inside and choose symmetric locations (Neven 1987, p. 429). Contrary to Neven, the first entrant bears the "burden" of entry deterrence alone in this range. The burden is put in quotation marks as the profit of the first entrant increases while that of the second is constant in spite of the increase in market size.

iv)   For $468.9 \leq N < 967.6$, the first entrant can no longer deter entry alone. The second entrant moves closer to the center in order to deter entry. The first entrant will move closer to the edge of the market.

        In this range the condition for entry deterrence at both the center and at location zero are binding. The calculation of the subgame perfect is complicated by the fact that the optimal location for entry at the left edge is not zero but a positive value. That is, the optimal location must be calculated.

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[6] Taking the fraction f_L/N one gets the values Neven derives.

At $N = 967.6$ the third entry deterrence constraint becomes binding. The two firms are located symmetrically at 0.330 and 0.670.[7]

v)   For $967.6 < N < 1136.9$, we find an oligopoly with three firms. Further entry is blockaded. The equilibrium locations are: First entrant: 0.426, second entrant: 0.889, third entrant: 0.074.[8]

Two general points arise from the diagrams.

First, market structure and profits are asymmetric, in general, even in the case of two firms with identical cost functions, once entry deterrence is taken into account. This result is in line with that of Gupta (1992) who analyses entry deterrence in a Hotelling model with spatial price discrimination. Gupta finds that in duopoly the first entrant mostly locates closer to the center than the second. Tabuchi and Thisse (1995) also stress asymmetry. They allow for locations outside the range [0,1] and show that the first entrant will locate in the center of the market while the second locates outside the market space. My calculations make clear that quite asymmetric locations (consider for instance the equilibria for N close to 470) can arise even in the standard model. As regards profits, the initial asymmetry induced by the order of entry leads to a pattern of profits which is perfectly correlated with the order of entry: Early entrants earn higher profits.

Second, increases in market size have different effects on prices and profits. Prices decrease monotonically in market size, while profits may also be greater in larger markets. Greater market size implies lower barriers to entry (the ratio of fixed costs to market size falls). As a result potential competition is more intensive, requiring the incumbents to locate closer to

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[7] This result again differs from Neven. His locations are .31 and .69. He claims that entry of a third firm can no longer be prevented for values of $f_L/N < 0.0255$. My calculations show that the respective value is 0.0258.

[8] The results for the equilibrium locations differ from Neven's by an order of 0.005. The third entrant earns higher profits in the locations I calculated.

each other. The resulting increase in actual competition adversely affects profits. However, by increasing demand, the increase in N also exhibits a positive effect on profits. Figure 2 and the above discussion of the ranges iii) and iv)[9] show that the latter effect benefits only the firm that gains a larger market share due to the required entry deterring 'relocation'.[10] The fact that multiple entrants must be deterred at the same time in the Hotelling model (in the relevant region) explains why it is not always the first entrant who gains from an increase in market size.

4. Industry structure in oligopoly with technology choice

In this section I examine the consequences of technology choice for both industry structure and the strategic behavior of incumbents. Key variables of the analysis are market size, the fixed costs of the small-scale technology (f_S), and the difference in marginal costs between the two available technologies. Simulations show how these exogenous parameters shape industry structure and strategic competition. I focus on situations with one to three active firms. Such a structure can be found in many retail and professional industries (see Bresnahan and Reiss, 1991) as well as in city pair markets in the airline industry (see Berry, 1992).

Before turning to the examples, I state the reduced profit functions and mention some general properties of the profit functions in the case with different technologies and two active firms. The marginal costs of the first entrant are assumed to be zero, that of the second are equal to c. The locations of the first and second entrant are x_1 and x_2, respectively. Furthermore, the profit is derived under the assumption that $x_1 < x_2$. The operating profits (gross of fixed costs) of the first and second entrant are

$$\pi^1(x_1, x_2, c) = \frac{((x_2 - x_1)(2 + x_1 + x_2) + c)^2 N}{18(x_2 - x_1)} \quad \text{and} \tag{4}$$

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[9] Profits of the first entrant fall in the latter range, whereas profits of the second rise.

[10] Of course, an increase in N affects all incumbents positively in regions where entry is blockaded.

$$\pi^2(x_1, x_2, c) = \frac{\left((x_2 - x_1)(4 - x_1 - x_2) - c\right)^2 N}{18(x_2 - x_1)}, \tag{5}$$

respectively. An important feature of the model is that the operating profits depend only on the differences in costs. Therefore the profit functions $\pi^1(x_1, x_2, 0)$ and $\pi^2(x_1, x_2, 0)$ apply not only to both firms employing the large-scale technology but also to all cases where the marginal costs of the firms are identical.

Two further properties derive from the case, in which the first entrant chooses the large-scale technology (See the appendix for a derivation of the properties).

Property 1. Given the locations, the first entrant always prefers a small rival to a large one ceteris paribus.

Property 2. The difference in operating profits between the large-scale and the small-scale technology increases with market size N and the distance between the firms $(x_2 - x_1)$.

Both properties are straightforward. They show that the model contains elements which seem to suggest a 'naive' view of competition, namely that firms should always try to keep their rivals small. Similarly, Property 2 suggests that larger markets lead firms to adopt large-scale technologies. The equilibrium analysis below shows both the conditions under which the naive view is true and that firms, in general, use much more sophisticated strategies.

In what follows, I perform simulations for two different values of c_S, namely 1/2 and 1/8. These values are supposed to represent 'large' and 'small' cost differences, respectively. Note that a single large incumbent located at the center would undercut a competitive fringe as soon as $c_S \geq 3/4$. Firms of the competitive fringe face zero fixed costs and set prices according to their marginal costs c_S. The respective value for small firms pricing according to the second stage price game is $c_S \geq 5/4$. The behavior of a large incumbent facing a single entrant who surely enters constitutes the main difference between the cost structures of the simulations. With $c_S = 1/2$ the incumbent will prevent large-scale entry as long as possible.

With $c_S = 1/8$ the incumbent prefers to compete with a large rival rather than with a small one if preventing its rival from switching to the large-scale technology requires locating at the center.

[Insert Figures 4 and 5 about here]

Figures 4 and 5 depict industry structure in the $(f_S / N, N)$ - space. Using the ratio of the fixed costs f_S to market size N rather than the absolute value of fixed costs allows for a simple graphical representation of equilibrium industry structure. Furthermore, f_S / N makes both the calculation and the interpretation of the results easier. The reason is that total profits from the small-scale technology are then proportional to N. Therefore, N does not influence the entry decision of small-scale firms, given f_S / N. Consequently, incumbents' locations do not change along the vertical dimension in the regions in which potential competition from small entrants matters.

The range covered by figures 4 and 5 is similar to that in the benchmark case. It starts at $f_S / N = .0220$. For smaller values of f_S / N entry of a fourth (small) entrant is no longer blockaded in the case of three small firms. I do not analyze this case, because of the rather involved computations. While the upper limit of f_S / N covered in the diagram is about .07 (0.15 in figure 5), the industry structure depicted in the diagram extends to larger values of f_S / N. An exception arises for $f_S / N > 25/144$ and below the locus dividing the monopoly regions with blockaded and deterred entry. For the respective parameter values, the monopolist will use the small-scale technology. To see this, note that in this case, the small-scale technology is sufficient to deter further entry of small firms and is also cost-efficient. The latter property follows from the fact that the locus equalizes costs associated with both technologies, i.e. the condition $25 = N/2 + f_S$ ($25 = N/8 + f_S$ for $c_S = 1/8$) is satisfied. Concerning market size, the benchmark case applies for values of N greater than those in the Figures 4 and 5 in a straightforward way.

The construction of Figures 4 and 5 can most easily be explained by starting with the monopoly region with blockaded entry (region I,a in figure 5). The horizontal upper borderline is drawn at $N = 144$, the value up to which entry of a second large firm is blockaded by a large incumbent located at the center. The vertical segment corresponds to $f_S / N = 1/16$ (9/64 for $c_S = 1/8$). Entry of small-scale firms is blockaded for values of f_S / N greater than 1/16 (9/64, resp.). The monopolist's choice of the large-scale technology is a strategic move in the region of deterred entry. With no entry threat the small-scale technology would be optimal. An assumption implicit in the diagram is that the first entrant always prefers to be a monopolist using the large-scale technology rather than a duopolist using the small-scale technology. This assumption requires the reservation price a to be sufficiently large. The condition a must satisfy in the case of $c_S = 1/2$ is

$$N(a - 1/4) - 25 > N/2 - f_S. \tag{6}$$

This equation leads to the constraint

$$a > 3/4 + 25/N - f_S/N. \tag{7}$$

This assumption becomes problematic only for small values of N. If the assumption were not satisfied, the area with two small firms active would be larger.

The general patterns of industry structure and strategic behavior of incumbents come out quite clearly from Figures 4 and 5. The figures reveal how both incumbents' technology choice and their choice of location depend on the parameters. The model entails various dimensions of market structure. Apart from the number of firms and the distribution of market shares both the technologies chosen and the choices of locations matter for the conduct of the firms. Two situations in which the distribution of market shares is identical may differ largely in the resulting prices if either the technologies used or the equilibrium locations are different.

In the following subsections I discuss the salient features in some detail.

4.1   Asymmetric industry structure and the degree of product differentiation

Result 1: Industry structure is asymmetric in general. Firms may differ in technologies, locations, or both.

In the case $c_S = 1/2$ (Figure 4) firms are symmetric only in the region with two large-scale firms and maximum product differentiation. Only in this area both the technology used and the market shares are the same for both firms. For $c_S = 1/8$ (Figure 5) symmetry holds in regions II,a and VI,a. The figures show that indivisibilities with respect to technology together with strategic location choice yield a quite heterogeneous industry structure even though potential entrants are identical except with respect to the order of moves. How asymmetric industry structure might become, is discussed in the next result.

Result 2: If the difference in marginal costs between the large-scale and the small-scale technology is large, the first entrant may choose a regime with 'minimum' product differentiation and low prices rather than maximum product differentiation and high prices. The second entrant is left with a market niche, which allows for small-scale entry only.

Result 2 refers to the duopoly case. What I call 'minimum' product differentiation in a slight abuse of terminology, is the situation in which the first entrant locates at the center of the market (location 1/2) while the second entrant locates at the edge of the market (location 1). This configuration is an equilibrium along the locus dividing the regions of excessive entry deterrence and the region with two large firms (Figure 4). In this situation both firms, although using different technologies, charge the same price (3/4). The first entrant prefers having a small rival rather than a large one. This holds even though she has to locate at the center while she could enjoy maximum product differentiation with a large rival. The equilibrium price would be one in the latter case. The first entrant goes for market share rather than for a relaxation of price competition. The first entrant chooses the respective configuration for a difference in marginal costs of at least .371. Thus we have a natural definition of what constitutes a large cost difference. For a small difference such as that

covered in Figure 5, the configuration with the first entrant located at the center does not arise. Nevertheless, a region exists in which the first entrant prevents the second from choosing the large-scale technology. This is discussed in the following, closely related result.

Result 3: Competition may be tougher than required by the threat of entry. The products are less differentiated than in a situation with exogenous technology. The first entrant's move aimed at preventing the second incumbent from using the large-scale technology leads to excessive entry deterrence. Actual competition rather than potential competition is the binding constraint for the strategic behavior of the first entrant in the relevant range.

Result 3 applies to the region of one large-scale and one small-scale firm and excessive entry deterrence in figures 4 and 5 (region V,e). In the respective regions the first entrant moves closer towards the center than required by deterrence of a third entrant. Only by doing this, the second entrant can be prevented from using the large-scale technology despite the large market size. From the viewpoint of a collusive choice of product specifications, entry deterrence is excessive. The reason is that the second entrant cannot commit to using the small-scale technology. Both incumbents are worse off than in the case where both firms collusively choose locations. Donnenfeld and Weber (1995) discuss and find excessive entry deterrence in a model of vertical product differentiation. Their result differs from mine in that entry accommodation would be the collusive choice in their model. The collusive and the non-cooperative regime differ in how they deal with potential entry. In my model it is actual competition which yields excessive entry deterrence. Figures 4 and 5 show that actual competition is particularly important for location choice compared to potential competition if (marginal) cost differences are large. As far as strategic behavior of the first entrant is concerned, there is a similar pattern: the first entrant is tough versus an entrant whose alternative consists of a technology with a large cost disadvantage. Toughness, meaning that the first entrant is even willing to locate at the center, prevents large-scale entry. If the cost

disadvantage of the rival is small anyway, the first entrant rather accommodates large-scale entry. The first entrant will not locate closer to the center than .202 in this case. Consequently, one finds an industry structure with two large-scale firms for $N < 144$, the market size up to which entry of a second large firm can be deterred (see region VI,a in Figure 5).

Now I turn to the discussion of how incumbents deal with potential entry.

4.2 Capital investments and strategic choice of locations: Substitute or complementary entry deterrence devices?

In a model with two entry deterrence devices, a natural question to ask is whether these devices are complements or substitutes when it comes to deterring entry. The answer from my model is that, depending on the parameter values, they may be both. To see this, note that investment in a large-scale technology can have two different implications regarding entry deterrence. First, a standard effect by preventing entry which could not be prevented otherwise. The standard effect is working for values of f_S for which entry of a third firm cannot be deterred unless one of the first two entrants invests in the large-scale technology (regions with three active firms are relevant). In order to deter a third entrant, typically both a large-scale investment by one firm and a move into the market area is necessary; see, for example, the region with the second mover advantage. Both devices are complementary.

Second, the investment can be a substitute for deterring entry by location choice. The reason for using a device which requires an investment rather than the costless instrument location choice is the competition reducing impact of the technology switch. The gains come from a reduction in actual competition. This effect is at work, for example, at the switch from the case of two small firms, both located inside the market area to the region of delegated entry deterrence (in figure 5 see regions II,c and IV). This is apparent from the locations, prices and market shares if $f_S / N = .0258$ and $c_S = 1/2$. In this case two small firms are located symmetrically at .330 and .670. The prices are .840 and the market is shared equally. In the

asymmetric case, the locations (prices) are .006 (.997) and .733 (.956) for the first and second entrant, respectively. The market share of the large firm (i.e., the second entrant) is .658. Note that the (absolute) mark-ups of both firms increase due to the investment. The investment makes it possible to ease price competition. The increase in mark-ups of **both** firms makes clear that an externality is associated with entry deterrence by capital investment.

An interesting feature of the above example is the fact that the second entrant makes the large-scale investment. That this investment is quite costly follows from the associated change in profits. The profit of the second entrant decreases from 6.56 to 3.66. The profit of the first entrant is unchanged, i.e. it stays at 6.56 even after the switch. We find delegated entry deterrence in this case. The meaning and the rationale of such a move are explained in the next section.

Another instance of capital investment as a substitute entry deterring device for location choice comes out most clearly in region VI,e, Figure 5. In this region, the first entrant employing the large-scale technology wants the second entrant to invest into the large-scale technology. The downward jump in the line at .0359 in Figure 5 shows that the first entrant prefers a large rival to a small one. Entry deterrence by location choice only would imply an industry structure that is more competitive than the situation where a large-scale investment by the second entrant takes place. In region VI,e the first entrant locates closer to the edge than required by entry deterrence by means of location choice. She concedes a greater market share to the second entrant in order to induce large-scale investment. It is interesting to note that the second entrant's profit increases due to the switch. This follows from the fact that the alternative market structure is the same in both cases, namely one large and one small firm deterring small entrants at the center and at one edge, but that the market share of the second entrant must be greater.

4.3   Delegated entry deterrence

Result 4: The first entrant may delegate entry deterrence. Rather than making strategic investments herself, she induces the second entrant to use the large-scale technology. The market share of the second entrant is larger in this case. Instances exist in which the first entrant maximizes the market share of the second entrant. Nevertheless, the profits of the first entrant are higher than those of the second entrant.

The result that early entrants may put the burden of entry deterring investments on later entrants was first shown by McLean and Riordan (1989). Their framework differs from mine only in that they assume a homogeneous product Cournot oligopoly. McLean and Riordan focus on the outcome of the incumbents' noncooperative choice of entry deterring investments. Three possibilities arise in their model: Either early entrants make the strategic investment or they delegate entry deterrence to later entrants. The third possibility is under-investment in entry deterrence. That is, incumbents may fail to deter entry although they would mutually benefit from entry deterrence.

To understand Result 4 and the derivation of the respective region (region IV in Figure 5), it is useful to examine the strategic behavior of the two firms in some detail. First, I discuss the case in which two small firms could deter further entry ($f_S / N \geq 0.0258$). I describe the situation for $c_S = 1/2$. The case $c_S = 1/8$ differs only slightly as I will mention in passing. As mentioned in the above example the profit of the first entrant is unchanged by the technology switch occurring at the locus separating the relevant regions (regions II,c and IV in Figure 5). Of course this must be so by definition. Along the locus the location of the first entrant is determined such that the first entrant earns the same profit in the asymmetric case with the second entrant being large and in the two small firms case with the respective locations from the benchmark case. It turns out that this location is quite close to, but different from zero (.006) for $f_S / N = .0258$. Equality of profits requires that the first entrant moves closer to the

center in the region of delegated entry deterrence as f_S / N increases.[11] This follows from the fact that the profit of the first entrant increases in the two small firms case as f_S / N increases (see the benchmark case). Therefore, a larger market share is necessary to keep the first entrant indifferent between the two regimes.

Having calculated the location of the first entrant if she were to face a large rival, it is straightforward to derive the market size N at which the second entrant will be ready to employ the large-scale technology. Due to the location choice of the first entrant the alternative for the second entrant is the situation with three small firms. For f_S / N > .0341 (f_S / N > .0282 for c_S = 1/8), the second entrant locates so as to keep a third entrant at the edge of the market. For smaller values of f_S / N it is even a situation in which deterrence of a forth entrant provides the alternative for the second entrant. From the benchmark case it is clear that the profit the second entrant could earn in these cases is quite low. This explains why the second entrant is willing to employ the large-scale technology for quite small market sizes. It also shows that industry profits fall drastically due to the technology switch.

Two further points require explanation. Firstly, the result that delegation does not occur for f_S / N > .0439 (the vertical bound of the respective region; the respective value is .0339 for c_S = 1/8). The explanation is straightforward. For f_S / N > .0439, profit equalization would require the first entrant to locate so close to the center that the second entrant could deter entry of a third firm even when using the small-scale technology. Of course, the second entrant would prefer the two small firms case here.

Secondly, profitability of delegation of entry deterrence for the first entrant remains to be explained. Strict dominance of the delegation regime is easy to establish for vectors inside the respective region. Note that, given f_S / N, increases in market size N make the large-scale technology more profitable in relation to the small-scale technology. The first entrant can

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[11] The location is .100 for f_S / N = .0439, for example.

move to the center as N rises, and nevertheless induce the second entrant to make the capital investment. The first entrant's profit increases more than proportional with N. As N increases further, obvious limits to this strategy of increasing market share arise. As in the above scenario, the second entrant may be able to deter entry of a third firm even when using the small-scale technology. This constraint is relevant for $f_S / N > .0379$ ($f_S / N > .0269$ for c_S =1/8). For smaller values of f_S / N the first entrant is the only firm to locate inside the market area.[12] That is, the part of entry deterrence which concerns location choice is performed entirely by the first entrant. As market size increases, the large-scale technology becomes ever more profitable. The first entrant eventually switches to the large-scale technology.

It remains to discuss strategic behavior for $f_S / N < 0.0258$, the range for which two small firms can no longer deter entry of a third firm. Entry deterrence requires large-scale investment in this range. The interesting thing here is the derivation of the locus separating the region with delegation of entry deterrence from the region with the second mover advantage and the three small firms region (in the $c_S = 1/8$ case), respectively. For vectors inside the region with delegation, the above arguments apply. At the locus in question, the important point to note is that the first entrant wants to induce adoption of the large-scale technology by the second entrant for as small a market size as possible. The first entrant locates at the edge of the market and thus maximizes the market share of the second entrant.[13] As mentioned above, the second entrant's alternative is a situation with three firms deterring a fourth entrant. This explains why the profits of the first entrant are more than 50% percent

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[12] The situation for $c_S = 1/8$ is slightly different. As both firms must move in the relevant range of f_S / N (see region V,c) the binding constraint for the first entrant is deterrence of entry at the left edge of the market.

[13] Again, the situation is slightly different for $c_S = 1/8$. As both firms must move in order to deter entry, the first entrant locates so as to maximize the second entrant's market share conditional on entry being deterred. For instance at $f_S / N = .0220$, the locations are .177 and .610 for the first and second entrant, respectively.

above the profits of the second entrant.[14] What requires explanation is the region with the second mover advantage. Discussion of that region is included under the next result.

The above discussion has shown that the spatial competition model provides similar incentives for delegation of entry deterrence as the homogeneous product model of McLean and Riordan (1989). The first entrant either delegates entry deterrence or provides the entry deterring investment herself. A general conclusion which goes beyond the findings of McLean and Riordan is the following. In cases in which the first entrant wants the second entrant to invest in the large-scale technology, she admits a market share just sufficient to induce the technology switch by the second entrant. Given that entry deterrence, in general, requires location of at least one firm inside the market area, the first entrant provides as much of the entry deterrence by strategic location as is compatible with the second entrant adopting the large-scale technology. Thus, the first entrant delegates only capital investment, which is the costly part of entry deterrence. She uses her first mover advantage to gain a greater market share relative to a situation in which she would delegate all entry deterring activities including strategic location. This result is similar to that found in the homogenous product, sequential entry oligopoly model by Church and Ware (1996). In that model, firms deter entry by committing to output levels beyond the equilibrium quantities in an *n*-firm Stackelberg leadership game. Early entrants expand their quantities up to the point where marginal costs equal the equilibrium price – marginal costs are assumed to be increasing - late entrants are forced to do the costly part of entry deterrence. They produce quantities for which marginal costs are greater than the equilibrium price.

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[14] For instance at $(f_S/N, N) = (.0220, 46.06)$, the first and the second entrant's profits are 5.79 and 3.74, respectively.

4.4   Second-mover advantage: the second entrant may earn higher profits

Result 5: A parameter range exists for which the profits of the second entrant are greater than the profits of the first entrant. The respective region of a 'second-mover advantage' is much smaller in the case of a small cost difference than in the case of a large cost difference (see region V,d in figure 5).

To put it in the terms of Eaton and Ware (1987), the existence of a late-mover advantage is a curious result in a model of sequential entry. In general, one would expect and one obtains a first-mover as well as an early-mover advantage (see McLean and Riordan, 1989). In Eaton and Ware, it is the second entrant who is worse off than the third entrant. The situation in Eaton and Ware is rather different from my model as the low profit of the second entrant is due to the strategic capacity choice of the first entrant. The explanation for the existence of a true second-mover advantage in my model is as follows. First, note that irrespective of which firm invests in the large-scale technology the first entrant would choose location such that the market share of the large firm is at a maximum. Thus, the profits of the large firm are the same irrespective of whether the first or the second entrant employs the large-scale technology. This is different with respect to the alternative the two firms face. The opportunity costs if the first entrant considers a large-scale investment is the profit from the blockaded entry, three small firms case (see the benchmark case). The opportunity costs are different for the second entrant. In order to induce adoption of the large-scale technology by the second entrant, the first entrant would locate at zero (for $c_S = 1/2$) and not strictly inside the market area as in the three small firms solution of the benchmark case. Consequently, the second entrants alternative leads to higher profits.[15] Because of the higher opportunity costs,

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[15] For $(f_S/N, N) = (.0220, 44.82)$, a point on the locus separating the three small firms case from the second-mover advantage region, the first and the second entrant's alternative profits in the three firms case are 2.96 and 3.63, respectively. At the respective parameter configuration the first entrant is indifferent between the

employing the large-scale technology is not profitable for the second entrant for as small values of N as it is for the first entrant. This is the reason for the existence of a second-mover advantage. This result clearly indicates that under-investment in entry deterrence cannot occur in my model. Different from McLean and Riordan (1989), entry is always deterred if entry deterrence is in the interest of at least the first entrant.

In the case $c_S = 1/8$, the region with the second-mover advantage (region V, d) is quite small. The reason is the more competitive situation. Entry deterrence requires both firms to move in the case with one small and one large firm in the range $.0258 \geq f_S / N > .0220$. Compared to the location of the third entrant in the benchmark case with three firms, the first entrant's location is closer to zero in a small range only, namely in the interval $[.0252, .0258]$. In this interval, the second entrant's alternative yields a higher pay-off than that of the first entrant. The respective values for the market-size range are in the interval $[93.8, 94.3]$. This explains why the region is hardly visible in figure 5.

4.5   Market size, market structure, and performance

To analyze the effect of changes in market size (and fixed costs f_S), I have added contour lines with given fixed costs in figures 6 and 7.[16]

[Insert figures 6 and 7 about here]

The diagrams explicitly show the relation between industry structure and market size. If one takes the case of $f_S = 1$ in Figure 6, one goes through a number of quite different industry structures as N increases. For small N, we start with a small monopolist (not in the

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two technologies. The profit of the second entrant is 5.63 when the first entrant chooses the large scale technology.

[16] Figure 7 also depicts regions where both firms under-invest (Region *UI*) and over-invest (Region *OI*), respectively. I discuss these cases below.

diagram, but to be derived from above arguments). As N increases, one first moves into the region of the large monopolist, before turning to the case with two, and then three small firms. For relatively 'small' values of N (of about 45) the first entrant will switch to the large-scale technology, and an asymmetric duopoly emerges. A further increase of market size eventually leads to the region of delegated entry deterrence. Two points worth mentioning arise from this example. First, the number of firms is non-monotonic in market size. An increase in market size implying a reduction in exogenous entry barriers may lead to a reduction in the number of firms. The model confirms similar results found for the market structure of monopolistic competition in a framework exhibiting technology choice (see Elberfeld and Götz, 2002). Non-monotonic relations may also arise with more general types of endogenous sunk costs (see Sutton, 1998).

Second, we find changes in the relative position of the incumbents as N increase. This is even more apparent from the locus with $f_S = 4.3$ in Figure 7. For small values of N both firms use the S-technology. As N increases first the first entrant becomes dominant, then the second, and finally the first again. Further details of the industry structure are illustrated in Figures 8, 9, and 10, which show how locations, market shares, and profits change as a function of N. The underlying parameters are $f_S = 4.2$ and $c = 1/8$. As N increases the above mentioned changes in relative positions take place. Profits of the first entrant are increasing in N with the exception of the range with two small firms, both located inside the market (see the benchmark case). Profits of the second entrant are non-monotonic and not continuous. The most interesting thing about profits is the high level which even the second entrant is able to realize. Note that in the relevant range, at least one of the two firms uses the small-scale technology with fixed costs f_S. Firms therefore earn pure profit of more than five times the fixed costs. This value is well above the values discussed in Eaton and Lipsey (1989). It demonstrates the importance of the additional entry deterring device available in my model.

[Insert figures 8 to 12 about here]

Turning to performance as a function of market size, the next result is obtained.

Result 6: Prices may be higher in larger markets. Prices may be non-monotonic and discontinuous in market size even if there is no change in the number of firms.

Both Figures 11 and 12 as well as the example mentioned on page 16 show that increases in N may lead to an increase in prices of both firms. Even if only one firm raises its price, a properly defined price index may increase. The price index used here is simply the average price paid, i.e. industry revenue divided by market size. Once market size is sufficiently large to allow for large-scale investments, prices rise even though one firm uses a technology with lower marginal costs. The explanation of this phenomenon is again the competition reduction effect of capital investment. This investment is clearly detrimental from a social point of view. At the jump occurring at a market size of about 120, industry profits fall and prices rise. To see the rather counterintuitive nature of Result 6, note that it requires only a change in market size, but no change in willingness to pay. In a standard Cournot model, prices would be unchanged in this case. In a monopolistic competition model of technology choice, a technology switch due to an increase in market size leads to a fall in prices (see Elberfeld and Götz, 2002).

4.6   Cost leadership and pricing

Result 7: The firm with lower marginal costs may well charge higher prices. This holds if the first entrant is the cost leader. The first entrant charges a higher price, in general, irrespective of whether she is the high cost or the low cost firm.

Figure 11 gives an example that the first entrant may always charge a higher price than the second entrant. This holds even in the case in which the first entrant employs the technology exhibiting lower marginal costs, that is, even in the case in which the first entrant might be called the cost leader. A similar result is derived in Tyagi (2001) in a duopoly

Hotelling model with exogenous cost differences. Tyagi assumes simultaneous entry and allows for locations outside the unit interval. In this setting cost leadership leads to a more central location. The large number of captive consumers associated with this location makes the cost leader 'soft'. She charges a higher price than her high cost. A similar mechanism is at work in my model. Examples show (see pages 17 and 27), however, that the cost leader may well charge lower prices if the cost difference is large. In Tyagi either the cost leader charges a higher price or it serves the complete market.

4.7   Fixed costs

The relation between industry structure and values of fixed costs of the small-scale technology, f_S, is rather self-explanatory. Nevertheless, a counter-intuitive result is well worth mentioning.

Result 8: Ceteris paribus, a fall in fixed costs f_S may imply that the respective small-scale technology is employed by fewer firms.

To see this result, note how market structure changes along a horizontal line, i.e., for given market size. If we take, for example, Figure 7 and $N = 150$, the small-scale technology is not employed for large values of f_S like 20.25. Moving to the left, thereby decreasing f_S, the small-scale technology is first employed by one and then by two firms. A further fall in f_S, eventually causes one firm to switch back to the large-scale technology. Interpreting the fixed costs as the cost of the capital equipment necessary for production, I obtain the rather strange result that falling prices of this equipment may reduce demand. The explanation of this phenomenon, however, is straightforward. Falling fixed costs reduce entry barriers. This makes the high-powered entry deterring device, i.e., the large-scale investment, more profitable. Formally, Result 8 is due to the fact that the slope of the loci separating regions II (and IV, respectively) and V changes frequently from negative to positive. The reason for this

pattern can already be found in the benchmark case. Depending on the importance of potential competition, an increase in fixed costs may reduce or increase profits.

4.8   Cost efficiency, over-investment, and under-investment

The final point I address concerns the welfare properties of the technology choices of the firms. I focus on the question whether the technologies employed in equilibrium are cost-minimizing, given the output levels. It turns out that cost efficiency is realized only by chance. Only in the case of a monopoly with blockaded entry, the monopolist switches to the large-scale technology in order to minimize costs. In general, two other effects motivate the choice of the large-scale technology. First, the entry deterrence effect. This effect was already discussed in some detail. Second, a market share effect: Due to the fall in marginal costs, a switch to the large-scale technologies implies market share gains. Note that, as a consequence, rivals are forced to decrease their price, resulting in falling absolute mark-ups. An example of the market share effect is the switch taking place at the locus dividing the regions with delegated entry deterrence and that in which the first entrant employs the large-scale technology in Figure 4 (regions IV and V in Figure 5). The first entrant switches to the large-scale technology and is thereby able to increase her market share from 43% to 67%, she reduces her price from 1.094 to .927. The price of the second entrant increases from .785 to .951. This is a large fall in the (absolute) mark-up as the marginal costs increase from zero to 1/2. Interestingly, the location of the first entrant is the same in both regimes (for $f_S / N =$ .0220 one gets .311).

Turning to the question of over-investment and under-investment, especially the above discussion on delegated entry deterrence suggests that the entry deterrence effect is likely to induce over-investment. Note that in my model over-investment and under-investment is simply determined by the question which technology minimizes average costs, given the equilibrium output level of each firm. Given this measure, the welfare conclusions are

straightforward. To obtain clear-cut results, I deal only with the cases where **both** incumbents either over-invest or under-invest.

Result 9: Both over-investment and under-investment by all active firms may arise in equilibrium. The two cases apply in the regions OI and UI, respectively, in Figure 7.

In terms of strategic investment, the over-investments occurring in Region *OI* is the extension of the standard results to the case of multiple incumbents. Incumbents over-invest in order to deter entry (see Tirole, 1988). There is an additional effect in my model. Incumbents also take into account that capital investment allows reduction of actual competition.

Less straightforward is under-investment, which occurs in Region *UI*. Both firms use the small-scale technology although their total costs would be smaller if they used the large-scale technology. The reason is that the mark-ups are fixed in absolute terms. Two firms located at the edges of the market always charge a price $p = mc + 1$ when they both employ a technology with marginal costs *mc*. Therefore, the firms' operating profits are independent of technology. Collusive technology choice would result in the choice of the technology with the smallest fixed costs. As region *UI* shows, this collusive result is stable in a certain range. We find the phenomenon that firms do not perform investments that are desirable from a social point of view. The result of firms not switching to a superior technology is similar to that of Fudenberg and Tirole (1985). In a framework dealing with the adoption of new technology, they show that firms may collusively choose too late an adoption date from a social point of view. This case applies if unilateral adoption merely transfers profits from one firm to the other and if the later adopter can regain former profits by following suit. Consequently, the potential investment gain is small. In my model the transfer of profits is embodied in the market share effect. This effect is only sufficient to induce the technology switch when market size becomes large enough so that we leave region *UI*. In region *UI*, business stealing associated with the market share effect is insufficient to compensate firms for the failure to

appropriate consumers' surplus. Under-investment arises. Taken together, regions *OI* and *UI* make clear how important potential competition is for the investment decision of the firms. If potential competition is tough, there is a tendency towards over-investment, if potential competition hardly exists, firms may well under-invest.

5.   Conclusions

In this article, I add technology choice to the standard Hotelling model of spatial competition. In my framework of sequential entry, this implies that firms can choose from two strategic devices for deterring entry. Both instruments come at a cost. Entry deterrence by location choice means less product differentiation and therefore smaller mark-ups. Using the large-scale technology for deterrence goes along with larger investment costs. The analysis reveals that firms invest in a large-scale technology either to deter entry or to gain market share. Only in the case of an unconstrained monopoly, efficiency reasons matter for the firm's investment decision. It is an equilibrium outcome that both firms in a duopoly do not make an investment in the large-scale technology, although this would reduce their average costs. It is obvious that the firms' incentives are in general quite different from that of a social planner. The article shows that apart from potential competition, actual competition may also lead incumbents to make strategic moves. In this case, the early entrant acts in order to keep the rival small. A final result I want to mention concerns fixed costs. A decrease in fixed costs can increase or decrease profits, depending on whether the implied reduction of the barriers to entry is more or less important than the induced cost savings. Even more interesting is the relation between the technology used and the size of the fixed costs of the **small-scale** technology. Decreasing these fixed costs may ceteris paribus lead firms to switch to the **large-scale** technology. The reason is that entry deterrence by means of strategic location choice becomes quite costly when barriers to entry get smaller.

This article demonstrates how a large number of phenomena which have been found in quite different frameworks can arise in a fairly standard model if one takes into account changes in market size and fixed costs. The model shows that differences in these parameters lead to different firm size distributions. Quite interesting changes in industry structure and performance can arise if one varies market size. An increase in market size may be associated with a fall in the number of active firms. A rather counter-intuitive result concerns the relation between market size and prices. Prices may be higher in larger markets. The reason is that larger market facilitate large-scale investments, which in turn allow firms to increase product differentiation without triggering entry. As a consequence, price competition is reduced. Finally, increasing market size may cause frequent changes of relative positions of the firms as far as market shares are concerned. This mobility in industry structure is the consequence of strategic actions of the first entrant rather than the result of some exogenous process. This phenomenon is of special interest for a dynamic interpretation of the static model. It might result in an industry with demand growth where firms produce successive generations of a product. The development of truly dynamic models capturing the strategic behavior of firms remains a task for future research. Taking the example of airlines, further avenues for future research are the introduction of multi-product firms as well as an examination of some forms of cooperation, not to say collusion among firms in this setting.

6. Appendix

Proof of the claim that the first entrant will deter a third entrant unilaterally in the range, in which the potential entrant would locate in the center and no other entry deterrence constraint is binding ($200 \leq N < 468.9$). To prove the result, I first show that the third entrant will always locate exactly halfway between the two incumbents.

The reduced profit function of the potential entrant reads

$$\pi^2(x_1, x_2, x_3) = \frac{(x_2 - x_1)(d + x_1 - x_2)(2 + d)^2 n}{18d} - f_L, \tag{8}$$

where $d \equiv x_3 - x_1$ is the distance between the incumbents. It is straightforward to derive the optimal location of the second entrant. One obtains: $x_2 = x_1 + d/2$.

The profit of the potential entrant depends only on the distance between the incumbents. Given the (entry deterring) distance between the incumbents, one can determine the profits in two cases. First, both firms move to the center by the distance *i*/2. (The locations are *i*/2 and 1-*i*/2) The profit of the first (and the second) entrant is $(1 - i)N / 2 - f_L$ in this case. If only the first entrant would move to the center by the distance *i*, one gets $(1 - i)(3 + i)^2 N / 18 - f_L$ (and $(1 - i)(3 - i)^2 N / 18 - f_L$ for the second entrant, respectively). The profit is greater in the second case, thereby proving the claim.

Proof of Property 1. The difference in profits between facing a large rival and facing a small one reads

$$\pi^1(x_1, x_2, 0) - \pi^1(x_1, x_2, c) = \frac{-\big(2(x_2 - x_1)(2 + x_1 + x_2) + c\big)cN}{18(x_2 - x_1)}, \tag{9}$$

which is negative.

Proof of Property 2. The difference in *operating* profits from the large and the small-scale technology reads

$$\pi^2(x_1, x_2, 0) - \pi^2(x_1, x_2, c) = \frac{\big(2(x_2 - x_1)(4 - x_1 - x_2) - c\big)cN}{18(x_2 - x_1)}. \tag{10}$$

Taking the pricing rules

$$p_1 = \big(c + 2(x_2 - x_1) - x_1^2 + x_2^2\big)/3 \qquad \text{and} \tag{11}$$

$$p_2 = \big(2c + 4(x_2 - x_1) + x_1^2 - x_2^2\big)/3, \tag{12}$$

and noting that the prices must not differ by more than the transport costs between the two locations (i.e. $(x_2 - x_1)^2$) in order for the pricing rules to apply, one gets a restriction for *c*:

$$c \le (x_2 - x_1)(5x_2 - x_1 - 2).$$

As $x_2 \leq 1$, the difference in the numerator of equation (10) must be positive. Operating profits are always higher with the large-scale technology. While the relation with respect to N is obvious, differentiating with respect to x_1 shows the impact of the distance. One gets a derivative that is unambiguously negative, therefore confirming the property.

7.   References

Berry, Steven T., 1992. Estimation of a model of entry in the airline industry. Econometrica 60, 889-917.

Bresnahan, Timothy F., Reiss, Peter C., 1991. Entry and Competition in Concentrated Markets. Journal of Political Economy 99, 977-1009.

Church, Jeffrey, Ware, Roger, 1996. Delegation, Market Share and the Limit Price in Sequential Entry Models. International Journal of Industrial Organization 14, 575-609.

Dixit, Avinash K., 1980. The Role of Investment in Entry-Deterrence. Economic Journal 90, 95-106.

Donnenfeld, Shabtai, Weber, Shlomo, 1995. Limit Qualities and Entry Deterrence. Rand Journal of Economics 26, 113-130.

Eaton, B. Curtis, Lipsey, Richard G., 1989. Product Differentiation. In: Schmalensee, Richard and Willig, Robert D. (Eds.), Handbook of Industrial Organization, Volume II, North-Holland, Amsterdam, New York

Eaton, B. Curtis, Ware, Roger, 1987. A Theory of Market Structure with Sequential Entry. Rand Journal of Economics 18, 1-16.

Elberfeld, Walter, Götz, Georg, 2002. Market size, technology choice, and market structure. German Economic Review 3, 25-41.

Fudenberg, Drew, Tirole, Jean, 1985. Preemption and Rent Equalization in the Adoption of New Technology. Review of Economic Studies 52, 383-401.

Gupta, Barnali, 1992. Sequential Entry and Deterrence with Competitive Spatial Price Discrimination. Economics Letters 38, 487-490.

McLean, Richard P., Riordan, Michael H., 1989. Industry Structure with Sequential Technology Choice. Journal of Economic Theory 47, 1-21.

Neven, Damien J., 1987. Endogenous Sequential Entry in a Spatial Model. International Journal of Industrial Organization 5, 419-434.

Pepall, Lynne, 1992. Strategic Product Choice and Niche Markets. Journal of Economics & Management Strategy 1, 397-417.

Schulz, Norbert, Stahl, Konrad, 1985. On the Non-Existence of Oligopolistic Equilibria in Differentiated Products Spaces. Regional Science and Urban Economics 15, 229-243.

Tabuchi, Takatoshi, Thisse, Jacques-Francois, 1995. Asymmetric Equilibria in Spatial Competition. International Journal of Industrial Organization 13, 213-227.

Tirole, Jean, (1988). "*The Theory of Industrial Organization,*" MIT Press, Cambridge, Ma, London.

Tyagi, Rajeev K., 2001. Cost leadership and pricing. Economics Letters 72, 189-193.

Ware, Roger, 1992. Entry Deterrence. In: Norman, George and La Manna, Manfredi (Eds.), "*The New Industrial Economics*", Edward Elgar, Aldershot, England, 66-83.

Ziss, Steffen, 1993. Entry Deterrence, Cost Advantage and Horizontal Product Differentiation. Regional Science and Urban Economics 23, 523-543.
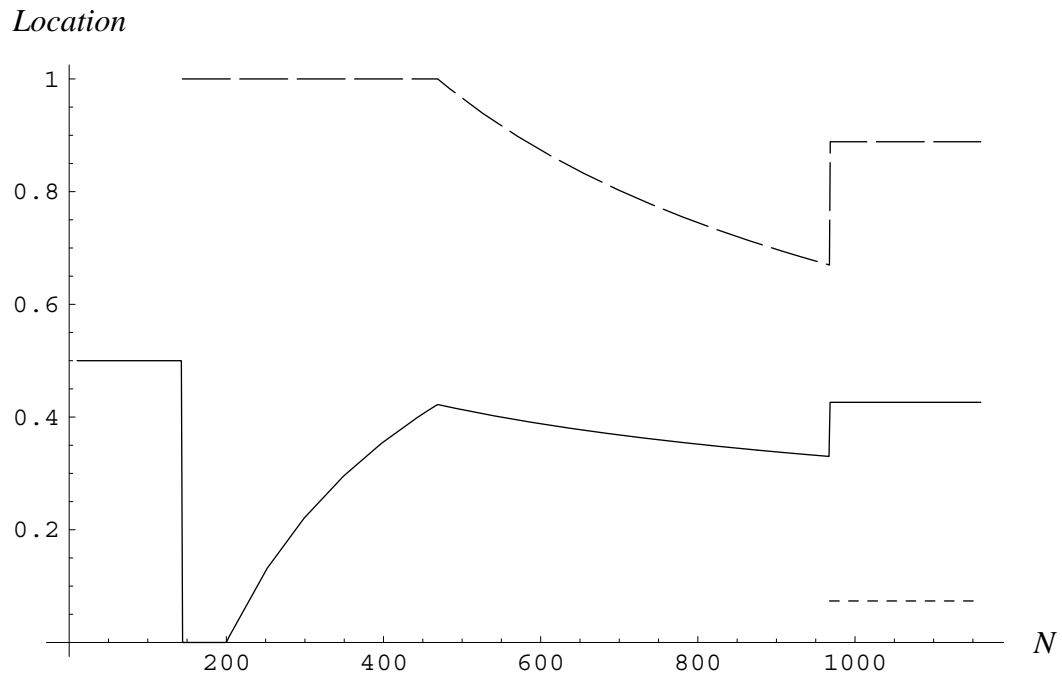
Figure 1: Equilibrium locations in the benchmark case. The solid line depicts the choices of the first entrant, the dashed lines are that of the second and third entrant
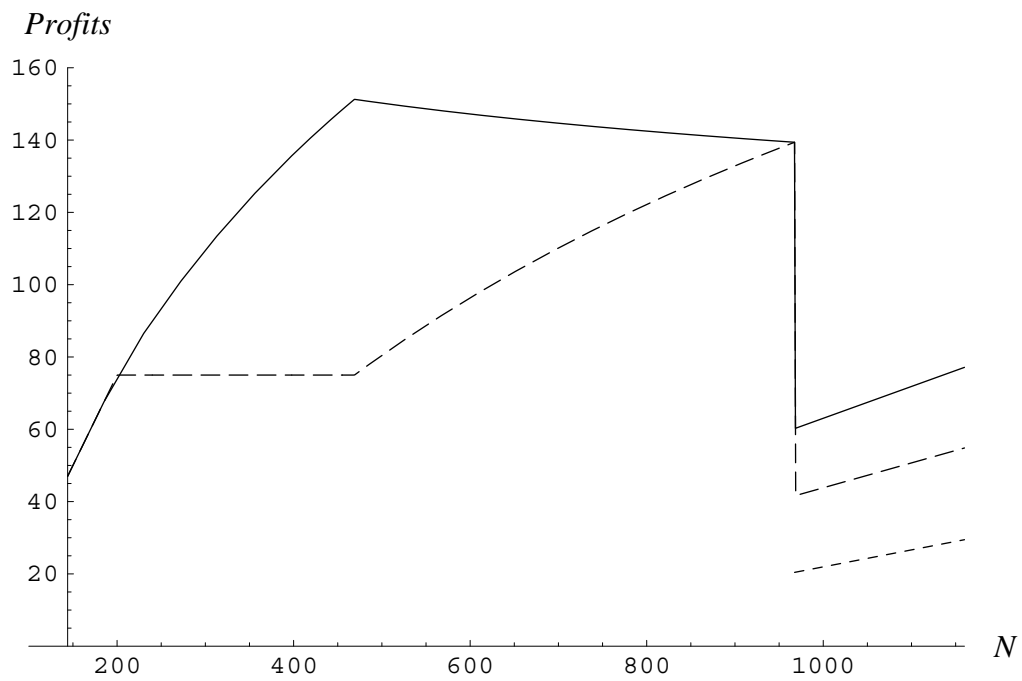
Figure 2: Equilibrium profits of the first entrant (solid line) and of the second and third entrant (dashed lines) in the benchmark case.

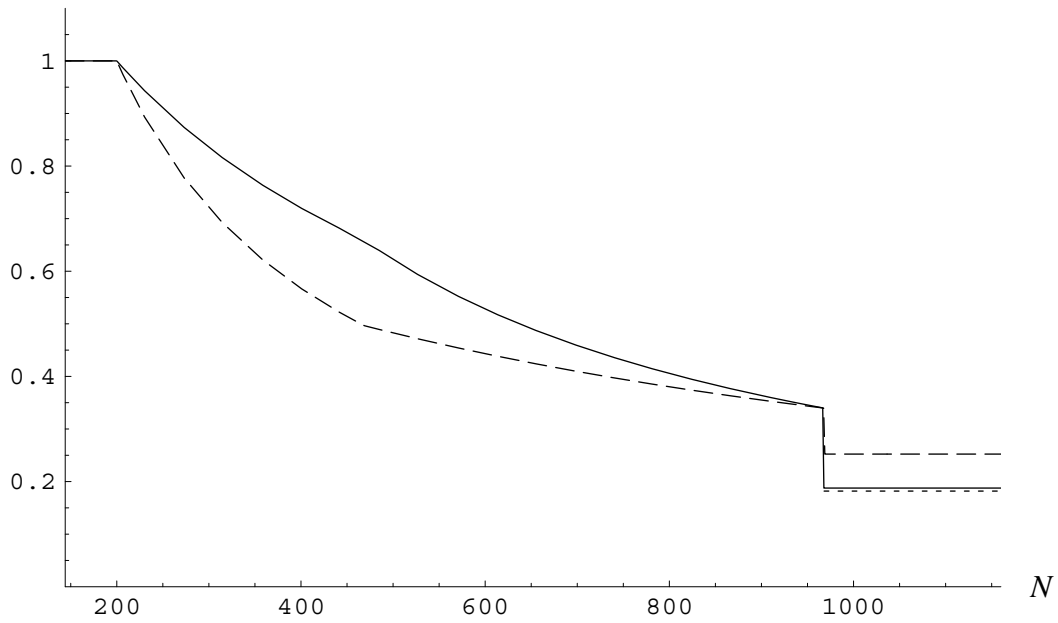Figure 3: Equilibrium prices of the first entrant (solid line) and of the second and third entrant (dashed lines) in
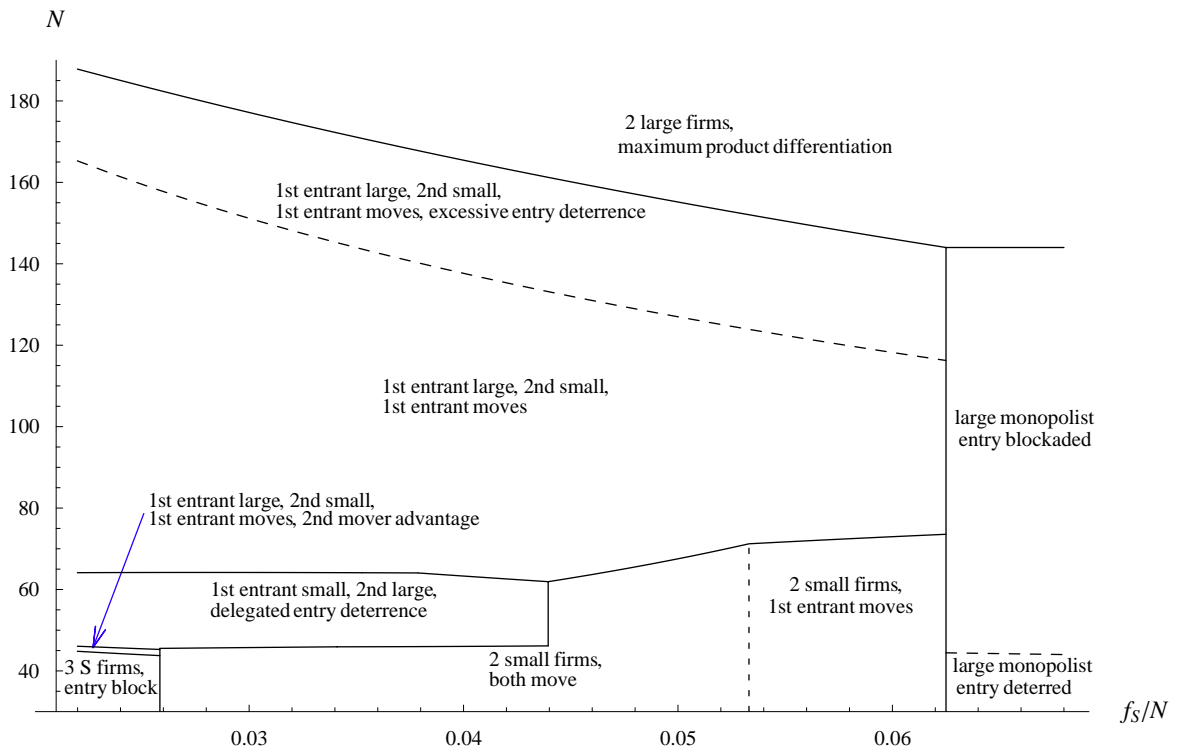
the benchmark case

Figure 4: Industry structure as a function of fixed costs to market size f_S/N and of market size N ($c_S = 1/2$)
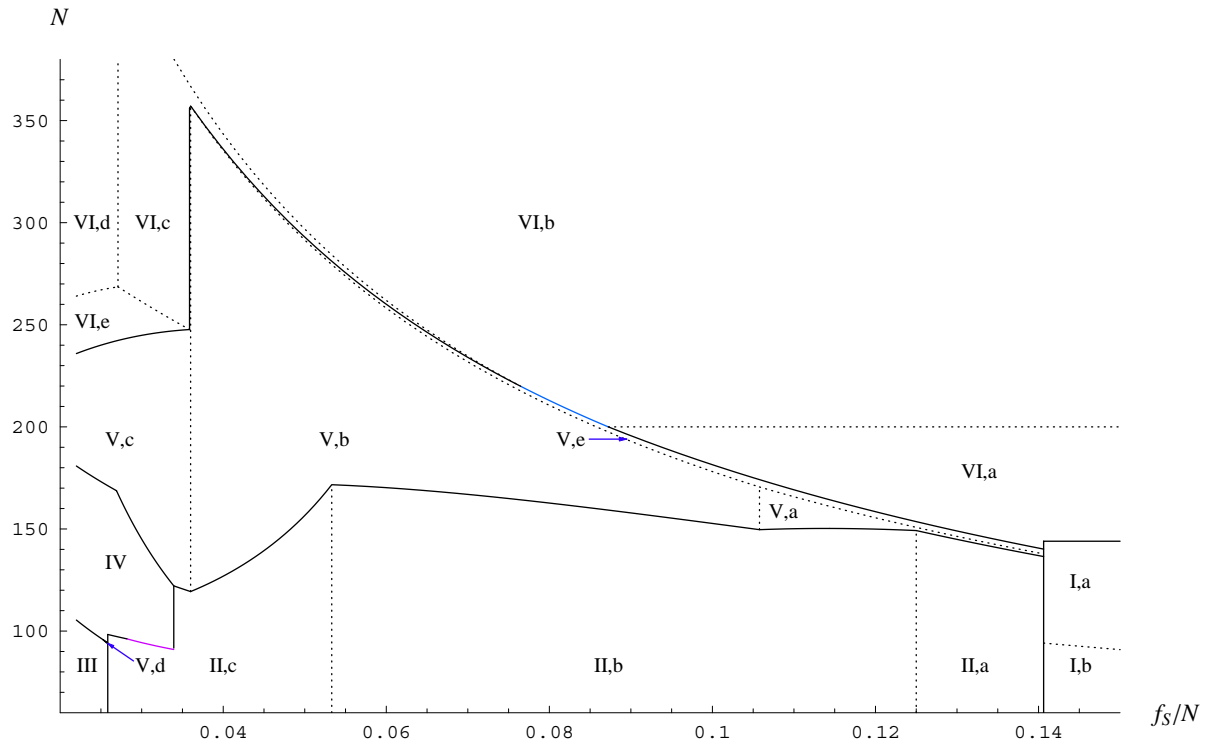
Figure 5: Industry structure as a function of fixed costs to market size f_S/N and of market size N ($c_S = 1/8$)

Legend: I,a: Large monopolist, entry blockaded

I,b: Large monopolist, entry deterred

II,a: Two S-firms, maximum product differentiation

II,b: Two S-firms, first entrant moves to deter entry

II,c: Two S-firms, both entrants move to deter entry

III: Three S-firms, blockaded entry

IV: First entrant small, second entrant large, delegated entry deterrence.

V,a: First entrant large, second entrant small, maximum product differentiation

V,b: First entrant large, second entrant small, first entrant moves to deter entry

V,c: First entrant large, second entrant small, both entrants move to deter entry

V,d: First entrant large, second entrant small, both move, second mover advantage

V,e: First entrant large, second entrant small, first entrant moves, excessive entry deterrence

VI,a: Two L-firms, maximum product differentiation

VI,b: Two L-firms, first entrant moves to deter entry of a **large** firm

VI,c: Two L-firms, first entrant moves to deter entry of a **small** firm

VI,d: Two L-firms, both entrants move to deter entry of small firms

VI,e: Two L-firms, both entrants move to deter entry of S-firms, first entrant concedes market share
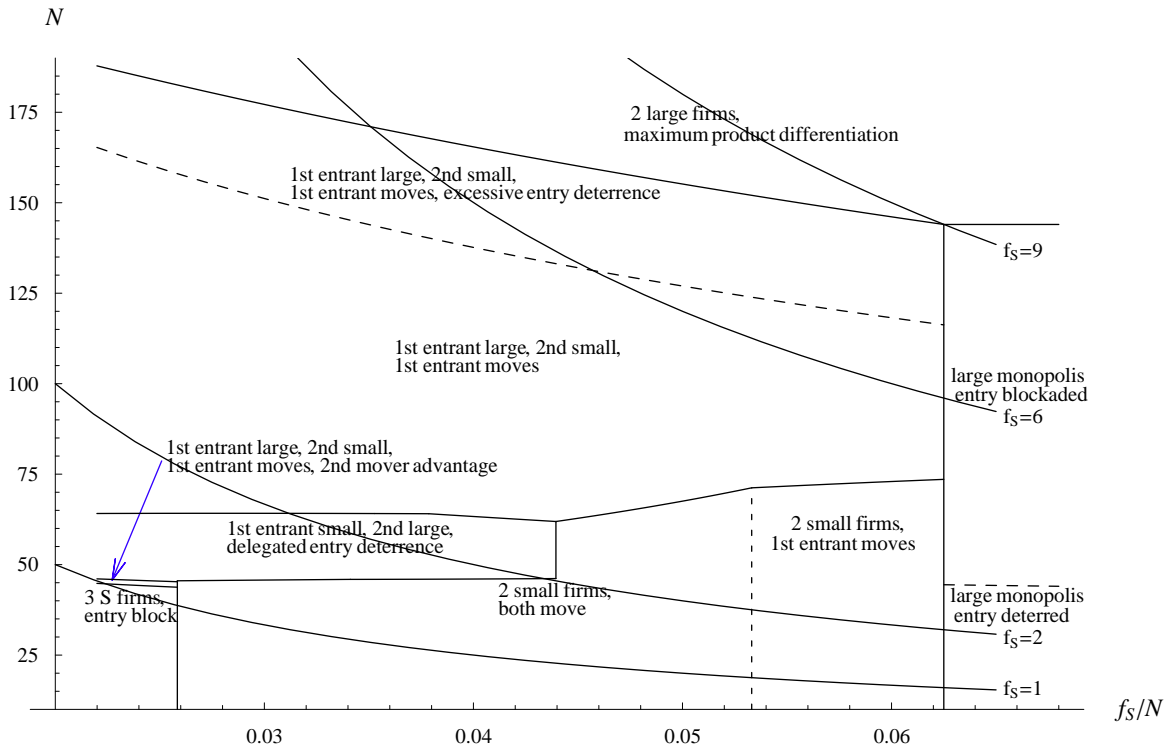
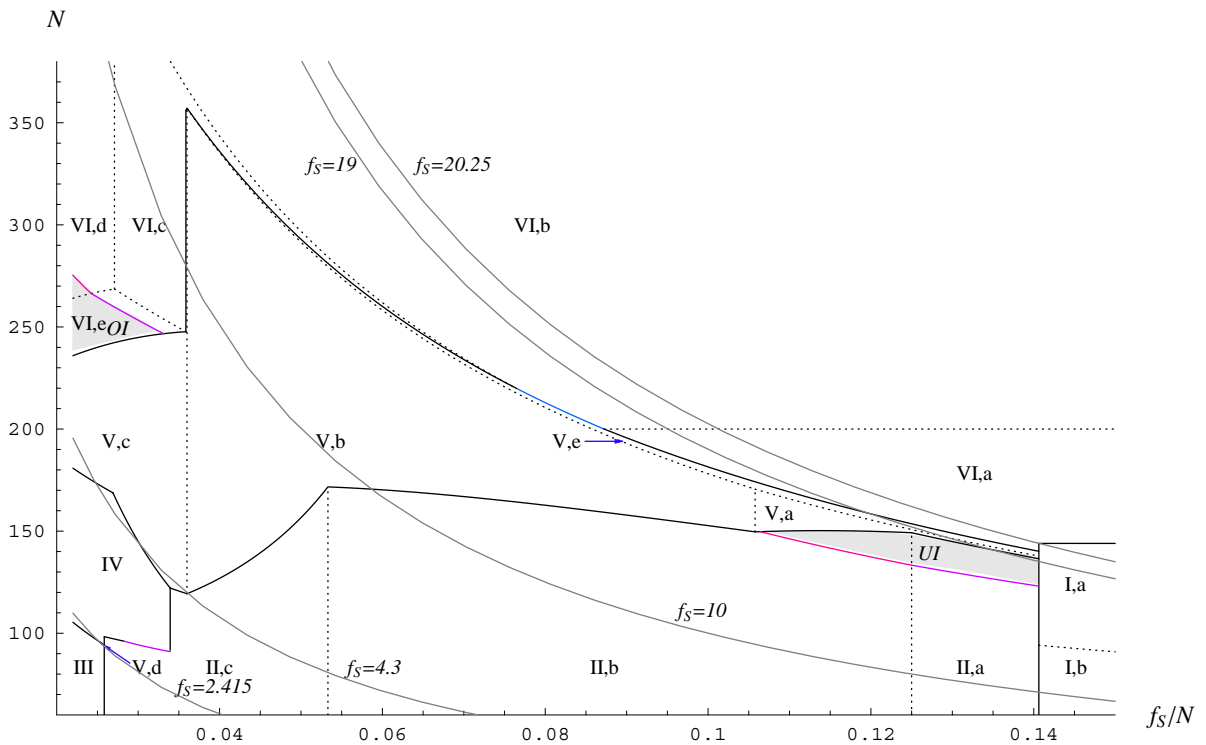Figure 6: Industry structure and the value of fixed costs f_S ($c_S = 1/2$)

Figure 7: Industry structure, fixed costs f_S, over-investment (shaded region *OI*), and under-investment (shaded
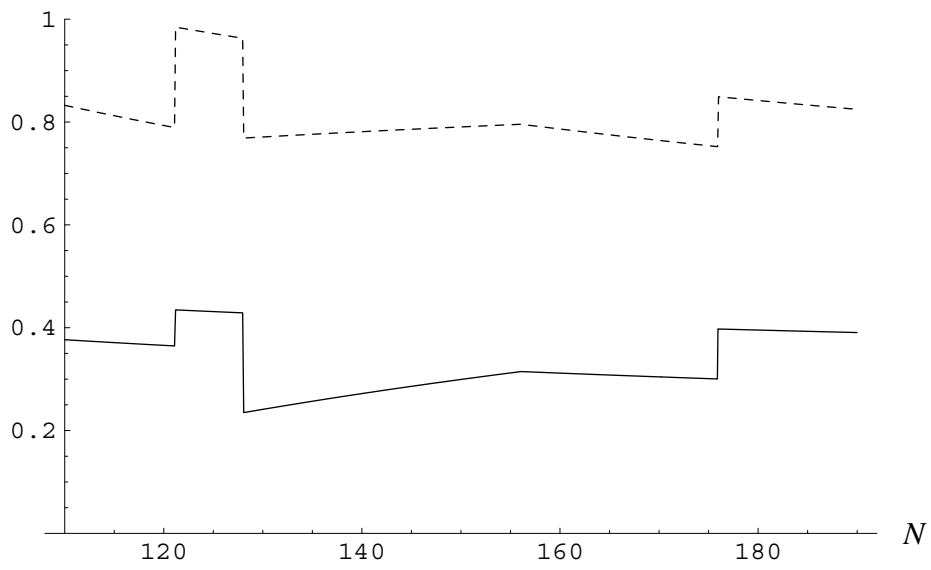
region *UI*) ($c_S = 1/8$)

Figure 8: Equilibrium locations of the first (solid line) and second entrant (dashed line), respectively, as a
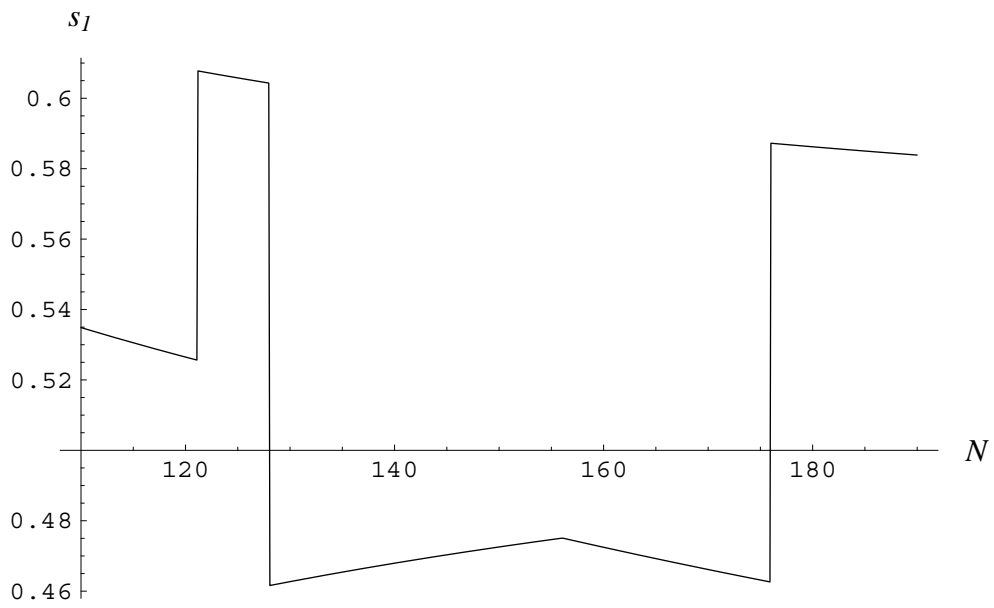
function of market size N.

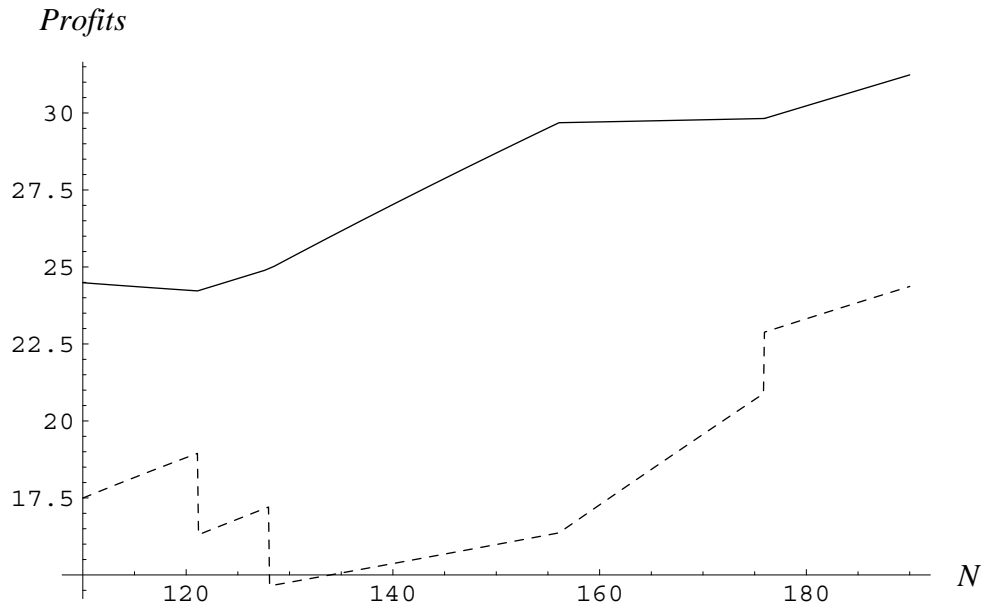Figure 9: The equilibrium market share of the first entrant (s_1) as a function of market size N.

Figure 10: Equilibrium profits of the first (solid line) and second entrant (dashed line), respectively, as a function
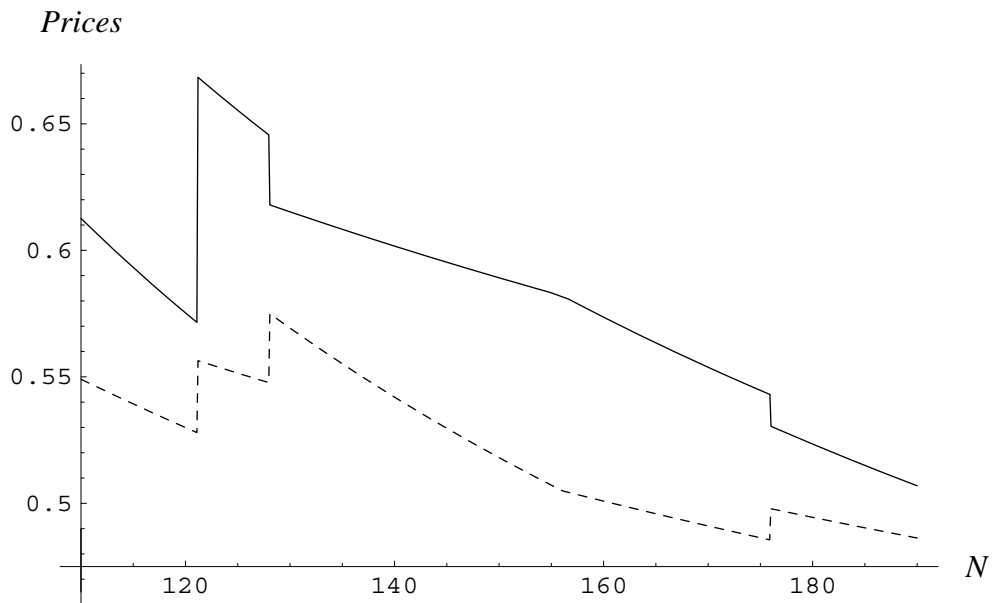
of market size *N*.

Figure 11: Equilibrium prices of the first (solid line) and second entrant (dashed line), respectively, as a function
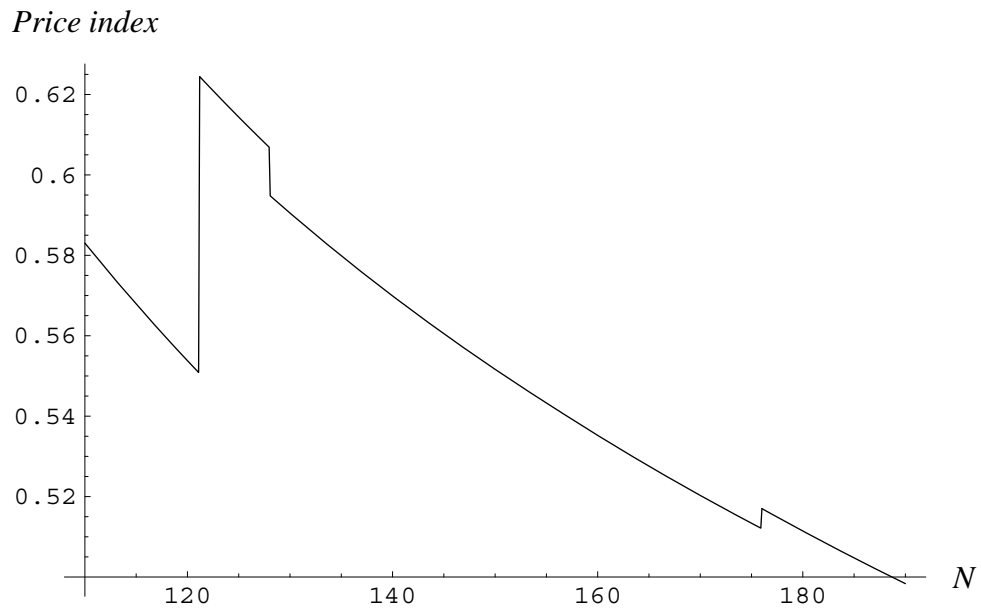
of market size *N*.

Figure 12: Average prices, defined as industry revenue divided by market size, as a function of market size *N*.