Location, Technology, and Competitive Strategy

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Abstract: Strategic (capital) investments and the strategic choice of product characteristics are among the most important devices to manipulate market positions in a favorable way. Synthesizing the economics and the strategy literature, this article discusses under what conditions as diverse features as excessive entry deterrence, second-mover advantage as well as delegation of entry deterrence emerge. By allowing firms to employ both strategies simultaneously, the paper examines in a unified framework under which circumstances combining cost leadership and product differentiation is good strategy. Furthermore, the paper shows that larger markets – by making large scale investment profitable – may enable firms to charge higher prices. Market size also determines whether it is optimal for a first mover to become the market leader or a niche player.

Keywords: Hotelling model, entry deterrence, over-investment, under-investment, first mover advantage.

JEL-Classification No.: L11, L13

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1. Introduction

Strategic (capital) investments and the strategic choice of product characteristics are among the most important devices to manipulate market positions in a favorable way. The use of these instruments is studied widely both in the economics and the strategy literature. In economics, the two different instruments are analyzed in two different 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 1987, Pepall 1992, Donnenfeld and Weber 1995, Götz 2005). When talking about product differentiation and cost-leadership strategies, the competitive strategy school (see Porter 1980) provides a somehow unified treatment. However, the question whether or not these strategies are mutually exclusive is much discussed (see Porter 1980, 1985 and Hill 1988).

My paper synthesizes the two strands of the economics literature. By allowing firms to employ both strategies simultaneously, the paper examines in a unified framework under which circumstances combining cost leadership and product differentiation is good strategy. I assume that there is an initial asymmetry among firms in the sense that firms decide sequentially. Early movers have the ability to make commitments which often – but as the paper shows not always – implies a first mover advantage.

The paper highlights the strategic opportunities of firms, in particular of early movers, once both strategic variables are available. The optimal pattern of business strategies depends in an intuitive way on the exogenous variables, in particular on the relation of market size to investment costs. Market size determines whether it is optimal for a first mover to become the market leader or a niche player. The paper also shows that minimizing average costs for given output might not be an optimal strategy. If barriers to entry are high, i.e. entry costs are high compared to market size, firms tend to under-invest, if barriers to entry are low, over-
investment results. Another interesting result related to market size concerns equilibrium prices: an increase in market size may lead to an upward jump in prices. Therefore, prices may be higher in larger markets.

To analyze strategic choice of product characteristics and the question of strategic investment, I employ a Hotelling model of spatial competition with quadratic transportation costs (see, e.g., Tirole, 1988) to which I add a stage with technology 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. 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, which may well be interpreted as R&D expenditures, lower variable production costs. There are no barriers to entry other than the fixed investments. As mentioned above, entry mode is sequential in my model.1

The results of the paper are derived in a simulation where I employ the parameter values of Neven (1987).2 In the simulations I consider only parameter constellations for which at most three firms are active. Such an industry 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). Examples in which both product differentiation and capital investments seem to be important range from the 19th century American brewing industry (see Manuszak, 2002) to modern grocery retailing (see Aalto-Setälä, 2000 and 2002 for a description of the situation in Finland). In the brewing industry the final product may be

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 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
differentiated with respect to both location (the saloon as the outlet where the beer is sold) and
taste. Technology relates to the size of the barrel used for brewing. For grocery retailing both
the product differentiation (location or areas of specialisation) and the technology (scanner
check-outs, sophisticated logistic systems) dimension seem rather natural.

Another example concerns city pair markets in 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.\(^3\) 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?\(^4\) Is the choice of the aircraft, i.e., 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.

An industry which appears to match the model's fundamentals and cross-sectional
properties particularly well is the market for office supply superstores. Location and
sequential entry appear to be of crucial importance for firm profitability. The first mover (i.e.
Staples) seems to earn consistently higher profits. Latecomers 'are forced' to make "real estate
mistakes" (see DSN Retailing Today, Nov 6, 2000), i.e. to choose inferior locations in the
model's terms. The model shows what kind of pricing behavior one might expect under such

\(^3\) Of course, the model captures only part of the 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.
circumstances. The model also yields hypotheses on the effects of market size on market structure and pricing in this market.

The remainder of the article is organized as follows. Section 2 describes the model, Section 3 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 examined. Section 4 concludes.

2. The model

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

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

I assume that the (common) reservation price $a \geq 5/4t$. This ensures that under competition all consumers 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 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.

\(^4\) The connections between Vienna and Geneva exhibit this pattern, for instance.

\(^5\) 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.
The consumer $\alpha$ who is indifferent between buying at $i$ and $j$ is defined by the condition
\[ \alpha_{i,j} = \frac{p_i - p_j}{2(x_j - x_i)} + \frac{x_j + x_i}{2}. \] (2)

Suppose $n$ firms are active. Analogously to Neven (1987) I define the sets
\[ L = \{0, \alpha_{i,1}, \ldots, \alpha_{i,n}\} \quad \text{and} \quad R = \{\alpha_{i,n+1}, \ldots, \alpha_{i,n+1}\}. \] (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 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.

3. **Industry structure in oligopoly with technology choice**

In this section I examine the consequences of technology choice for both industry structure and the strategic opportunities 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.

3.1 General properties: The naïve view of competition and technology choice

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 \( x_1 < x_2 \). Operating profits of the first and second entrant are

\[
\pi_1(x_1, x_2, c) = \frac{(x_2 - x_1)(2 + x_1 + x_2 + c)^2 N}{18(x_2 - x_1)} \quad \text{and} \quad (4)
\]

\[
\pi_2(x_1, x_2, c) = \frac{(x_2 - x_1)(4 - x_1 - x_2 - c)^2 N}{18(x_2 - x_1)}, \quad (5)
\]

respectively. An important feature of the model is that 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 concerning the case, in which the first entrant chooses the large-scale technology, are worth mentioning. (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 ‘naïve’ 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.

3.2 The simulations: Preliminaries and first results

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. 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.

Figures 1 and 2 depict industry structure in the ($f_S/N$, $N$) - space. Using the ratio of 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 $f_S/N$.

The range covered by Figures 1 and 2 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 2), the industry structure depicted in the diagram extends to larger values of $f_S/N$. An exception arises as soon as the small-scale technology becomes sufficient to deter further entry of small firms and is also cost-efficient. This happens 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.

For values of $N$ greater than those in Figures 1 and 2 the single technology case dealt with in Neven (1987) and Götz (2005) applies in a straightforward way.

The construction of Figures 1 and 2 can most easily be explained by starting with the monopoly region with blockaded entry (region I,a in Figure 2). 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

$$N(a - 1/4) - 25 > N/2 - f_s.$$  \hspace{1cm} (6)

This equation leads to the constraint

$$a > 3/4 + 25/N - f_s/N.$$  \hspace{1cm} (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.

A first result from Figures 1 and 2 concerns industry structure. Even though (in the case of two active firms) the entrants are ex-ante identical apart from the order of entry, the outcome is asymmetric in general. Firms may differ in technologies, locations, or both. In the case $c_S = 1/2$ (Figure 1) firms are symmetric only in the region with two large-scale firms and
maximum product differentiation. For \( c_S = 1/8 \) (Figure 2) symmetry holds in regions II,a and VI,a.

3.3 Business strategies in the face of actual and potential competition

A naïve view of business strategy might be that you either try to keep your rivals out of the market or, if that is not possible to keep them as small as possible. Figures 1 and 2 show the circumstances under which this view applies and when qualifications are in order. Keeping the rivals out applies in particular in the monopoly-regions of both figures. In the regions with deterred entry (Region I,b in Figure 2) the first entrant invests in the large-scale technology in order to sustain the monopoly position. Such a strategy is optimal when consumers’ willingness to pay (the parameter \( a \)) is large, an assumption underlying both figures. Only then does the monopoly position justify heavy capital (over-)investment.

As soon as two firms are active, both actual and potential competition become relevant to the first entrant. Potential competition implying the need to take steps to deter entry is relevant for a large part of the parameter range considered in Figures 1 and 2. Actual competition, i.e. the desire to keep the rival small, is hardly relevant if the cost difference between the technologies is small. It shapes the strategic decisions of the first entrant only in region V,e. As is obvious from Figure 1 (the region with excessive entry deterrence applies), however, keeping the rival small is really important when the cost difference between technologies is large. In this case, 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.

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

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6 The latter property follows from the fact that the locus equalizes costs associated with both technologies, i.e. the condition \( 25 = f_S + N / 2 \) (\( 25 = f_S + N / 2 \) for \( c_S = 1/8 \)) is satisfied.
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 1). In this situation both firms, although using different technologies, charge the same price \( p = 3/4 \). 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 2, the configuration with the first entrant located at the center does not arise. Nevertheless, as noted above, a region exists in which the first entrant prevents the second from choosing the large-scale technology. In this range, actual competition rather than potential competition is the binding constraint for the strategic behavior of the first entrant. 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.

3.4 Dealing with potential entry: Strategies when there are two incumbents

Understanding how two incumbents deal with potential entry requires knowledge of which instrument they use to deter entry and whether one or both firms make the necessary strategic moves. It is useful to notice a difference in the two instruments: Deterrence by
means of strategic location does not require an investment, but it comes at the cost of intensified actual competition, the incumbents need to locate closer to each other. The costly investment in the large-scale technology comes at the benefit of a relaxation in actual competition. The associated low marginal costs allow incumbents to locate further apart since lower marginal costs imply more aggressive pricing in case of further entry.

Next I distinguish various cases in which different values of the exogenous variables, in particular of market size and of fixed costs of the small-scale technology, give rise to different patterns of strategic behavior. First, I look at the influence of changes in the fixed costs of small-scale technology for given market size. In the presentation of the results, I mainly deal with the intuition and the derivation of general conclusions. The exact values can be found in the diagrams.

3.4.1 Very small markets ($N$ of about 40 or less if $c_s = 1/2$, $N$ of about 90 or less if $c_s = 1/8$). 7

For the case of a constant market size, we can derive the firms’ reactions to decreases in $f_s$ from the case in which only one technology is available 8 (see Götz, 2005). For large values of $f_s$ the first entrant will locate strategically so as to deter entry, while the second entrant locates at the edge of the market. If an investment in entry deterrence by moving closer together is required, this otherwise costless investment is made by the first mover. As a result the first mover’s market share and profit are higher than that of the second mover. As $f_s$

7 Of course, market size has to be seen in relation to the values of the other variables, in particular to marginal costs. This explains why the values for a “small” market differ between the two different cases of marginal costs. When the difference in marginal costs between the small-scale and the large-scale technology decreases, the small scale technology becomes profitable for larger values of $N$.

8 In graphical terms, we move along a horizontal line towards the y-axis in Figures 1 and 2. While $N$ is fixed in this case, $f_s/N$ and $f_s$ are decreasing.
becomes smaller, the second entrant must also move towards the center leading to a more symmetric relation between the incumbents, but also to ever-increasing competition. Finally, for very small values of $f_S$ further entry can no longer be deterred implying a huge fall in profits.

3.4.2 Small markets ($N$ of between about 45 and 65 if $c_S = 1/2$, $N$ of between about 100 and 150 if $c_S = 1/8$).

The main difference between a “small” and a “very small” market is that in the latter case the market size is too small to justify investing in the large-scale technology. In the former case the expensive capital investment is called for if the alternative would be the entry of a third firm, a situation which leads to very intensive competition and low profits. In the region of delegated entry deterrence in Figure 1, (region IV in Figure 2), it is the second entrant who faces this situation. Note that the second entrant can deter entry of a third small entrant only by investing in the large-scale technology even though the values of $f_S$ are (in a large part of the respective region) such that two small-scale firms could deter further entry. (This holds for $f_S/N \geq 0.0258$ in the case of $c_S = 1/2$). This shows that the first entrant also moves strategically. She locates in a way that the second entrant invests in the large-scale technology rather than making the expensive investment herself. McLean and Riordan (1989) who find a related result for a sequential entry model of a homogeneous product Cournot oligopoly call such a behavior delegated entry deterrence. To see what happens to profits, locations, prices and market shares when we enter the small market size, consider the borderline case $f_S/N = 0.0258$ and $c_S = 1/2$. Two small firms are located symmetrically at .330 and .670 in this case. 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. The profit of the second entrant decreases from 6.56 to 3.66 once she invests in the large scale technology.
She nevertheless makes the investment since her alternative would be the situation with three firms also implying a profit of 3.66. The profit of the first entrant is unchanged, i.e. it stays at 6.56 even after the switch. Along the relevant locus the first entrant is indifferent between the two scenarios. If market size increases for given $f_S/N$, the first entrant is able to increase her market share since in a larger market a smaller market share is sufficient to compensate the second entrant for the investment in the large-scale technology.

Three general points arise from these results. Firstly, capital investment is in this case a substitute to strategic location when it comes to deterring entry. The investment makes it possible to reduce actual competition because it allows incumbent firms to locate further apart. This benefits both firms. Therefore, the second point to note is the positive externality implied by the capital investment. This positive effect induces the first entrant to delegate entry deterrence. Thirdly, a general conclusion which goes beyond the findings of McLean and Riordan (1989), simply because these authors consider only one strategic choice: The first entrant delegates only capital investment, which is the costly part of entry deterrence. As far as entry deterrence by strategic location is concerned, the first entrant provides as much deterrence as is compatible with the second entrant adopting the large-scale technology. 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. Latecomers are forced to expand production above the levels where prices cover (the increasing) marginal costs.

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, capital investment and strategic location are complementary in deterring entry. For a market size of about 45 (in the $c_S = 1/2$ case) the first entrant invests in
the large scale technology. What is even more surprising is that the profits of the second entrant are greater than the profits of the first entrant in the respective region.

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). The explanation for the existence of a true second-mover advantage in my model and of the failure of the first entrant to delegate entry deterrence is as follows. First, note that irrespective of which firm invests in the large-scale technology the first entrant would choose a 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. In this case all firms locate strictly inside the market area (see Götz 2005). The opportunity costs for the second entrant is the situation in which she has the center position while the first entrant locates at 0. The second entrants alternative leads to higher profits. Therefore, adopting the large-scale technology is not profitable for the second entrant even though it is for the first entrant. The first entrant cannot delegate entry deterrence, but needs to and does invest in the large-scale technology herself. This 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.

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9 For \((f_3/N,N) = (0.0220, 44.82)\), 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 two technologies. The profit of the second entrant is 5.63 when the first entrant chooses the large scale technology. Of course, the first entrants profit is 2.96 in this case.
With $c_S = 1/8$, 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 towards the center if one small and one large firm are active.\(^\text{10}\)

### 3.4.3 Medium-sized markets ($N$ of between about 65 and 150 if $c_S = 1/2$, $N$ of between about 150 and 250 if $c_S = 1/8$).

The characterizing feature of a medium sized market is that we have one large-scale and one small-scale firm and that it is always the first entrant who invests in the large-scale technology. Market size is sufficiently large to warrant investment in the large-scale technology by the first mover. As in the previous section, the effect of the investment is a reduction in actual competition: The incumbents are able to locate at a greater distance from each other, resulting in higher margins. The investment by the first mover is accompanied by a market share effect: the leader increases her sales at the expense of the second mover. The market share effect drives the switch taking place at the locus dividing the regions with delegated entry deterrence and that where the first entrant employs the large-scale technology (see Figure 1, in Figure 2 regions IV and V apply). The first entrant switches to the large-scale-technology at the locus and is thereby able to increase her market share from 43% to 67% (for $f_S/N = .0220$), while reducing 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 marginal costs increase from zero to 1/2.

There is also a region in which it is purely the market share effect which motivates the strategic investment of the first mover. Such a region can clearly be identified in Figure 2 in the area where barriers to entry are so high that we find maximum product differentiation

\(^{10}\) Only in the interval [.0252, .0258], the first entrant adopting the small-scale technology would locate closer to zero than the third entrant in the three small firms case. The respective range for the market size is the interval [93.8, 94.3].
even when both firms employ the small scale technology (Regions II,a and parts of region V,a). In the (very small) area in region V,a above region II,a entry deterrence is not an issue, therefore the only motivation for investing is the gain in market share.

An interesting point here is that it is not cost efficiency which induces a switch to the large scale technology. Figure 4 depicts an area (Region UI) in which both firms under-invest compared to a cost-minimizing firm. Each firm’s total average costs would be smaller if the firms were to make use of the large-scale technology. Under-investment is optimal from the viewpoint of the firm because 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 the technology they use. 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 make investments that are desirable from a social point of view.

### 3.4.4 Large markets

(N of between about 150 and 180 if \( c_S = \frac{1}{2} \), N of between about 250 and 400 if \( c_S = \frac{1}{8} \)).

In principle, large markets can sustain two large-scale firms. Whether the strategic decisions of the firms actually leads to this market structure depends crucially on the threat of potential entry (i.e. on \( fS/N \)) and on the size of the cost difference. In the case of a large cost difference (\( c_S = 1/2 \)), we obtain the above mentioned case of excessive entry deterrence. The first entrant even locates at the center if that is required to prevent the second entrant from investing in the large-scale technology. The large cost advantage of the small-scale technology renders this strategic move profitable.

In the case of a small cost difference (i.e. \( c_S = 1/8 \)) the situation is different. While the first entrant also prefers a small rival for high barriers to entry, the situation changes for low
barriers to entry (more exactly for \( f_S/N < 0.0359 \)).\(^{11}\) For reasons of more effective entry deterrence, the first entrant prefers a large rival. This even leads to the case where the first entrant concedes market share to the second in order to induce large-scale investment by the rival (region \( VI,e \), Figure 2).

If we once again take cost minimization as a benchmark, we find even cases in which strategic investment in entry deterrence capacity leads both firms to invest in large-scale technology although cost minimization would require that both firms employ the small-scale technology. Put differently, we find that both firms overinvest from a social point of view (see region \( OI \) in Figure 4). The above results show that the market size which allows two large-scale firms to be active depends crucially on the strategic behavior of firms facing a threat of entry.

### 3.4.5 Very large markets \((N > 180 \text{ if } c_S = 1/2, N > 400 \text{ if } c_S = 1/8)\).

In very large markets the availability of a small scale technology is irrelevant. Due to the large output the small scale technology’s fixed cost advantage can no longer outweigh the disadvantage in terms of variable costs. Götz (2005) shows that prices of both active large scale firms are below \( 1/2 \) for markets of a size greater than 600. This implies that small scale technology would not even affect behavior in this market if its fixed costs \( f_S \) were 0.

\(^{11}\) Note that \( f_S/N = 0.0359 \) is the value at which the downward jump of the locus separating the two large firms case from the one with a large and a small firm occurs (Figure 2, next to region \( VI,c \)). By construction of Figures 1 and 2, entry barriers for small-scale entrants do c.p. not change along the vertical dimension. A similar property holds for the profits of the first entrant: The question whether sharing the market with a large- or with a small-scale rival is more profitable is independent of market size. This property does not hold in cases in which actual competition matters, i.e. when we find excessive entry deterrence (region \( V,e \), Figure 2). The reason is the need to change location if market size changes, as a greater market makes the large scale technology more profitable for the rival. Note that excessive deterrence applies for \( f_S/N > 0.0361 \).
3.5 Cross-sectional properties of the model

The preceding section looked at the effects of changes in barriers to entry as measured by $f_S/N$ and of market size $N$ in isolation. This allowed for a rather general analysis of firm behavior. Now I focus on changes in market size for given values of fixed costs $f_S$. As a consequence the height of the barriers to entry changes once market size changes. This analysis is more specific as it examines the cross-sectional properties of the framework. I therefore obtain the optimum firm strategies in different geographical markets with different market sizes but identical technologies, i.e. identical cost structures.

To perform the cross-sectional analysis, I have added contour lines with given fixed costs in Figures 3 and 4.\textsuperscript{12}

The diagrams explicitly show the relation between industry structure and market size. If one takes the case of $f_S = 1$ in Figure 3, 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 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 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

\textsuperscript{12} Figure 4 also depicts regions where both firms under-invest (Region $UI$) and over-invest (Region $OI$), respectively. I discussed these cases above.
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 $N$ increases. This is even more apparent from the locus with $f_S = 4.3$ in Figure 4. 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 5, 6, and 7, 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 Götz 2005). 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 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 5 to 9 about here]

An important question in cross-sectional analysis concerns the relation of market size and prices (see for instance Campbell and Hopenhayn, 2005). My framework, with entry deterrence and strategic interactions among a small number of agents, shows that prices may well be higher in larger markets. Even if there is no change in the number of firms, increases in market size may induce non-monotonic and discontinuous changes in prices. Both Figures 8 and 9 as well as the example mentioned on page 13 provide cases in which increases in $N$ 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 the result, 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).

An industry which appears to match the model's fundamentals and cross-sectional properties nearly perfectly is the market for office supply superstores. As found by the FTC and Judge Hogan in the Staples - Office Depot merger case, there are many geographical regions in which one, two or three firms are active in this industry (p. 9, ruling). Additionally the firms typically operate not more than one outlet in such a market. According to the company website, Staples operates two different store models; the typical Staples superstore with about 20000 square feet and the "14600 square foot Barrington model", which "serves customers in smaller markets" (www.staples.com/about/media/overview.asp). Furthermore, location and sequential entry appear to be of crucial importance for firm profitability (see DSN Retailing Today, Nov 6, 2000). The first mover (i.e. Staples) seems to earn consistently higher profits (ibid. and DSN Retailing Today, Sep 20, 2004). Latecomers 'are forced' to make "real estate mistakes" (see DSN Retailing Today, Nov 6, 2000), i.e. to choose inferior locations in the model's terms. While a full analysis of the industry is beyond the scope of this paper and a topic for future research, the model sheds some light on the complex interaction between pricing behavior, market size, and concentration, i.e. the number of firms (see
Newmark, 2001 and 2004). The effect of market size on barriers to entry may well explain the effect that smaller markets typically exhibit higher prices (see Newmark, 2004 for an overview of pricing patterns and market size effects). But - as demonstrated - the model also allows for exceptions.

A final point concerning the pricing behavior of firms concerns the question of whether the cost leader charges a lower or a higher price than its rival. Tyagi (2001) analyzes this question in a duopoly Hotelling model with exogenous cost differences, assuming simultaneous entry and allowing for locations outside the unit interval. He shows that leadership results in a more central location and to the result that the cost leader charges a higher price than her high cost rival. Figure 8 shows that a similar mechanism is at work in my model: for the parameter values underlying Figure 8, the first entrant always charges a higher price than the second entrant, irrespective of whether she is the high cost or the low cost producer. However, the cost leader may well charge lower prices if the cost difference is large (see page 16). At this stage I want to examine under what circumstances a product differentiation and a cost leadership strategy are compatible. To do this I assume for the moment that a product differentiation strategy implies choosing a position in the market center as the “most attractive location” (see Tyagi 2000). Furthermore, I require a cost leadership strategy to imply “aggressive pricing” (Porter 1980, p. 36) in the sense that a cost leader charges lower prices than its rivals. Figure 10 depicts the locations of the first entrant \((x_1)\) for which both firms would charge the same price given the first entrant’s cost advantage \(c\). For locations above the curve and therefore closer to the “most attractive location” the first entrant charges a higher price than the second entrant. Figure 10 shows that with the large cost difference considered in the simulations \((c = 1/2)\), the first entrant employing the large scale technology will always charge the lower price.\(^{13}\)

\(^{13}\) Prices of both firms are identical if the first entrant locates exactly at the center.
Product differentiation and cost leadership are compatible in this case. However, if the difference in marginal cost is smaller the first entrant will charge a higher price even for positions which are not particularly close to the center. Product differentiation and cost leadership strategy in the sense of aggressive pricing are not optimal here. The above treated case of a small cost difference \( c = 1/8 \) shows that this scenario applies for a wide range of parameter values. The location \( x_1 \) for which both firms charge the same price is as close to the edge as 0.0670. Since the first entrant locates closer to the center for \( f_s/N < 0.0928 \) in region \( V,b \) of Figure 2, it is clear that we should hardly find firms with a more attractive position charging a lower price even if they have a cost advantage. Product differentiation and aggressive pricing are not jointly optimal if the cost advantage is not very large.

3.6 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. 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 4 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, the result 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. Depending on the importance of potential competition, an increase in fixed costs may reduce or increase profits.

4. 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. 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. Concerning fixed costs, two results are worth mentioning: 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. A final result I want to mention 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.

5. Appendix

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

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

which is negative.

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

$$\pi^2(x_1, x_2, 0) - \pi^2(x_1, x_2, c) = \frac{(2(x_2 - x_1)\left(4 - x_1 + x_2\right) - c)cN}{18(x_2 - x_1)}.$$  

Taking the pricing rules

$$p_1 = \frac{(c + 2(x_2 - x_1) - x_1^2 + x_2^2)}{3} \quad \text{and} \quad p_2 = \frac{(2c + 4(x_2 - x_1) + x_1^2 - x_2^2)}{3},$$

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 \(c\):

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

As \(x_2 \leq 1\), the difference in the numerator of equation (9) 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.

6. References


Figure 1: Industry structure as a function of fixed costs to market size $f_S/N$ and of market size $N$ ($c_S = 1/2$)
Figure 2: Industry structure as a function of fixed costs to market size $f_2/N$ 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 3: Industry structure and the value of fixed costs $f_S (c_S = 1/2)$

Figure 4: Industry structure, fixed costs $f_S$, over-investment (shaded region $OI$), and under-investment (shaded region $UI$) ($c_S = 1/8$)
Figure 5: Equilibrium locations of the first (solid line) and second entrant (dashed line), respectively, as a function of market size $N$.

Figure 6: The equilibrium market share of the first entrant ($s_1$) as a function of market size $N$. 

Figure 7: Equilibrium profits of the first (solid line) and second entrant (dashed line), respectively, as a function of market size $N$.

Figure 8: Equilibrium prices of the first (solid line) and second entrant (dashed line), respectively, as a function of market size $N$. 
Figure 9: Average prices, defined as industry revenue divided by market size, as a function of market size $N$.

Figure 10: Locations of the first entrant ($x_1$) for which both firms would charge the same price, given the first entrants cost advantage $c$. 