Determinants of product differentiation: A Survey*

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Abstract

This paper reviews the Hotelling literature of product differentiation. The purpose of this work is to examine the impact of the market structure on price competition and equilibrium differentiation. The existence of a general 'principle of differentiation' is rejected. In contrast, differentiation depends on a number of market parameters such as the costs of disutility, the demand elasticity, the number of firms, the density of consumers, and so forth. It is argued that the analysis of the predictive validity of this research stream by experimental and empirical studies is overdue.

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1 Introduction

Differentiation is often viewed as a necessary condition to gain competitive advantage over rival firms. Following a different strategy is perceived as providing the opportunity to obtain unique or at least superior access to resources and customers. McMillan and McGrath (1997: p. 133) have recognized that

> "Most profitable strategies are built on differentiation: offering customers something they value that competitors don't have."

Although differentiation was not the target of economic theorizing itself,[1] researchers paid much attention on differentiation along the dimensions of product characteristics. During the past decades, product differentiation has become a well developed field of industrial economics. The amount of optimal product variety and the proximity of different brands in equilibrium are central questions addressed in this area. In order to model consumer and firm behavior, two prevalent research streams evolved: the class of spatial models in the spirit of Hotelling (1929) and Lancaster (1979), and the class of non-spatial models in the spirit of Chamberlin (1933), Spence (1976), and Dixit and Stiglitz (1977). In particular, the Hotelling branch of this literature has attracted considerable interest in the previous years. Consequently, this paper surveys this part of the literature on product differentiation.[2]

What is the aim of this survey? Hotelling models were criticized for delivering rather unrobust results. Hotelling's main proposition is that firms agglomerate in the market center. A seemingly slight modification of the model led to the opposite result of extreme differentiation (D'Aspremont, Gabszewicz, and Thisse 1979).[3]

[1] One exception from the business literature is Deephouse (1999).

[2] We concentrate on horizontal product differentiation which implies that there is no general agreement between consumers how to rank the products according to their preferences. Vertical product differentiation, however, is distinct from it because such a unanimous agreement about a ranking exists (Gabszewicz and Thisse 1979). For an analysis of how vertical differentiation is related to horizontal differentiation see Anglin (1992).

[3] Although the result of Hotelling has shown to be wrong (d'Aspremont, Gabszwewicz, and Thisse 1979), there were several successful attempts to restore the minimum differentiation equi-

Both findings were exaggeratedly called 'principles of differentiation'. Obviously, such a universal principle cannot be derived from the literature. Also in reality, we find both: agglomeration and differentiation. The former occurs, for example, in the form of shopping malls, while the latter can be associated with a great variety of differently designed consumer goods. Hence, differentiation seems to be related to different parameters of the model in a complex way. We aim at showing how the amount of differentiation is determined by some parameters of the market structure.

Competition in Hotelling games is local, i.e. firms compete for customers with their direct neighbors along a spatial domain. The equilibrium results of Hotelling games are driven by a basic trade-off between two opposite effects of relocation: the positive (short-run) demand effect which leads firms to locate close to their direct neighbors in order to attract a high demand, and the negative (long-run) price effect which results from the increased local competition. The relative strength of those effects decides upon which equilibrium pattern is established: either the maximum, the minimum, or an in-between differentiation solution (given an equilibrium solution exists). Minimum differentiation subsumes every spatial configuration in which firms choose the same location in equilibrium. In the maximum differentiation solution, firms maximize the respective distances to their neighbors. The in-between equilibria consists of all the remaining formations. The model of spatial competition mutates into a model of product differentiation just by reinterpreting the domain of the model and the underlying utility function.[4]

Hotelling's model was reviewed and modified many times such that now a huge body of literature exists from which we can draw. Given the purpose of this work and in order to keep the number of articles manageable, we restrict the paper selection using the following criteria. First, only those papers are considered which focus strongly on the original Hotelling model, i.e. which change only few features of the model setup. Otherwise, it might be hardly possible to disentangle the various effects which lead to different equilibrium solutions. In particular, we almost com-

librium (e.g. Stahl 1982) .

[4]Lancaster (1966, 1971) provides a full formal structure for this approach.

pletely neglect articles which do not model both the location and price setting stage. Furthermore, we concentrate on the sequential game of location and price choice, not allowing for any kind of Stackelberg games (Anderson 1987, Harter 1996). Second, we concentrate on the issue of product differentiation. Papers which are of more interest in fields like public finance (e.g. Hohaus, Konrad, and Thum 1994) or political theory (e.g. Weber 1998) are ignored in our review. The dominant equilibrium concept is the subgame perfect Nash equilibrium in pure strategies. However, keep in mind that pure strategy equilibria sometimes cease to exist whereas mixed strategy equilibria do not (Osborn and Pitchik 1987).

This survey may be of some general value in industrial economics and related fields. To the best knowledge of the author there is no other recent survey of this topic (Gabszwewicz and Thisse 1992, Lancaster 1990, Waterson 1989). About one half of the cited papers were published after 1990. Further, it seems that the subtleties of the model are not always fully acknowledged because often it is concentrated on the focal results of maximum or minimum differentiation. As we will see they only represent equilibrium solutions for a subset of all the considered models. Finally, models of spatial competition may be of some broader interest in business policy. For example, Tang and Thomas (1992: p. 325) suggest that the implications of the model "can be extended to non-spatial competition based upon reliability, availability, customer credit, etc."

Reviewing the literature shows that the relative strength of the centripetal and the centrifugal forces in the model depends on a variety of features of the considered market, in particular on how the price competition is set up, on the demand elasticity, on the incentives to collude, on the distribution of customers, on uncertainty, and on the number of firms and dimensions.

The organization of the paper is as follows. In the next section the reference model will be presented. In Section 2.3 the literature survey provides the reader with the determinants of differentiation. Finally, Section 2.4 concludes the paper.

2 The model

In this section the basic model is described. The games considered in the following survey can be derived from it by generalizing or restricting the model parameters appropriately. Since the model is a formal, mathematical one it is open to different interpretations. Most common are interpretations which go along spatial and product differentiation. As intimated already, there might exist other strategic domains for which this model can reasonably be applied. However, in order to avoid confusion we stick to the conventional interpretation of product differentiation.

There are n firms producing a good at zero marginal cost. The products are horizontally differentiated. We consider a domain of product characteristics which is projected onto the unit interval, i.e. each value from the $[0,1]$-interval represents an amount of the product characteristic. In some cases we allow for a unit circumference representation. There is an infinite number of customers i whose preferences for the product characteristics w_i are distributed along the unit interval with distribution $F(w_i)$.

The model is a two-stage game of complete information. In the first stage, firms $i = 1, .., n$ choose product characteristics $\bar{x} = (x_1, x_2, .., x_n) \in [0,1]^n$ simultaneously before posting prices $\bar{p} = (p_1, p_2, .., p_n) \in R^n$ in the second stage of the game. This reflects the idea that producing a product requires a long-term commitment while setting the price can be done instantaneously. Without loss of generality, we assume $0 \leq x_1 \leq ... \leq x_n \leq 1$. Finally, customers decide if and which product to buy. This decision is determined by the preference w_i of the customer, the available products, and their respective prices according to the following indirect utility function:

$$u\left(k_j, w_j, p_i, x_i\right) = \begin{cases} 0 & \Big| \; q_{ij} = 0 \\ k_j - p_i - d\left(x_i - w_j\right) & \Big| \; q_{ij} = 1 \end{cases}$$

where q_{ij} is the quantity of product i consumer j buys. In general, $q_{ij} \in [0,1]$, i.e. consumer i buys no more than one unit of the product j. Further, consumers only buy a product from one firm. p_i is the price charged for the product of firm i. d represents any distance function which is monotonously increasing. This function measures the disutility which is related to the difference between the amount of the characteristics of the most preferred product w_j and the considered product x_j. These "distaste" costs are referred to as transport costs in this paper. An outside option is accounted for by reservation price $k_j > 0$.[5]

The model exhibits a coordination problem. Assuming that equilibria exist in which firms do not choose the same location it remains unclear which firm should locate at which of the different positions. Of course, one solution would be to consider mixed strategies, i.e. firms would be allowed to follow different strategies in equilibrium, each with a certain probability. Since this requires high analytical capabilities the equilibrium concept might be implausible for real situations. To circumvent this problem, we assume that the number assigned to a firm corresponds to its rank in the spatial ordering, i.e. firm 1 is at the extreme left and firm n is at the extreme right.

We focus on Nash equilibria as the only equilibrium concept. Other equilibrium concepts such as adaptation, evolution, etc were suggested to be more relevant in reality since they require less capabilities (Camerer 1991). However, they are widely ignored in the literature being surveyed and extending the analysis would be beyond the scope of this work.

3 Determinants of differentiation

As we will see below, the considered models allow for a great variety of equilibrium outcomes in prices and locations which range from minimum to maximum differentiation and from soft to tough price competition. For a subset of model parameters, the games are plagued with the non-existence of equilibria. In these situations, we cannot predict prices or locations. Consequently, we do not suggest the existence of very general relationships of differentiation. Rather, we show how differentiation

[5]The problem of non-existence of the price equilibrium occurs if it is assumed that income is sufficiently heterogenous such that some customers cannot afford to buy a differentiated good (Peitz 1999). Throughout the paper, we neglect this case.

is affected by a variety of parameters of the game. This overview is, of course, restricted by the availability of results on the various modifications of the model. By far, recent research on product differentiation does not provide results on every possible case of the model. Among other reasons, the complexity which the model poses on the equilibrium concept often increases dramatically with incremental generalizations. However, we try to identify the drivers and the inhibitors of differentiation for an important subset of the class of all models. We start with the determinants of price competition.

3.1 Price competition

The competition in prices is affected by two model features: the transportation costs and the general pricing strategy of the firms. The former directly influences the "toughness" of price competition. The latter limits the ability of firms to spatially discriminate customers. Let us first concentrate on the impact transportation costs have on price competition. They play a central role in research on product differentiation because the way in which they are modeled decides on how much firms differentiate their products in equilibrium. Furthermore, existence of price equilibrium and thus the existence of subgame perfect equilibrium for the whole game depend on transport costs.

Transport costs influence the price competition between two firms by the amount of customers which a firms is able to withdraw from (lose to) its neighbor by decreasing (increasing) its price by one unit. We refer to this as the *degree of price competition*. More formally, this measure is represented as the first price derivative of the demand function. Note that it may depend on the locations of the firms. Table 1 lists the papers which are related to modifications of the transport costs. The first five articles are devoted to the interval model and the last two papers consider the circumference domain. The models assume a duopoly with uniformly distributed customers and inelastic demand. The third row of Table 1 shows the functional form of the transport cost, while the fourth row indicates if a price equilibrium exists for this class of cost functions. In the class of interval models, this is only the case for quadratic and a subset of convex non-linear functions considered by Economides (1986). However, convexity is not sufficient to ensure the existence of the price equilibrium (see fifth and sixth row). Rather, it is the non-quasi-concavity of the profit function which prevents the equilibrium existence.

Further, one could suspect that the degree of price competition is related to the existence of a price equilibrium. Both cases which provide the existence of an equilibrium are associated with an infinitely high degree of price competition if firms are very close (see last column of Table 1). In contrast, in the setup examined by Gabszewicz and Thisse (1986) and Anderson (1988) price competition has an upper bound even if firms locate at the same position. However, as proved by Anderson (1988) configurations in which firms are located very close and in which firms are located very distant imply an equilibrium. For a region in-between, the equilibrium breaks down. Hence, there is no clear relationship between the degree of price competition and the existence of a price equilibrium for the interval model.

Unfortunately, previous analysis is restricted only to rather simple functional forms. Although it would be nice to have some theorems on the conditions of non-existence of the price equilibrium, to establish them "seems to be a hopeless task." (Gabszewicz and Thisse 1986: p. 167). Thus, for a great variety of transport functions no price equilibrium and hence, no subgame perfect equilibrium exist. Furthermore, the degree of price competition is not linked to the existence of price equilibria via a simple relationship.

Interestingly, in the circumference model the price equilibrium does not exist in the case of linear transport costs (Kats 1995) but if costs are linear quadratic (de Frutos, Hamoudi, and Jarque 1999). Hence, convex and concave functions may allow price equilibria. De Frutos, Hamoudi, and Jarque (1999) underlined that if linear costs are assumed firms perceive prices and locations as strategic substitutes whereas otherwise, they are perceived as strategic complements. In the linear case, this leads to situations in which it becomes profitable to undercut a rival's price if firms' locations are sufficiently distant. However, in the non-linear case prices increase with distance such that it would not be profitable to deviate form this price

Article	domain	cost function	price equilib. exists?	equilib. locations	level of price competition[6]
Hotelling (1929)	interval	$d(x) = ax$ $a > 0$	no	-	$\frac{1}{2a}$
d'Aspremont, Gabszewicz, Thisse (1979)	interval	$d(x) = bx^2$, $b > 0$	yes	max. diff.	$\frac{1}{2bx}$
Economides (1986)	interval	$d(x) = bx^\alpha$, $b > 0$, $1 \leq \alpha \leq 2$	if $1.26 < \alpha \leq \frac{5}{3}$ if $\frac{5}{3} < \alpha \leq 2$ not otherwise	interior max. diff. -	$\frac{1}{\alpha b\left(y_2^{\alpha-1}+y_1^{\alpha-1}\right)}$, where $y_i =$ $\|D_1(p) - x_i\|$
Gabszewicz, Thisse (1986)	interval	$d(x) =$ $ax + bx^2$,	no	-	$\frac{1}{2a+2bx}$
Anderson (1988)					
Kats (1995)	circular	$dx = ax$, $a > 0$	no	-	$\frac{1}{a}$
de Frutos, Hamoudi, Jarque (1999)	circular	$d(x) = ax+$ $bx^2, a \geq 0$, $b \in R$	if $a = 0$ or if $a = -b$ not otherwise	max. diff. max. diff. -	$\frac{1}{a+bx}$

Table 1: Papers on horizontal product differentiation and transport costs

equilibrium even if firms are distant.

Concentrating on the cases where equilibrium existence is of no concern which are all covered by Economides (1986) we see that the degree of price competition and the pattern of differentiation are related in the way intuitively expected. Hence, given a price equilibrium exists for the duopoly Hotelling model with uniformly distributed consumer preferences on the unit interval, then the higher the degree of price competition the stronger is strategic differentiation.

However, it is worth mentioning that differentiation does not range from min-

[6] $D_i(p)$ is the demand of firm i given prices $p = (p_1, p_2)$.

imum to maximum differentiation but rather from in-between to maximum differentiation. From this result, minimum differentiation does not seem to be a likely outcome other than a random result in the case without equilibrium existence. We will see below that minimum differentiation can be obtained by relaxing different model parameters. For the circular model de Frutos, Hamoudi, and Jarque (1999) show that the principle of maximum differentiation is dominating because firms always would like to differentiate unless linear transport costs are assumed.

In the previously mentioned papers, transport costs were taken to be exogenous. However, several examples like PCs designed to fulfill a wide range of functions or cosmetic articles ("all in one") suggest that firms try to reduce the disutility of consumers incurred by the distance of their preferred good and the offered good measured in the space of product characteristics. Von Ungern-Sternberg (1988) and Hendel and de Figueiredo (1997) tackle this problem for the circular domain. In their model, firms first choose to enter and then a location. Subsequently, they set transport costs and prices simultaneously (von Ungern-Sternberg 1988) or sequentially (Hendel and de Figueiredo 1997). If the transport costs are close to zero, the 'general purposeness' of the product is said to be high. Otherwise, the product design is said to be focused. Transport costs are assumed to be linear with a variable slope parameter.

In the simultaneous choice model, firms set transport costs at a rather low level (lower than socially optimal) which increases price competition. In the sequential setup of Hendel and de Figueiredo (1997), however, the choice of the focus introduces a strategic effect on pricing. The impact strategic focussing has on price competition is not straightforward. In the duopoly case where changing the focus is costless, firms have an incentive to increase their focus in order to relax price competition. For the case $n > 2$ this does not hold anymore. Here firms are interacting with two different neighbors which results in external effects of the attempt to soften price competition. Consequently, firms increase the general purposeness of their products leading to prices at marginal costs. Given that entry only occurs at fixed cost there is no equilibrium with more than two firms. Hence, despite of free entry, in equilibrium there are only two firms in the market. However, if changing the focus is associated with costs the results change for $n > 2$. In this case, the focus will be increased by the firms leading to positive prices and hence, possible oligopoly equilibria. Thus, the level of transport cost and consequently, the level of price competition depend on the costs of altering the transport costs and on the possibility to act strategically on them.

A final note should be made regarding the plausibility of different functional forms of transport costs. Lancaster (1979, Chapter 2) argues that linear transport costs are inconsistent with plausibly shaped indifference curves. In contrast, quadratic costs are not inconsistent. Thus, a justification for the frequent assumption of this particular functional form is provided.

3.2 Pricing strategies

The lion's share of papers on Hotelling models assumes mill pricing, i.e. firms sell the products at a fob price (*free on board*) which is not related to the location of the consumers. Another possibility would be to charge spatially discriminatory prices. Here, for example, firms charge lower prices from customers which are more distant. Applied to the domain of product differentiation there exist two possible interpretations. The obvious one is that firms compensate the disutility customers incur from buying a product whose characteristics are not aligned to their preferences by adjusting the price accordingly. That is, firms would charge different prices depending on the location of customers in the characteristics space. Another interpretation is that firms redesign the goods to be sold (which is assumed to be done at zero cost), pay the cost of transport and charge a uniform total price. Both price strategies can be observed in reality: discriminatory and non-discriminatory price-setting. An industry where the two forms occur simultaneously is the book retail industry. Books may be either bought in the book shop or by one of the numerous mail-order or internet book retailers at a similar compound price (including transportation).

The impact of different price regimes on spatial competition was considered by Hoover (1937), Eaton and Wooders (1985), Thisse and Vives (1988), Norman and

Thisse (1996), Tabuchi (1999), and Zhang (1995). From the competition point of view, the impact of the choice between mill pricing and discriminatory pricing is not straightforward. First, the opportunity to discriminate on prices increases the firm's flexibility. A lot of articles show the profit enhancing effect of monopolistic price discrimination (Tirole 1990). However, in the short-run firms would prefer mill pricing. This is because mill pricing offers the opportunity to commit to a set of prices while in discriminatory pricing it is possible to cut prices at each location separately. Gabszewicz and Thisse (1992) point out that under discriminatory pricing, there is a separate Bertrand price game at each location of the interval. Hence, price competition is tougher under discriminatory pricing resulting in lower equilibrium prices (Thisse and Vives 1988). Moreover, it was shown for a general set of conditions that if prices and price regimes are chosen simultaneously, discrimination occurs as an equilibrium. Additionally, under more rigid assumptions the sequential subgame of first choosing the price regime and then posting a price simultaneously delivers the same result (Thisse and Vives 1988).

The case in which marginal costs of production differ between discriminatory and mill pricing was considered by Tabuchi (1999). Here mill pricing results as an equilibrium only if marginal costs of discriminatory pricing are much larger than marginal costs of mill pricing. However, taking into account the long-run effect of discriminatory pricing on entry it appears that less firms enter the market. The higher concentration of firms is accompanied by higher profits (Norman and Thisse 1996). Consequently, discriminatory pricing can be applied as an effective deterrent of entry. However, if entry is blockaded exogenously, incumbent firms would generate greater profits using mill pricing.

Zhang (1995) examines the effect of price-matching policies on the Hotelling game. If a firm follows a price-matching policy it is committed to match or beat the prices of its competitors. The game has three stages: (1) location choice, (2) decision about the price-matching policy, and (3) setting the price. Here again, an instrument which seems very competitive leads to a softer price competition via the strategic effect of entry deterrence. Consequently, although assuming quadratic transport costs minimum differentiation prevails as an equilibrium.

3.3 Elasticity of demand

The standard Hotelling model makes the rather unrealistic assumption that demand is inelastic. Relaxing this assumption may have two effects. First, equilibrium prices can be expected to decrease if demand elasticity is sufficiently high because then it is worthwhile for the firms to attract new demand by decreasing their prices. Second, price competition between the firms may be cooled because the firms' focus will become increasingly local. Since transport costs are payed by the customers, the real prices are lower for customers close to the firm which are easily attracted even if demand elasticity is high. Consequently, this would lower the incentives to differentiate to the maximum.

Smithies (1941), Salop (1979), Böckem (1994, 1996), and Hinloopen and Marrewijk (1999) contribute to model generalizations in this respect. Smithies (1941: p. 432) investigated a setting in which the consumers are individually endowed with a linear inverse demand function. He argued informally, not being provided with modern game theoretic tools, that firms would locate "closer to the center than to the quartiles." Customers in the hinterland of each firm are not necessarily attracted by the respective firms if demand is elastic. Salop (1979) concentrates on the price stage given symmetric locations of firms on the circumference and shows existence of the price equilibrium if there is an outside good. Böckem (1994, 1996) models a continuum of consumers whose reservation price $k \in [0,1]$ is distributed uniformly over the interval. Assuming a duopoly with quadratic transport costs it is shown that a price equilibrium exists and further, that firms locate between maximum and minimum differentiation. The numeric solution of equilibrium locations is [0.272,0.728]. Indeed, it is the effect that it pays for the firms to be close to the demand which attracts them towards the market center.

The study of Hinloopen and Marrewijk (1999) examines a similar setup where transport costs are linear and the reservation price is constant across consumers. Given the reservation price is sufficiently high, the original Hotelling result holds in which no price equilibrium exists. If the reservation price is low, firms become local monopolists which leads to a continuum of equilibrium locations including maximum and intermediate differentiation. However, reservation prices in-between imply symmetric equilibrium locations where the distance between the firms is between one fourth and one half of the market. For a range of reservation prices there exists a negative relationship between this value and the amount of differentiation. Thus, summarizing we conclude that given a price equilibrium exists for the duopoly Hotelling model with uniformly distributed consumer preferences on the unit interval then the higher the elasticity of demand the less firms will differentiate.

3.4 Collusion

The games usually considered in spatial competition assume non-cooperative behavior of firms. However, through frequent interaction firms might partially build up a cooperative attitude towards their competitors resulting in collusive agreements. Firms may collude on both, locations and prices. In the duopoly examined by d'Aspremont, Gabszewicz, and Thisse (1979) this would lead to profit maximizing (and socially optimal) locations at the quartiles. Jehiel (1992) and Friedman and Thisse (1993), however, argue that firms will likely collude on prices only since locations are fixed once for all. Following the collusive agreement implies bearing the risk of being cheated. If a rival deviates from the collusive outcome, revenge could be taken only via prices which may not be credible.

For the case that firms are allowed to collude only in prices, Jehiel (1992) and Friedman and Thisse (1993) consider a game of location choice in the first stage followed by an infinitely repeated price game. While Jehiel applies Nash bargaining within the cartel, Friedman and Thisse use a profit-sharing rule corresponding to the respective ratio of profits without collusion to determine the collusive outcome. Without allowing for money transfers between the two competitors in both models minimum differentiation results, i.e. both firms locate at the market center. This result may be expected since through collusion the threat of fierce price competition preventing the firms to approach each other disappears. Moreover, taking the same position has the advantage that the threat of cutting the price has the greatest effect on the rivals' profits and thus, making it more probable for collusion to sustain. However, Jehiel introduces *ex post* money transfers between the firms which leads to cases where firms' distance is not greater than one half. In this case, it becomes inessential to be well located in order to punish the rivals for deviating. Hence, firms are more attracted by the profit maximizing locations at the quartiles.[7]

Cartel stability of spatial models of product differentiation was investigated by Ross (1992) and Rothschild (1997). Locations are assumed to be equidistant on the linear market without boundaries. The distance between two direct neighbors is interpreted as a measure of product differentiation. In the case of inelastic demand the result is clear-cut: Here the cartel stability is monotonously increasing in the measure of product differentiation (Ross 1992). Introducing demand elasticity, however, complicates the result. In this case, the impact of the amount of differentiation could have any direction, depending on the other model parameters (Rothschild 1997). The impact of collusion in the location choice stage (holding prices fixed) was examined theoretically by Huck, Knoblauch, and Müller (2000). Interestingly, it was shown that collusion is stable only if the number of colluding firms is large.

3.5 The number of firms

Let us now address the question of how a firm's choices of location and price is affected by the number of firms. In general, the analytical tractability of Hotelling models decreases with the number of firms. This is because a firm's actions depend on actions of every other firm. Further, in the interval model asymmetry arises because it matters how many neighbors a firm has on each side. Hence, there is only a limited number of contributions to the multiple firms model.

Examining the model on the circular domain Salop (1979) proves the existence of the price stage equilibrium given an equidistant location setting. However, an equilibrium does not exist for every feasible subgame. Again, as in the duopoly this

[7] This holds when a sufficiently low finite reservation price is assumed.

problem can be circumvented by assuming quadratic transport cost. This assures the existence of a price equilibrium in every subgame and further, the equilibrium existence of the whole game (Economides 1989). The locations in this equilibrium can be interpreted as following the principle of maximum differentiation. That is, firms locate equidistantly in order to maximize the minimum distance to their direct neighbors. Hence, in the circular domain the number of firms does not have a significant effect on the relative amount of differentiation.

In the linear market, the failing of a price equilibrium of Hotelling's original model could be remedied by allowing more than two firms to enter (Economides 1993). However, as there are strong incentives for the firms to agglomerate at the market center, a location equilibrium could not be established. Agglomeration is not stable since it is associated with Bertrand competition and deviating increases profits. In (non-equilibrium) equidistant configurations the corner firms are provided with some kind of market power which enables them to charge higher prices than their competitors. This is attributable to the fact that corner firms only have rivals on one side and hence, price competition is lower than for inside firms. The price structure is U-shaped, i.e. prices decrease towards the center firms.

A similar setup with quadratic transport costs was analyzed by Brenner (2001). He showed that a price equilibrium exists for every feasible subgame and further, that the principle of maximum differentiation does not carry over to the multiple firms case. For games with up to nine players equilibria are calculated which are characterized by a U-shaped price structure. Moreover, corner firms locate inside the interval which manifests their market power. However, if more than three firms are in the market the equilibrium differentiation pattern does not much deviate from the socially optimal pattern.

In summary, allowing more than two firms to compete has the following effects. The price competition is not endangered although it seems to be softened. This effect arises because there exists an externality of a price change. By responding to an action of one neighbor a firm also has to take into account the response of the second neighbor. Consequently, the maximum differentiation equilibrium in the linear market with quadratic transport costs is destroyed. Furthermore, given a market boundary the corner firms enjoy a market power from possessing a hinterland which is reflected in higher prices and higher profits than their competitors if $n > 3$.

3.6 Customer distributions

In the standard model customers are distributed uniformly over the unit interval or the circumference. This was sometimes viewed as one of the most unrealistic assumptions of the model. In the domain of product characteristics one usually finds customers' preferences clustered around some brands while in geographic space there is often an agglomeration of inhabitants at the business center of a town. Intuitively, we might expect that differentiation decreases as the density at the interval center increases while price competition gets fiercer. In the extreme case where all the density is concentrated in one point the Bertrand paradigm results.

Several attempts have been made to relax the uniform distribution assumption. Shilony (1981) has proven that the problem of equilibrium non-existence in Hotelling's original model could not be solved by allowing more general density functions. Interestingly, however, the locations which provide price equilibria still imply a tendency to agglomerate. Assuming quadratic transport costs, Neven (1986) has shown that for concave symmetric distributions a price equilibrium exists and further, that the whole game has an equilibrium. For distributions which are not too concave maximum differentiation holds. From a certain degree of concavity onward, however, firms choose inside locations which are not more than one eighth away from the interval boundaries.

In their frequently cited paper, Caplin and Nalebuff (1991) have shown that price equilibria exist for the broader class of log-concave distributions.[8] This has led to the question of whether equilibrium existence holds for the whole game. Tabuchi and Thisse (1995) found that symmetric locational equilibria do not exist for the subclass of triangular density functions. It was suspected that the undifferentiability of the density at the median point would be the reason for this. However, Baake

[8] These are distributions which are concave after log-transformation.

and Oechssler (1997) have proven that it is not the undifferentiability but rather the steepness of the density at the center which prevents the equilibrium existence.

The most general approach to this problem so far was presented by Anderson, Goeree, and Ramer (1997). Considering a setup of quadratic transport costs and unrestricted locations on the real line they have shown for the class of log-concave distributions that symmetric location equilibria exist only if the distribution of consumers is not too concave at the center. Otherwise, asymmetric equilibria may appear given the distribution is not too asymmetric. By positioning asymmetrically firms shift the marginal consumer away from the very competitive region of high density to a more remote area in order to relax the competition.

Some marketing scholars may argue that the distribution of consumers is not completely exogenous. Rather, it can be influenced by firms via advertising. How this affects the price competition was examined by Bloch and Manceau (1999). In their model, firms are allowed to spend money on advertising which leads to a shift of consumers' preferences towards the advertised product. Locations are fixed at the interval boundaries. The two main findings of their work are that first, the price for the advertised product increases and second, there are incentives to equalize the distribution. The latter means that only that firm engages in advertising which is not favored by the initial distribution. Further, it pays to advertise until the uniform distribution is reached. The uniform distribution is preferred by the firms since it minimizes the price competition for the considered set of distributions.

3.7 Uncertainty

Uncertainty by the firms about an auxiliary dimension of product characteristics was introduced by Rhee, de Palma, Fornell, and Thisse (1992). In their model of linear transport costs, a variety of possible outcomes exist. If consumers exhibit sufficient heterogeneity along the unobservable attribute, minimum differentiation results. In contrast, the level of differentiation increases along the observable attribute as the uncertainty about the other dimension decreases. Moreover, increased uncertainty makes the competition more and more irrelevant leading to increasing prices.

3.8 Multiple dimensions

Finally, it is considered if adding further dimensions of differentiation influences the outcome of the game. Neven and Thisse (1990) and Tabuchi (1994) challenged the generality of the principle of maximum differentiation which holds for the analogous one-dimensional game by adding a second dimension. In the case of Neven and Thisse (1990) this is a dimension of vertical product differentiation while Tabuchi (1994) introduces another horizontal product differentiation dimension. Interestingly, their equilibrium solutions are rather similar. In the first case of vertical product differentiation, maximum differentiation prevails at one dimension while agglomeration is observed at the other. Along which dimension distance is maximized depends on the relative length of those domains. For the case of a two-dimensional plane of horizontal product differentiation (a square) minimum differentiation results along one and maximum differentiation along the other dimension.

These findings give rise to the question of whether introducing further dimensions along which firms are able to differentiate from rivals leads to more or less differentiation. Irmen and Thisse (1998) show that along all but one dimension firms agglomerate. Dimensions are weighted differently according to their relative importance. The dimension which is weighted maximally is used to differentiate. Hence, in this case the principle of minimum differentiation possesses more plausibility than its counterpart. Even for the three-firms case it could be shown that maximum differentiation is never an equilibrium. The main reason for this result is that differentiation along one dimension suffices to relax price competition.

4 Conclusions

In a preceding survey, Waterson (1989: p. 24) suggested that "with product differentiation, anything can happen". Further twelve years of research confirmed his view regarding the non-existence of something like a general 'principle of product differentiation'. This survey reveals that differentiation - either in geographic or product space - depends delicately on parameters of the market structure. With respect to the degree of price competition, the existing literature suggests that it becomes tougher

- as the transport costs become more convex,
- as discriminatory pricing or price-matching is available as a strategy,
- as the demand elasticity becomes lower,
- the fewer firms are competing,
- the less concentrated the density of consumers is in the center of the market,
- as firm's uncertainty increases regarding the heterogeneity of consumers' preferences of a second dimension of product characteristics,
- if advertising tools are available which shift consumers towards the advertised product.

Furthermore, price competition vanishes, of course, if firms are able to collude in prices. If the number of dimensions increases, price competition seems to become more and more irrelevant since differentiation occurs only along one single dimension. Endogenous transport costs, however, are inconclusive with respect to price competition.

The degree of price competition affects the location choices via the strategic effect. If price competition becomes tougher, differentiation is fostered, and vice versa. Furthermore, there are effects of the model parameters which directly influence profits of the location choice. In particular, differentiation is increased if the density of customers becomes more concentrated. Furthermore, there is a tendency to agglomerate when collusion is permitted in order to punish a deviating rival maximally.

One of the points of concern about the Hotelling literature is the strong imbalance between the number of theoretical papers on the one side and the number of empirical and experimental papers on the other. Notable exceptions are the empirical studies of Feenstra and Levinsohn (1995), Thomas and Weigelt (2000), and Pinkse, Slade, and Brett (2001). The former two estimate a highly localized discrete-choice model in a space of several dimensions of product characteristics. The latter discriminate between theories of localized and global competition. Simplified versions of the Hotelling game were subject to experimental research. The impact of collusion in the location choice stage was examined by Brown-Kruse, Cronshaw, and Schenk (1993) and Brown-Kruse and Schenk (2000). In laboratory experiments, individuals have chosen to locate at the center if communication was possible. Otherwise, there was a tendency towards the profit maximizing point at the quartiles. Huck, Müller, and Vriend (2000) investigated how individuals behave in a four-players game without price competition. In the Nash equilibrium, two players locate at each of the quartiles. The experimental results, however, suggest that because of best-response dynamics there is a tendency to locate at the center of the market. An experiment with location and price choice was carried out by Barreda, García, Georgantzís, Andaluz, and Gil (2000). They found that differentiation is smaller than predicted by economic theory.

Further research in the Hotelling tradition could strongly benefit from extending this branch of literature empirically and experimentally. Thus, it would be possible to test if the model assumptions and the equilibrium concepts are appropriate and if its conclusions better describe reality than competing theories. Otherwise, this literature remains purely conceptual without having any predictive power. Our review may facilitate to test some predictions of the model. On the theoretical side, it may be interesting to investigate the relationship to other theories. The paper by Anderson and de Palma (2000) who synthesize a unifying framework of local and global competition, seems to be quite promising in this respect.

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