



## An experiment on spatial competition with endogenous pricing

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### ABSTRACT

Hotelling's (1929) principle of minimum differentiation and the alternative prediction that firms will maximally differentiate from their rivals in order to relax price competition have not been explicitly tested so far. We report results from experimental spatial duopolies designed to address this issue. The levels of product differentiation observed are systematically lower than predicted in equilibrium under risk neutrality and compatible with risk aversion. The observed prices are consistent with collusion attempts. Our main findings are robust to variations in three experimental conditions: automated vs. human market sharing rule for ties, individual vs. collective decision making, and even vs. odd number of locations.

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### 1. Introduction

Since Hotelling's (1929) seminal paper establishing the principle of minimum product differentiation, it is widely accepted among economists that firms may strategically choose the position of their products on the space of characteristics. Later, D'Aspremont et al. (1979) and Economides (1986) showed that, when prices are contingent on product positioning, the subgame perfect equilibrium of location-then-price competition models may involve firms locating their products at sufficient distance from each other, in order to relax price competition. In fact, Shaked and Sutton (1982) established a similar result in a non spatial context. Although these seminal papers have inspired a vast theoretical literature, there has been little empirical testing of the hypothesis that differentiation is used by firms to adapt their products' characteristics to consumer tastes and, at the same time, to reduce the fierceness of price competition in the market.<sup>1</sup>

The lack of systematic empirical testing of the product differentiation theory can be explained as a result of the difficulties faced by economists to successfully represent the product differentiation

variable by proxies based on real-world, non-price data.<sup>2</sup> In fact, when empirical work accounts for product differentiation, the latter is treated as an explanatory variable of other economic phenomena. Therefore, in a strict sense, the product differentiation theory remains an empirically unexplored field of our discipline.

Like in the case of many other phenomena for which real world data leave little space for empirically testing economic theories, product differentiation models have been tested in the laboratory. Brown-Kruse and Schenk (2000), Collins and Sherstyuk (2000), and Huck et al. (2002), study experimental spatial markets with two, three and four firms, respectively. However, all these articles report experiments in which the individual subjects' only decision variable is location. That is, like in earlier work by Brown-Kruse et al. (1993), prices are exogenously given, as a fixed parameter of the experiment. In fact, all these papers have assumed that prices are sufficiently low to guarantee full market coverage for all possible firm locations. Their experimental results support either minimal product differentiation, predicted by the theory as the non-cooperative equilibrium for the framework used in Brown-Kruse et al. (1993) and Brown-Kruse and Schenk (2000), or intermediate differentiation, predicted as the collusive outcome of the framework in which communication among subjects is allowed.<sup>3</sup> Note

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<sup>1</sup> Other phenomena related to pricing and product differentiation have been studied theoretically, but an exhaustive list of them falls out of the scope of this paper. As representative examples, we mention minimal differentiation and variety clustering (Eaton and Lipsey, 1975), predation (Judd, 1985) and multiproduct activity (Aron, 1993) or the lack of it (Martínez-Giralt and Neven, 1988).

<sup>2</sup> Along this line, an assumption that seems to be broadly accepted by economists is that R&D expenses are a good proxy for vertical product differentiation, and advertising levels can be used as a proxy for horizontal differentiation. For a critical review of some of these assumptions, see Greenaway (1984).

<sup>3</sup> We use the term intermediate to refer to a product differentiation that lies between minimal differentiation (both firms locate in the middle of the segment) and maximal differentiation (each firm occupies one of the two extremes of the line). In fact, the degree of product differentiation that corresponds to the joint profit-maximizing solution can be shown to require the firms to locate on the quartiles of the segment.

that the assumption of non-price competition in the aforementioned experimental studies is especially appealing for the analysis of electoral competition.<sup>4</sup>

Adopting an endogenous consumer location framework, which is rather specific to residential choice models, Camacho-Cuena et al. (2005) is, to our knowledge, the only experimental study allowing for endogenous prices and firm locations. However, given the endogeneity of consumer locations, that setup significantly deviates from the standard location-then-pricing model of product differentiation. In contrast to all of these studies, the spatial differentiation framework has recently been used by Orzen and Sefton (2008) to study price dispersion as predicted by mixed strategy equilibria, while firm locations are exogenously fixed.

An alternative experimental approach to product differentiation is the business simulator SINTO-Market developed by Becker and Selten (1970), and extended by Becker et al. (2007). In this management game, the subjects interact in a triopoly market with brands differentiated in multiple dimensions, and they have to take complex decisions on several strategic variables. Although rich results can be obtained from such an approach, the number of variables interacting and the inner workings of the program provide too complex an environment for explicitly testing the prediction of higher prices resulting from more differentiation.

From the preceding review, we see that, surprisingly, one of the most popular intuitions in economics, namely that firms use product differentiation in order to relax price competition, has never been formally tested so far. In this article we experimentally test the predictions of a location-then-price spatial competition model of product differentiation. A difficulty associated with this approach is that, by endogenizing prices, we must account for the subjects' ability to raise prices above levels guaranteeing full market coverage. In fact, by making subjects choose locations before competing in prices, we test the heart of the product differentiation theory. As a consequence, our subjects are asked to perform a more difficult task than in Orzen and Sefton (2008), whose subjects' only aim is to keep prices above marginal cost. Intuitively, in the endogenous location and pricing setup studied here, there is more scope for product differentiation than in the exogenous pricing framework and more space for price collusion than under exogenous locations.

As a benchmark against which to compare our results we study the theoretical predictions for our setup considering collusion and non-cooperative behavior under different risk attitudes. Despite early insightful work by Baron (1970, 1971), Sandmo (1971), Leland (1972), Rubinstein (1976) and, more recent contributions by Appelbaum and Katz (1986), Hviid (1989) and Kao and Hughes (1993), the analysis of market competition under behavioral considerations has received more skepticism than attention. In a more recent paper, Asplund (2002) presents a formal analysis of oligopolistic competition with risk-averse firms. Asplund reviews previous empirical findings, by Schmalensee (1989) and Bresnahan (1989), that could be re-interpreted under the testable hypotheses emerging from his theoretical framework. Among other things, he shows that under demand uncertainty, price competition is expected to be less fierce when firms are risk-averse. Due to the existence of ties, the theoretical implications of our model contrast with those of Asplund's (2002) framework. Despite the fundamental differences between his framework and the model studied here, his arguments on the relevance of managers' risk attitudes in the strategies of

oligopolistic firms offer a strong point in favor of studying markets with non risk neutral firms.

Our experimental design and the analysis of the data obtained are aimed at testing the following hypotheses:

- H1.** Whether subjects choose to differentiate themselves more than minimally.
- H2.** Whether by actively choosing higher degrees of differentiation they maintain higher prices.
- H3.** Whether the prices attained are so high that uncovered market configurations are observed.

Whereas the first hypothesis has already been addressed by several authors mentioned above, the second and the third remain virtually unexplored.

Despite important differences between the spatial market implemented in our lab experiment and the Hotelling (1929) model, our results support mainly the principle of minimum product differentiation, compatible in our model with risk aversion, together with prices which lie below collusion and closer to (but above) the competitive level. These results are robust to the different experimental conditions that we implement.

The remaining part of the paper is organized as follows: Section 2 offers a detailed description of the theoretical framework and the experimental design, with a brief discussion of theoretical problems and behavioral considerations which should be taken into account in order to explain our subjects' behavior. In Section 3 the results are presented and discussed. Section 4 concludes. Details on the derivation of equilibrium prices and the instructions to the subjects are presented in the Appendix A.

## 2. Theoretical framework and experimental design

### 2.1. Basic model and parameters

We present first a location-then-price game corresponding to the baseline case, labeled as *Simulated Consumers Treatment* (SCT), in which we assume individual sellers, an odd number of locations and an automated probabilistic sharing rule in the case of ties. These baseline features are varied in order to implement three alternative treatments which will be described later in this subsection.

Let two firms, *A* and *B*, play a two-stage game. The goal of firm  $i \in \{A, B\}$  is to maximize the expected utility of its profits  $\Pi_i = P_i \cdot Q_i$  under the following CRRA function:

$$U(\Pi_i) = \Pi_i^r, \tag{1}$$

where  $r > 0$  is the risk parameter, with  $r = 1$  ( $r < 1$ ,  $r > 1$ ) corresponding to risk neutral (risk-averse, risk loving, respectively) behavior,  $P_i$  is the price and  $Q_i$  is the quantity demanded. Both the firms' costs are zero. In the first stage, firms simultaneously choose a location  $L_i \in \{1, 2, \dots, n\}$  among  $n$  equidistant points along a unit-length linear segment. In the second stage, after location choices are publicly announced, firms simultaneously choose their prices,  $P_i \in \{0, 1, 2, \dots, P^{max}\}$ . Given the assumptions stated below,  $P^{max} = 10$ . They sell their product to  $n$  consumers, each located on one of the equidistant points on the linear segment.

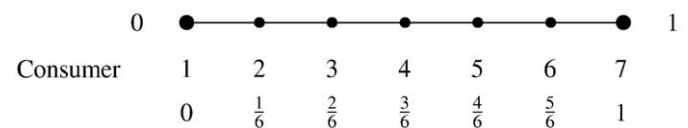


Fig. 1. Linear city with 7 locations.

<sup>4</sup> Since Downs' (1957) work, non-price competition by firms choosing locations on a closed linear segment along which a population of consumers (voters) are uniformly distributed, is often adopted by theoretical political scientists to model electoral competition between political parties. For a more detailed review of this literature, see Collins and Sherstyuk (2000).

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