
Classroom

EXPERNOMICS

Volume 11

<http://www.marietta.edu/~delemeeg/expernom.html>

2002

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We would like to thank Kristen Gaubatz for providing editorial assistance with this issue.

Classroom Expernomics Reader Shares Nobel Prize in Economic Sciences!!!!

The 2002 Nobel Prize in Economic Sciences was awarded to Vernon Smith of George Mason University and Daniel Kahneman of Princeton University. Professor Smith was awarded his share of the prize for “for having established laboratory experiments as a tool in empirical economic analysis, especially in the study of alternative market mechanisms.” Each one of us who utilizes “experimental” exercises in the classroom is deeply indebted to Vernon for his pioneering work in establishing experimental economics as a credible subfield of economics.

Vernon was a subscriber to this humble newsletter (in its former hardcopy form) at its inception, and was almost certainly the first to cite one of its articles in a “serious” journal when he cited Gillette and Del Mas (*Classroom Expernomics*, 1(2), 1992) in his 1994 JEP article, “Economics in the Laboratory.”

In 1990, Vernon (and I) attended a conference on experimental economics at the University of Pittsburgh. Since I was one of the (semi-)locals who had a car at the conference, I had the privilege of driving Vernon (and three others) to a dinner party one evening in my (*very* crowded) Toyota Tercel. I recall him being sandwiched between two other economists in the back seat for what must have been a very uncomfortable ride. (I only hope that he doesn't remember it as well as I do.)

- John Neral

Hotelling in the Classroom

Nicolas Eber*

Introduction

The theory of spatial (or horizontal) competition is recognized both by researchers and teachers as one of the most important parts of the modern theory of industrial organization (IO). All the advanced books on IO devote at least one section or chapter to models of spatial competition, especially to the seminal Hotelling (1929) model.¹ Applications of the Hotelling model are incredibly numerous since they include, for instance, firms' location choices, industrial geography, competition between television networks, and political competition. Thus, Hotelling's framework is actually widely used in modern economic theory.

Yet the treatment of this model in standard microeconomics textbooks is often poor since it usually reduces to the "ice-cream-vendor story", according to which two ice-cream vendors on a beach will finally cluster around the center due to the harsh competition in market shares. This story, which is a very loose (though usual) presentation of Hotelling's model, is an important but small part of the theory of spatial competition. For example, it is well known that the clustering strategy is indeed a reasonable theoretical solution only when one restricts the analysis to *nonprice* competition.

One (good) reason for this misrepresentation of the Hotelling model in standard textbooks is that most of the developments from the seminal paper are very technical, dealing especially with the problem of the existence of (pure strategy) Nash subgame-perfect equilibria for the sequential location-price game. A key result, proved by d'Aspremont, Gabszewicz and Thisse (1979), is that there is no price equilibrium around the center of Hotelling's linear town, precisely where the firms are supposed to strategically choose their locations; d'Aspremont et al. identify a mistake in Hotelling's reasoning so that the

minimum differentiation result he proposed is simply invalid. More precisely, Hotelling's clustering solution only applies in a nonprice competition context, i.e., when firms only compete in locations (but not in prices). Moreover, d'Aspremont et al. (1979) also show that we may (correctly) get an opposite result to the one proposed by Hotelling (i.e., maximum instead of minimum differentiation) with a very small change from the seminal model, namely switching from linear to quadratic transportation costs. Other developments of Hotelling's seminal treatment of spatial competition are interesting; they highlight, for example, the crucial impact of the geographical distribution of the customers or of the number of firms.

All these (somewhat technical) developments of the Hotelling model are very important to the understanding and the interpretation of spatial competition. They are, however, almost absent from standard microeconomics textbooks.

Here, as in many cases, experiments may help to address issues which may seem very technical and abstract using standard teaching methods. There are already several classroom experiments dealing with industrial organization theory and especially with oligopoly theory but, to the best of our knowledge, none specifically devoted to spatial competition.

The purpose of the very simple classroom experiment we develop in this paper is precisely to present to students the key facets of the Hotelling model in a very intuitive yet comprehensive way. An interesting point is that the experiment actually allows one to deal with a priori purely technical issues such as the non-existence problem identified by d'Aspremont et al. (1979). The purpose of the experiment is thus to capture the whole story of spatial competition, including the clustering tendency by firms, price-competition problems, the demand-proximity effect, regulation aspects, and the political competition interpretation of spatial models.

In this experiment, we simulate a Hotelling-type market with students geographically distributed in the classroom. Several rounds of the same experimental design are proposed, with

¹ E.g., Tirole (1988, section 7.1), Martin (2001, chapter 4) or Carlton and Perloff (2000, chapter 7).

or without price competition, with different geographical distributions of customers, with two or three “firms”, or with collusion between firms, etc. All these variations will allow us to introduce *progressively* the key facets of modern location theory, from the so-called “*Principle of Minimum Differentiation*,” based on Hotelling’s seminal paper, to the more recent developments.

The general experimental setup

There is some experimental economics literature on Hotelling’s model. Brown-Kruse, Cronshaw and Schenk (1993) conducted a series of Hotelling duopoly experiments (with only location competition between firms) and actually found a strong tendency for subjects to choose locations around the center. More recently, Collins and Sherstyuk (2000) used a very similar procedure to experimentally test Hotelling’s framework with three firms. In both papers, the experimental sessions were conducted on computer. In each period, the subjects were asked to choose their location from the set $\{0, 1, 2, \dots, 100\}$. As soon as all the participants had entered their locations, each subject’s computer screen showed the subject’s location choice, the locations of the competitors, the demand to each firm in the market and the profit. Of course, such a device is poorly suited to the classroom so we need to develop a specific experimental design.

The experiment requires preparation of the classroom, since it will work only in a specific configuration of it.

First, define the number of markets you will set up (generally one, except for large classes where two or more markets can be organized). Each market involves 11 groups of students where one group may be composed of one or several student(s) depending on the class size. Each group will be either *one* “firm” or *one* “customer”, independent of its size.² For example, for a class of 25 students, define one market of 11 groups, with 8 groups of two students and 3 groups of three students.³

² It means that groups can be of different size so as to involve all the students of the class.

³ For larger classes, it is possible to operate with

The market will be geographically represented by a row of nine desks numbered from 0 to 8.⁴ To each desk, we will assign one group. The group will sit behind its assigned desk. Thus, nine groups will be seated behind desks. Each group represents *one* consumer (regardless of the size of the group). The remaining two groups will be the “firms” and will have to choose a location on the “desk line”. Accordingly, the configuration of the classroom should be as indicated in Figure 1.

For the first round of the experiment, assign randomly a desk to each of nine groups and let the two remaining groups be the mobile “firms.” For the next rounds, define a simple rotation rule among groups so that it is not always the same groups which play the role of firms. For example, say that at each round, groups of consumers move *two* desks forward, the groups at desks 7 and 8 becoming the “firms” while the two groups which were a firm in the previous round become the consumers at desks 0 and 1. Since we will propose 7 rounds, this simple rotation rule guarantees that each group will act as a firm at least once.

Once groups are formed, define and announce to *all* groups the following rules of the game:

- Consumers want to buy 10 units of a fictitious good, irrespective of its price. However, they have to pay (except in Round 7) a transportation cost which depends on the distance to the seller. The distance unit is the number of desks which separates the customer from the firm (which will necessarily be located in front of one of the 9 desks). The transportation cost is linear in distance and the transportation rate is equal to 10 cents. Thus,

several markets. Anyway, notice that it is better to have groups of more than one student because it is always easier for students, especially in college or undergraduate classes, to act within a team rather than alone.

⁴ It is of course possible to choose another number of desks. I have a preference for 9 desks because it is a good size (neither too big nor too small) and it allows players to clearly identify the center and the quartile locations.

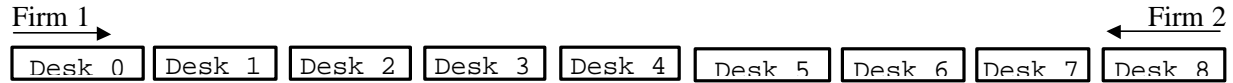


Figure 1. Configuration of the classroom.

for the consumer group located at desk 0, buying at an f.o.b. (free on board) price of \$1 from a firm located, for example, in front of desk 4, the good costs exactly $\$1 + \$0.1 \times 4 = \$1.4$. The consumer must choose the firm which offers the lowest “delivered price”, defined as the sum of the f.o.b. (or “mill”) price and the transportation cost. If the delivered prices offered by firms are equal, then consumers must choose the closest firm. If delivered prices are equal and if both firms are the same distance from a customer, then the customer purchases 5 units from each firm.

- Firms sell a homogenous good. Thus, the only (potential) differentiation between firms is horizontal/spatial and comes from different locations. Firms maximize their profits. To make computations simple, firms incur no costs so that a firm’s profit is simply the price multiplied by the demand, where the demand depends on the number of consumer groups which address the firm and on the number of units purchased by each group, either 10 (if the firm offers the lowest delivered price or, in cases where delivered prices offered by firms are equal, if the firm is closer to the consumer group), or 5 (if both firms offer the same delivered price and are located at equal distance from the consumer).
- In each round, firms will have to select a location on the “desk line”. More precisely, one firm will start from desk 0 and the other from desk 8 and they will then be allowed to move (if they want); they will walk along the “desk line” and stop in front of one of the nine desks.⁵ Changes of locations will be allowed within a period of 1 minute, for example. In

some rounds (Rounds 3 and 4), firms will also be asked to select prices.

- Once firms have selected their locations (and their prices, in Rounds 3 and 4), consumer groups choose one of the two firms and reveal their choice, by moving towards the firm they have chosen or, for the “indifferent” consumers who will buy 5 units from each firm, by staying at their desk.
- Then, for each firm, the demand and the profit (equal to the price multiplied by the demand) will be computed.

Each round will work according to this standard setup but will differ in some details as indicated below.

The different rounds

- **Rounds 1-2: Nonprice competition**

The f.o.b. price is *fixed* at \$1. Both firms choose a location on the “desk line”. Let one group start from desk 0 and the other from desk 8 and ask them to move (or not) as they want along the “desk line” to choose freely a location in front of one of the nine desks. Changes of locations are allowed within a period but in the limited time of one minute, for example. Once the time is over, locations are fixed and recorded for each firm and demand and profits are then computed.

These rounds should typically yield to locations at the center of the market, i.e. to both firms clustering in front of desk 4. Indeed, each “firm” tends to move toward the center and stop at desk 4. A question is whether the time period is long enough to allow a complete adjustment of locations. In some classes, one minute is clearly enough even in the first round of the experiment.⁶

⁵ Notice that for a good and quick course of operations, it is better to rule out intermediate locations, i.e. locations *between* desks.

⁶ Of course, the rapidity of the convergence to the

Round 2 is identical to Round 1, except that groups move according to the rotation rule defined above. Generally, locations at the center will be observed more rapidly than in Round 1. This second round is important especially when no clustering has been observed in Round 1.

Several comments are in order. First, it should be noted that the game considered in these two rounds is a nonprice competition game since (f.o.b.) prices are fixed. Hence, firms only compete in locations. It is well-known that such nonprice competition theoretically leads firms to cluster at the center of the market, as suggested by Hotelling (1929) under the concept of “minimum differentiation”. Thus, the results from Rounds 1 and 2 of the experiment generally replicate the theoretical solution.

Second, formal experiments on Hotelling’s model also imply locations at the center as predicted by theory: Brown-Kruse et al. (1993), who conducted a series of Hotelling duopoly experiments, actually find a strong tendency for subjects to locate at the center.

Third, these rounds of the experiment may be an excellent starting point of discussion about nonprice competition, especially with regard to competition in time slots among TV networks or, more traditionally, spatial political competition.

- ***Rounds 3-4: Location-price game***

Let the groups move according to the rotation rule defined above. Rounds 3-4 are identical to Rounds 1-2, except that firms now have two choice variables, namely locations (as before) and also f.o.b. prices. More precisely, one firm starts from desk 0 and the other from desk 8 and both then move (or not) as they want along the “desk line”. The new point is that, at each location, the firm

center locations probably depends on whether students are already familiar with the Hotelling model, especially with the “ice-cream-vendor story” presented in the standard textbooks.

must announce a f.o.b. price between \$0.20 and \$2.00 (with increments of 10 cents),⁷ for instance by writing the selected price on a slate or a sheet of paper. Changes of locations as well as prices are allowed within a period of one minute.

These rounds yield very different results across rounds and across classes. However, we never observed maximum differentiation (locations at the edges) and the most frequently, we get intermediate solutions, i.e. locations at desk 2 or 3, for one firm, and at desk 5 or 6, for the other firm. As for the price, its level is frequently at an intermediate level, around \$1. It is worth noting that sometimes locations at the center with a very small price may be observed. More generally, students appear not to be very confident in their strategies and the solution seems to be very “unstable”; small wonder then that the solution in Round 4 rarely replicates that of Round 3. Anyway, the outcome of this location-price game should be considered by the teacher as very uncertain, but this “uncertainty” is interesting in itself since it will be a stimulating discussion point as explained below.

There are (at least) two interesting points in these rounds. A first one is that “firms” will feel quite immediately the crucial trade-off in the location-price game between the interest to move toward the center in order to increase its market share, on the one hand, and, on the other hand, the interest to move away from the center in order to differentiate and, hence, to avoid a Bertrand price war which leads to minimum profits for both firms. Indeed, at the start of the rounds, firms may tend to opt for the highest f.o.b. price, namely \$2. As they move towards the center, they clearly tend to

⁷ It is important to restrict the set of price strategies available to firms in order to get quick and clear choices by students. Notice also that I impose a floor price (at 20 cents) so that the price cannot be zero and that non-differentiated firms have always interest to cut their price by 10 cents in order to increase their market share, according to the standard Bertrand price war.

decrease the price. Students rapidly understand that if both firms cluster at desk 4, they will not be differentiated any more and will thus be engaged in a standard price competition (à la Bertrand) with minimum profits for both firms. This is of course the basic trade-off in Hotelling's location-price game.

A second interesting point is the lack of confidence of students in their strategies and the fact that the solution appears very "unstable" to them (and very uncertain to the teacher/experimenter). This can be linked to the technical result in d'Aspremont et al. (1979) who precisely shows that price equilibria fail to exist in Hotelling's model for locations near the center.

- **Round 5: Geographical distribution of customers**

F.o.b. prices are again fixed at \$1. Round 5 is then similar to Rounds 1-2, except that 4 groups of "customers" are placed at desk 0, 4 groups at desk 8, and, in order to guarantee a symmetric distribution of customers along the "desk line", one group is left outside the market.

In this round, we generally observe a completely differentiated solution, with one firm at desk 0 and the other at desk 8.

The main interest of this round is to verify the crucial importance of the geographical distribution of the customers with the well-known demand-proximity effect, i.e. firms tend to locate where the demand is.

- **Round 6: Three firms**

Replace customer groups as in Rounds 1-4, i.e., one group at each desk. In the case where groups are formed by two or more students, divide one of the "firm" groups into two groups, so that there are now three "firm" groups. Then repeat with these groups the setup of Rounds 1-2, namely the location game with a fixed f.o.b. price equal to \$1. Notice that if two or three firms locate at the same position, the firms share equally the total

quantity demanded by all the customers that buy from the group of firms.

Generally, two main configurations may emerge. The first one consists in all firms clustering at the center (i.e. front of desk 4). Most frequently, however, we observe one firm at desk 2, one firm at desk 4 and one firm at desk 6.

Notice that in a series of experiments on the (nonprice competition) Hotelling model with three firms, Collins and Sherstyuk (2000) find that subjects do not cluster at the very center and choose, most frequently, to locate in the central quartiles of the market.

This round allows us to discuss two theoretical results linked to the inclusion of a third firm in Hotelling's framework (in the nonprice competition context).⁸ The first result is that there is no pure-strategy location equilibrium for simultaneous location choices by firms. The second is that if one considers *sequential* (instead of simultaneous) entry in the market by the three firms, then an equilibrium does exist, with the first and second firms located at $\frac{1}{4}$ and $\frac{3}{4}$ and the third firm between them (Prescott and Visscher (1977)).

- **Round 7: Socially optimal locations**

Each "consumer" group is located at one desk, the f.o.b. price is fixed at \$1, and there are again *two* "firms". Require that firms now have to deliver the product to the customer's door, i.e., incur the transportation cost. Then ask the two "firm" groups to collude and choose their locations in a *cooperative* way.

Generally, students understand that locations have to be chosen in order to minimize total transportation costs in the market and, hence, that optimal locations are the quartiles, namely desks 2 and 6.

⁸ Notice that Hotelling (1929) himself falsely conjectured that the tendency to cluster near the center of the market would persist in the case of more than two competing firms.

The purpose of this round is to present the socially optimal locations in the Hotelling framework. This can be a good starting point for discussing regulation in this framework. Another interesting possibility is to discuss concepts of product delivery and, hence, of spatial price discrimination in the Hotelling framework. This can be a good starting point for explaining why spatial price discrimination strengthens the competition between firms in Hotelling's framework, leading to lower profits for firms and to socially optimal locations, i.e. locations at the quartiles, as formally proved by Lederer and Hurter (1986).⁹

Conclusion

Finally, our very simple experimental setup allows us to realize and/or illustrate a complete course on spatial competition since the key facets of the theory are made apparent in (at least) one of the several rounds of our experiment. Moreover, the experiment offers interesting starting points for discussions about, for example, nonprice competition or spatial price discrimination. I think this is an efficient way to substantially improve the standard presentation of spatial competition theory and to make clearer the Hotelling model.

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⁹ In this respect, the use of Hoover's (1948, p. 57) metaphor is meaningful: "The difference between market competition under f.o.b. pricing (with strictly delineated market areas) and under discriminatory delivered pricing is something like the difference between trench warfare and guerrilla warfare. In the former case all the fighting takes place along a definite battle line; in the second case the opposing forces are intermingled over a broad area."