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Buyer–seller interaction in experimental spatial markets

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Abstract

We report results from experimental spatial markets with endogenous buyer location on a discrete version of Hotelling's linear city. Buyer locations favor more often the hypothesis of transportation cost minimization than that of strategic location aimed at increasing price competition between sellers. However, the latter of the two hypotheses receives systematic support too. Differentiation by seller-subjects is substantially less than the theory would predict for the specific framework used. Our results suggest that location strategies adopted by subjects can be seen as a rational process favoring conservative product design and spatial agglomeration of economic activities.

JEL classification: C91; L10
Keywords: Experimental spatial markets; Transportation costs; Intermediate good markets; Agglomeration; Two-vendor policy

1. Introduction

It is a well known fact that strategies adopted by oligopolists may lead to competition in product characteristics and prices.[1] Contrary to sellers, buyers are often assumed to maximize their utility by simply deciding on whether to buy or not and on which firm to be supplied by, taking the features of the products, the market structure and the corresponding equilibrium prices as given.

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[1] Important contributions on product diversity include Dixit and Stiglitz (1977); Salop (1979); Ethier (1982); Helpman and Krugman (1985); Deneckere and Rothschild (1992).

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There are numerous examples of strategies adopted by powerful buyers aimed at mitigating their suppliers' market power. Such strategies go far beyond the choice of a supplier and may include repeated and large-scale purchases, long run contracts and other binding agreements, or, even, strategies affecting the structure of the upstream market. This is often the case in intermediate good markets where buyers are large, and therefore, strategic enough to account for the effects of their (present) actions on the (future) market outcome.[2] An example of this are *Two-Vendors Policies*, adopted by large-scale Japanese manufacturers aiming at establishing long-term relations with two suppliers, in order to avoid giving too much power to one of them alone. Such strategies can be partly interpreted as precommitments by strategic buyers who would be willing to incur higher transaction costs (due to the existence of multiple suppliers) in order to maintain two active competitors in the upstream market.[3] In this way, buyers can affect both the market structure and the resulting equilibrium.[4]

A common feature in these examples of strategic precommitments by buyers is that they may imply higher transaction costs than exclusive buyer–seller relations would, whereas their expected benefits emerge from the resulting mitigation of sellers' monopolistic power by intensifying competition among them. It is important to bear in mind that, although formal economic models usually treat price competition as a short run element of market functioning, in many real world markets, prices may be fixed while other short run variables may be used by firms to extract consumer surplus (attention to the client, post-sales services, punctuality, etc.). Therefore, our analysis is applicable to a generic situation in which both, buyers and sellers, are strategic enough to anticipate short run market equilibrium with their decisions concerning their strategies in the medium and the long run. Following this reasoning we propose a framework in which both, buyers and sellers can undertake strategic decisions in the context of a (potentially) differentiated market.

The existing literature on product differentiation is based on two paradigms: the representative consumer framework and the address model of product differentiation. With the exception of very few articles in which consumers are assumed to play an active role in the marketplace, both strands consider consumers who are passive and impersonal receivers of price and quality signals deciding whether to buy or not and, in case they buy, the firm to be supplied by. Exceptionally, Dudey (1990, 1993) considers the formation of markets in which firms cluster in order to attract consumers whose menu of strategic variables includes visiting one of the markets formed in order

[2] In Snyder (1996, 1998); Boal and Ransom (1997) we find theoretical explanations of why downstream firms may have power in input markets. Early empirical research on this issue is reported in Brooks (1973); Lustgarten (1975); McGuckin and Chen (1976); Clevenger and Campbell (1977). A different but conceptually related argument by Stole and Zwiebel (1996) refers to the strategic choice of organizational design.

[3] Even smaller and less powerful consumers can be strategic enough to commit themselves to signals and actions, which will make the resulting market conditions more favorable to them. For example, airplane passengers may be willing to pay a higher price for a ticket, which gives them the flexibility of changing to another flight in case the one initially booked is cancelled.

[4] See, for example, Farrell and Gallini (1988).

to look for the best market conditions. Although in Dudey's analysis transportation costs are negligible, his framework has some common features with the framework used in our experiments. In a setting which has a purely geographical interpretation, Fujita and Thisse (1986) allow for a consumer location stage which follows the firm location stage and precedes the price competition one, in the standard address model of product differentiation. However, in that paper, individual consumers are not strategic enough (because they are treated as zero mass particles of a continuous consumer distribution function) to account for their locations' effects on the resulting market equilibrium.

García-Gallego et al. (1995) study the location of a number of discrete, strategic consumers on Hotelling's line as a non-cooperative one-shot game. Consumers, in general, agglomerate in the middle between the two firms although this situation implies higher transportation costs. This result is determined by the interaction of two factors: minimization of transportation costs and the *intensity-of-competition* effect of consumer agglomeration.

Using the same game structure as Fujita and Thisse, García-Gallego et al. (2001), consider individual buyers choosing a technological profile from a closed linear space. Sellers offer them a potentially differentiated input, which is also represented on the aforementioned version of the Hotelling line. In the pricing stage, sellers compete setting discriminatory prices. Results range from minimum to sufficient differentiation with one or two local monopolies formed on seller locations. However, for intermediate degrees of differentiation, buyers' locations are such that non-minimal (including maximal) transportation costs are incurred in order for competition between sellers to be kept as fierce as possible.

Experimental work on endogenous[5] product differentiation[6] has focused on firm location, keeping prices[7] and consumer locations fixed. A previous work by Barreda et al. (2000) studies an experimental spatial market were consumers' locations are fixed[8] and the demand side (which is not strategic) is simulated by the computer. In the experiments whose results are reported here, we modify the framework in García-Gallego et al. (2001) to account for several phenomena which correspond, in a generic way, to some stylized facts from real world markets with individual, thus potentially strategic, consumers. First, endogenous prices (like buyer and seller locations) are taken from a discrete space. Second, location decisions are assumed to be more rigid than pricing and purchasing decisions. Third, the static framework is repeated over a finite number of sub-periods in which the *price-then-purchase* subgame is repeated holding locations fixed. At the end of each sub-period, sellers and buyers have the possibility of relocating along the line for a new sub-period over which pricing and purchasing

[5] García-Gallego (1998); García-Gallego and Georgantzís (2001) study the effect of exogenous product differentiation on the behavior of subjects in experimental oligopolies with single-product and multiproduct firms.

[6] There is a relatively recent and short list of papers on this issue: Brown-Kruse et al. (1993); Brown-Kruse and Schenk (2000); Collins and Sherstyuk (2000); Huck et al. (2002).

[7] With the exception of Barreda et al. (2000), where prices are endogenous.

[8] Contrary to our paper, in this work consumers are uniformly distributed with unitary density along the line.

decisions will be made. The effect of the length of sub-periods is studied by comparing results obtained from two treatments in which five- and two-period subgames are introduced. Our results indicate that rigidity (longer sub-periods in which locations have to be kept fixed) is associated with lower degrees of product differentiation. This finding may be related to the fact that differentiation in this set up is a risky option. That is, a seller's location at a sufficient distance from its rival (which is the clear cut prediction of the static framework under risk neutrality) entails the risk of not attracting sufficient (or even *any*) consumers in the consumer location stage. In that case, a seller would *monopolize* a small (or an empty) market. Furthermore, a constant (across treatments) percentage of consumers seem to incur positive transportation costs in order to mitigate seller power. Less systematic evidence indicates that some patterns of buyer strategies include intertemporal punishment of sellers by buyers who have been exploited by local monopolists in the past. Another interesting finding is that buyer loyalty is inversely correlated with price levels.

The remaining part of the paper is organized as follows. In Section 2, we present the framework. In Section 3, we describe the experimental design. In Section 4, the results are discussed. Section 5 concludes.

2. Framework

Consider the following differentiated input market. Two sellers, A and B, and n buyers play a four-stage game. In the first stage, each seller $i \in \{A, B\}$ chooses an input specification (location) $l_i \in \{1, 2, \ldots, L\}$, which corresponds to L available technologies represented as equidistantly distributed points on a segment $[1, L]$. All technologies are ex ante (before buyers have made any decision) equally efficient in producing each downstream firm's final good. A simple production function is assumed to exist according to which each buyer's total output in the final market requires one indivisible unit of the input. In the second stage, each buyer $j \in \{1, 2, \ldots, n\}$ chooses a technological profile (location) $l_j \in \{1, 2, \ldots, L\}$ from the available alternatives represented by the same L points on the segment. These two decisions determine $x_{ij} = |l_i - l_j|$, which is the degree of incompatibility between each buyer's ideal input specification (technological profile) and that of the inputs actually offered by the two sellers. An alternative and probably simpler interpretation of the framework corresponds to the choice of *address* by sellers and buyers from a discrete set of locations on a linear city. It is straightforward that the disutility associated with the distance between a buyer's and a seller's addresses would, then, correspond to *transportation costs*. In the third stage, sellers set input prices p_i, which are net of a constant average cost which, for simplicity, is assumed to be zero. Finally, in the fourth stage, each buyer j purchases a maximum of one unit of input from seller i, yielding a profit:

$$\Pi_j = \max\{R - p_i - x_{ij}, 0\} \tag{1}$$

where R is the exogenously given reservation price, which corresponds to the total (maximum) revenue earned by buyers in the downstream market from employing a unit of the (potentially) differentiated input.[9] All decisions made in the same stage are simultaneous.

Given the number $q_i \in \{0, 1, \ldots, n\}$ of buyers who have decided to purchase the input at seller i, supplier i earns:

$$\Pi_i = p_i \cdot q_i \tag{2}$$

It is straightforward[10] that, if the segment is long enough (or unit transportation costs sufficiently low), perfect equilibrium involves sufficient differentiation between sellers. Then, "middle" (between seller) locations become unprofitable for the buyer and two local monopolies are formed by buyers locating near (or on) seller locations. If the segment is not long enough for such an outcome to emerge (or sellers cannot predict the benefits of differentiation), strategic buyers will locate in the middle between sellers in order to induce maximal upstream competition (whose benefits to the buyers always offset non-minimal transportation costs). As far as prices are concerned, the first type of equilibrium in the buyer–seller location subgame (labeled as "local monopolies") yields monopoly pricing by the sellers, while the second type ("strategic buyer location") yields competitive pricing of the input.

3. Experimental design

Our experimental design aims at testing the aforementioned theoretical predictions. The parameter values used ($R=10$ and $L=21$) are chosen so that the perfect equilibrium prediction involves sellers locating sufficiently apart from each other (at a distance weakly exceeding 10).[11] In that case, two local monopolies are expected to be formed by buyers locating close to each one of them. More precisely, García-Gallego et al. (2001) show that some assumptions on weak social rationality according to which consumers, ceteris paribus, weakly prefer low transportation cost configurations, guarantee full agglomeration *on* seller locations. Of course, this result requires risk-neutral sellers who correctly anticipate that their equilibrium location at a sufficient distance from each other, will attract *half* the consumer population. Our choice of an odd number $n=7$ of consumers makes this prediction impossible to fulfill in one period, although long run (repeated) behavior should make the deviation between ex ante and ex post behavior negligible from a risk-neutral player's point of view. An example of how this kind of set up leads to mixed strategy equilibrium is in Barreda et al. (2000).

Learning and adaptation to equilibrium strategies are obviously important factors to take into account in the experimental implementation of the theoretical framework. In

[9] In a more general theoretical analysis, García-Gallego et al. (2001) consider different scenarios concerning the size of R, which may depend on the size of the downstream market and the degree of downstream competition among retailers.

[10] A formal proof is provided in García-Gallego et al. (2001).

[11] Thus, Hotelling's (1929) non-existence problem (see d'Aspremont et al., 1979) is avoided by construction.

order to study interaction between sellers and buyers both in the short and in the long run, the basic structure described above is repeated over 25 periods according to two different time patterns labeled as treatment 1 and 2. A total of 10 sessions per treatment were run. In treatment 1, seller and buyer locations are kept constant for five periods in which the price setting and the purchase decision stages are repeated only. In treatment 2, the location decisions are kept constant over two repetitions of the *price-then-purchase* subgame. The only link between successive periods is experience gained by subjects from past actions and knowledge acquired concerning the strategies adopted by other players. In (non-behavioral) game-theoretic terms, repeating the basic structure over a finite number of periods does not change the theoretical prediction of sufficient differentiation by sellers. However, lower prices could result from the effort by sellers of gaining a reputation for being a *cheap seller* in order to attract more buyers at a given local monopoly. Also, other behavioral issues (learning strategies, risk attitudes, etc.) are implicitly introduced which should be responsible for any systematic deviations between observed behavior and the theoretical predictions.

Together with the role of strategy discreteness and reputation, our experimental design is aimed at capturing the fact that, when product re-design is rigid (treatment 1), seller location involves a higher risk[12] of not attracting sufficiently many consumers on a monopolized location. Therefore, differentiation should be easier to obtain when design decisions are more frequent (treatment 2) and thus, choosing a location strategy, which fails to attract the buyer, is less costly to the seller. Another way to put this is by considering the increase in the frequency with which locations can be changed as an increase in the horizon of the location game. In contrast with a set up with more rigid product design, a subject faced with the possibility of more frequent changes in the design assigns a lower value to the losses (gains) emerging from locating on the *wrong* (*right*) point on the segment. At the same time, price strategies are played over a shorter sub-period during which locations are kept constant. This reminds us of real world industries in which product design changes so rapidly, that firms have little, if any, time to *learn* the equilibrium price.[13] Any difference across treatments will shed light on the controversial issue of the effects of frequent product design changes on market efficiency and consumer welfare.[14]

Subjects were volunteers recruited among second and third year students in Business Administration at the Jaume I University in Castellón (Spain). Each subject participated in only *one* of the sessions run. Their training at the moment of recruitment guaranteed some knowledge of Microeconomics and successful completion of at least one of the optional courses on Industrial Economics or the Economics of Technical Change, all including a thorough revision of Hotelling's (1929) model of

[12] Because it will take five periods for the seller and the buyers to modify an ex post unprofitable location.

[13] Anecdotic evidence from the toy industry in Alicante (Spain) refers to cases of toys which, although very successfully evaluated by children, failed to sell because of a wrong price due to limited time available for any price experimentation.

[14] Using a very different approach, Chang (1991, 1992); Häckner (1995, 1996); Ross (1992) have associated flexibility in product design (inversely associated with the cost of product re-design) with the ability of sustaining collusion among oligopolists. A general result is that costly re-design facilitates collusion.

product differentiation. Subjects were paid in cash (Spanish Pesetas) immediately after each session (and informed that this would be so before participating) according to their performance in the experiment.[15] Average earnings were approximately 12 Euros (2000 Pesetas). At the beginning of each session subjects were randomly assigned to the role of seller or buyer and no communication among them was allowed. Instructions for each role were provided as well as any necessary clarification concerning the information available to them. Real monetary rewards were obtained applying a 5/1 (real/experimental currency units) exchange rate for sellers and a 10/1 exchange rate for buyers.[16] In each stage, decisions were made simultaneously by all subjects involved in the corresponding decision. After each round, individual decisions became public information and so were individual results following each purchasing decision stage.[17] Data on the behavior of 40 seller-subjects (20 for each treatment) and 140 buyer-subjects (70 for each treatment) were collected.

4. Data analysis and results

In this section, we discuss the experimental results in a way, which enables us to test the theoretical hypotheses and address some additional questions, which can be raised in this framework.

In the first place, our discussion will address four main hypotheses whose order follows the solution of the game by backward induction.

H1(a). Each buyer purchases the good from the seller whose price plus transportation cost at the buyer's location is the lowest.

Looking at purchasing behavior, we can see that buyers (with the exception of a constant across treatments percentage of 1.8%) have behaved in a rational way. That is, they have purchased the product, which has maximized their period earnings.

H1(b). If the generalized prices of two sellers at a buyer location are equal, the buyer randomizes between sellers.

In a framework like ours, with atom (rather than zero mass) buyers, ties are important and so is the method of resolving them. An obvious candidate (at least in theoretical analysis) is the hypothesis that buyers randomize between two economically identical options. In theoretical and experimental literature, alternative hypotheses based on social efficiency[18] or justice[19] have often been proposed.

[15] An alternative payment method was also used and the results were compared to those obtained under the standard payment method described above. Subjects paid according to this alternative method, received an increase in their classroom grades. Comparison of the results obtained under the two payment methods confirms that no significant difference exists with respect to any of the decisions made by the subjects.

[16] This tends to equalize buyer-subjects' individual expected rewards to those of sellers.

[17] Information on other players' performance is often used in experiments as a learning-facilitating device. In any case, our objective was to endow our setting with more realism, given that, in real world markets with small numbers of participants, information on other players' performance and strategies tends to be perfect.

[18] See, among numerous other models, Thisse and Vives (1988) or García-Gallego et al. (2001).

[19] There is a vast literature on inequity aversion in experimental subjects' behavior.

Table 1
Results of the linear regression of prices (p_i) over the level of product differentiation (D), (t-test values within parenthesis)

	Constant	D	R^2
Treatment 1: p_i	2.507 (19.803)	0.317 (7.447)	0.100
Treatment 2: p_i	2.247 (12.355)	0.555 (14.883)	0.306

In 27.4% (18.8% in treatment 2) of the cases in which buyers have had a choice,[20] they were indifferent between buying from one seller and buying from the other. In those cases, social efficiency through transportation cost minimization (buying from the seller which is closer to the buyer location) was sought in 22.6% (26.8%) of the decision periods involved. Price minimization (patronizing the *fairer* seller) could explain a 17% (26.8%) of the decisions, while lower prices in the past charged by the seller would explain a 13.1% (4.3%) of the corresponding choices. The remaining 47.3% (42.1%) would be left unexplained by any of the alternative factors, which can be interpreted as clear evidence in favor of the most commonly used probabilistic sharing rule implied by H1(b).

H2. Higher seller differentiation yields higher prices.

A Spearman test confirms a positive correlation between the level of seller differentiation and prices.[21] This finding confirms a standard result in the literature on product differentiation as a means of relaxing price competition.[22]

An alternative way of presenting this finding is by looking at the significance of the linear relationship between prices and product differentiation displayed in Table 1.

H3. Buyers locate either on seller locations or in the middle, between them.

In order to test this hypothesis, we define the Strategic Location Index, $\mathrm{SL}_j = \frac{v x_{cj}}{x_m} \in [0, 1]$, where $x_{cj} = \min\{x_{Aj}, x_{Bj}\}$. The denominator x_m is the (*minimum*) transportation cost implied by the buyer's decision to strategically locate in the middle (or, in case of an *odd* distance between sellers, on the location *closest* to the middle) between sellers. This definition is based on the fact that a population of strategic buyers accounts for the result in García-Gallego et al. (2001) concerning the benefits of locating on the competition intensifying location, whereas non-strategic buyers pay zero transportation costs by locating exactly *on* seller locations. Of course, the term *strategic* is just a label, given that an individually (selfishly) strategic buyer could free ride on collectively strategic buyers' location between sellers and benefit from transportation cost-minimizing choices. At the same time, if this individualistic behavior were adopted by all buyers, the resulting market equilibrium would be of the worst (local monopolies) type for consumers.

In Figs. 1 and 2 we depict the distribution of individual SL's and the corresponding absolute transportation costs (x_{cj}) associated with each one of them. On aggregate, subjects

[20] We should have in mind that, in some cases, prices were too high and buyers were located too far from sellers to have access to any of the products or were restricted (for the same reasons) to buy from one specific sellers.

[21] The Spearman correlation coefficients are 0.359 and 0.563 for treatment 1 and 2, respectively.

[22] See Shaked and Sutton (1982).

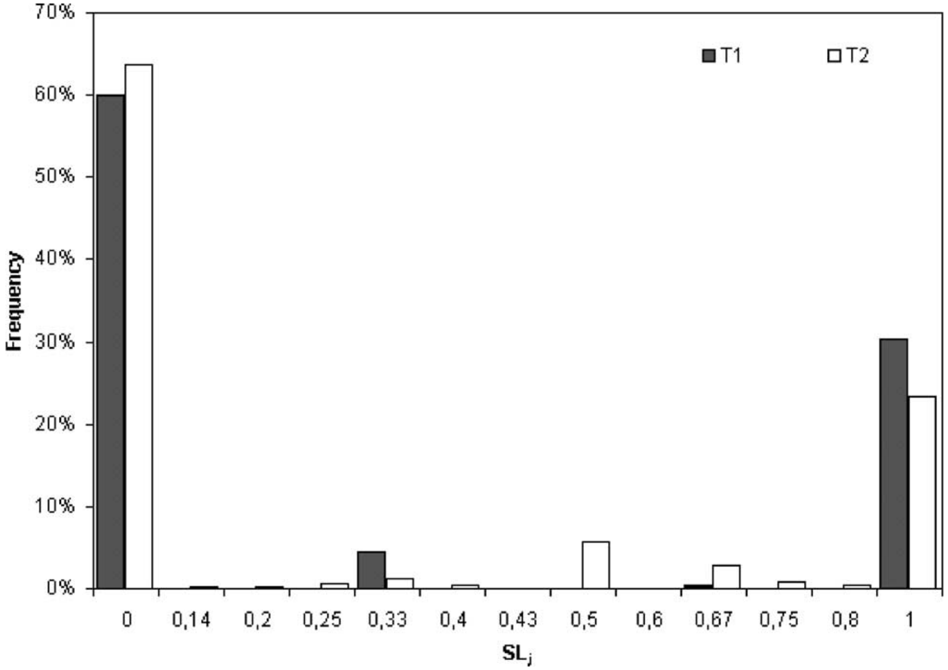

Fig. 1. Distribution of SL.

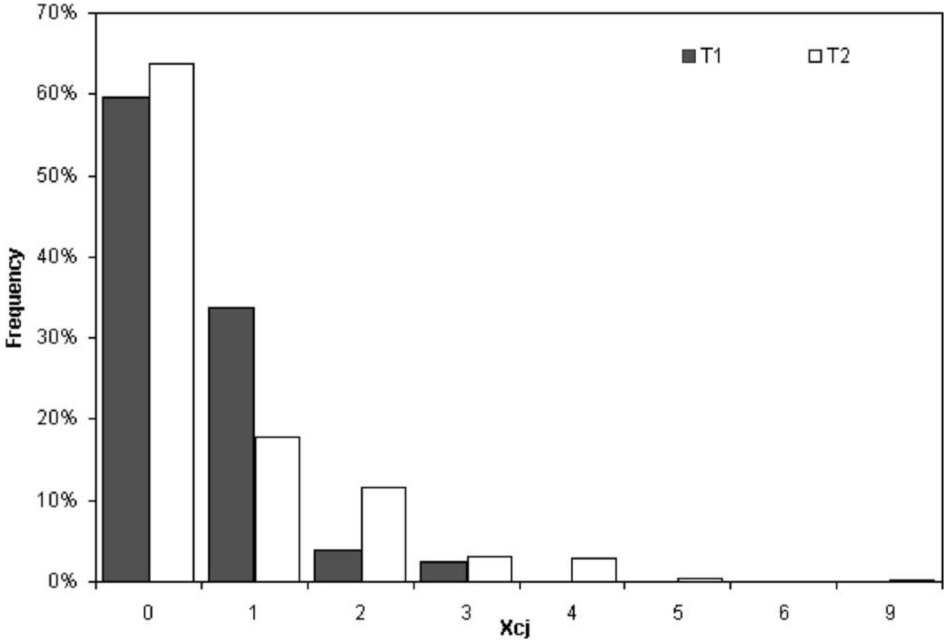

Fig. 2. Distribution of x_{cj}.

Table 2
Summary statistics (location data are grouped by pairs of points which lie at equal distances from the center)

	Treatment 1				Treatment 2			
	Mean	S.D.	Maximum	Minimum	Mean	S.D.	Maximum	Minimum
l_i	9.53	1.59	11	4	7.05	3.10	11	1
D	2.10	2.10	10	0	5.50	4	18	0
l_j	9.61	1.45	11	3	7.10	2.98	11	1
SL_j	0.33	0.13	1	0	0.31	0.22	1	0
p_i	3.20	2.10	9	1	4.40	2.90	10	1
x_{ij}	0.57	1	7	0	0.81	1.32	10	0
Π_i	270.78	160.85	588	89	367.17	139.36	601	178
Π_j	158.91	44.06	212	51	125.16	35.21	198	55

are distributed in a way, which clearly indicates their aversion towards paying high transportation costs. However, the distribution of SL indicates that our buyer data can be very successfully organized under the two predictions in H3: *transportation-cost minimization* and *strategic location*. The former corresponds to approximately 2/3 of location strategies by buyer-subjects (60.1% in treatment 1 and 63.7% in treatment 2), whereas the latter represents less than 1/3 of them (30.3% in treatment 1 and 23.5% in treatment 2). Each type of behavior corresponds to a peak of a bi-modal distribution of SL, each one on an extreme (0 and 1) of the interval over, which the index is, defined (see Fig. 1).

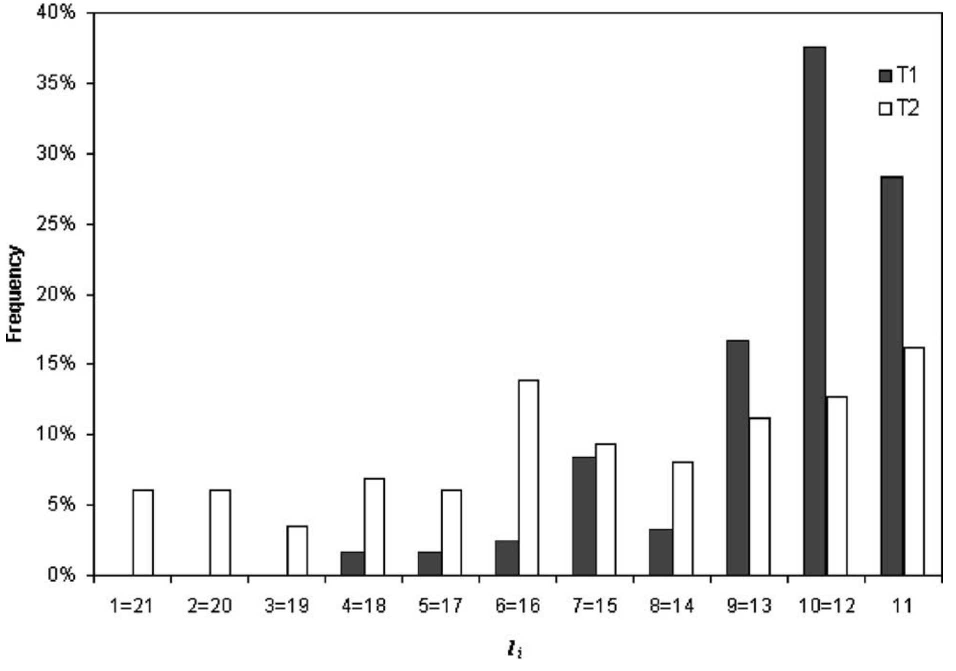

Fig. 3. Distribution of sellers' locations (l_i).

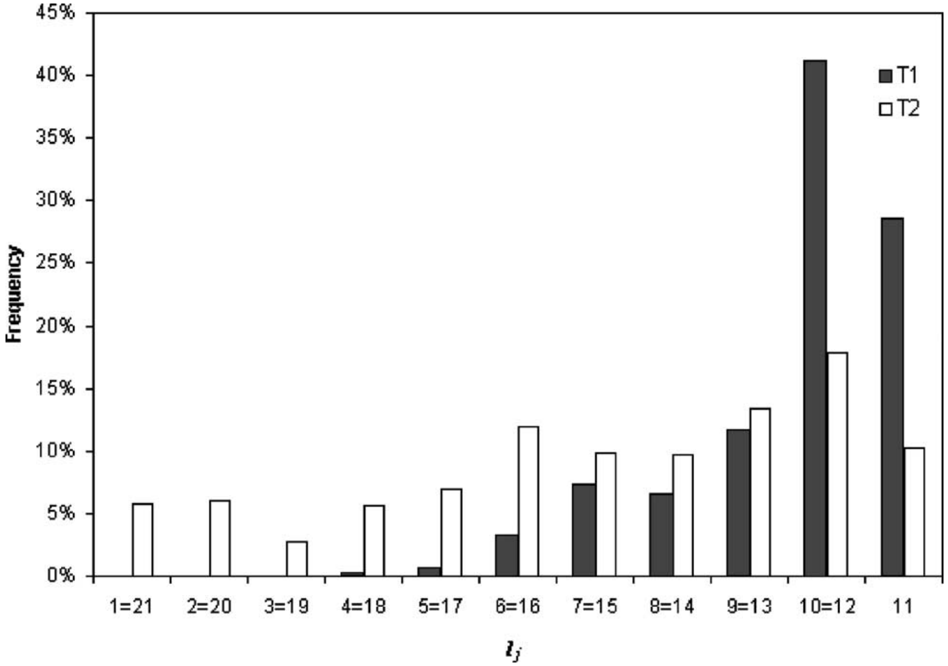

Fig. 4. Distribution of buyers' locations (l_j).

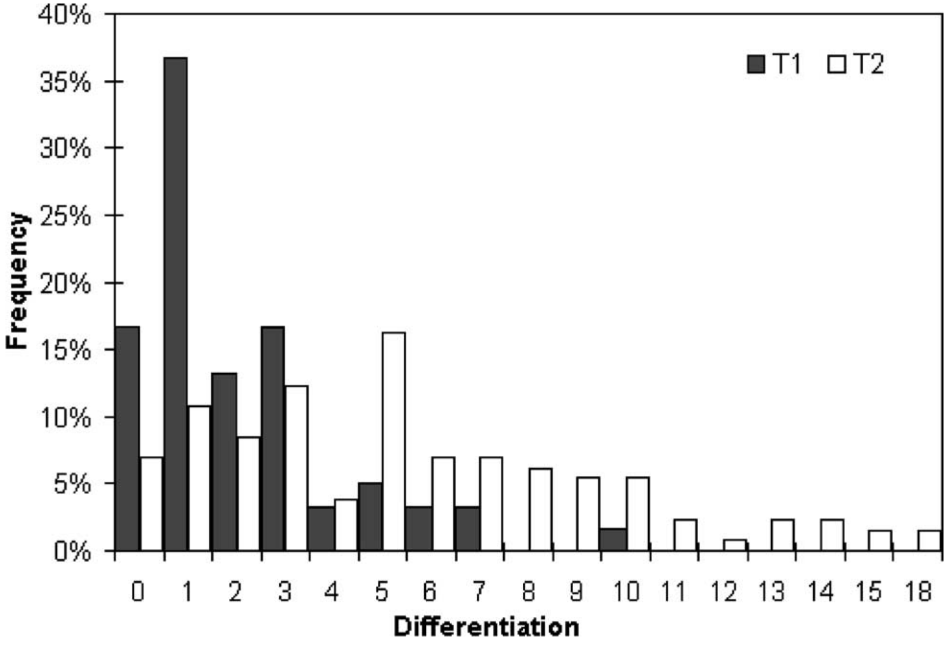

Fig. 5. Distribution of differentiation levels (D).

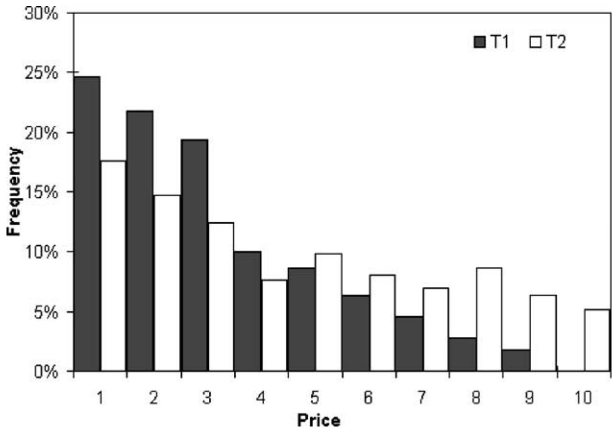

Fig. 6. Distribution of prices (p_i).

H4. Sellers locate at a sufficiently long distance from each other, keeping their potential market areas separate, so that strategic buyer locations become non-feasible.

Scarce evidence favoring this hypothesis was obtained. In fact, seller locations are such that in a vast majority of the cases (98% in treatment 1 and 92.8% in treatment 2), the potential market areas of the two sellers overlap. The failure of establishing local monopolies is confirmed even *after* buyer locations are announced and in cases where the choice of sufficiently high prices by sellers could have created de facto monopolies (each buyer can only buy from one of the two sellers). This was achieved by sellers in only 2% of the cases in treatment 1 and 30.4% in treatment 2. In fact, in almost all cases, buyers have been able to purchase the good, except for one buyer in treatment 1 (periods 1 and 2) and 4.4% of decision periods in treatment 2.

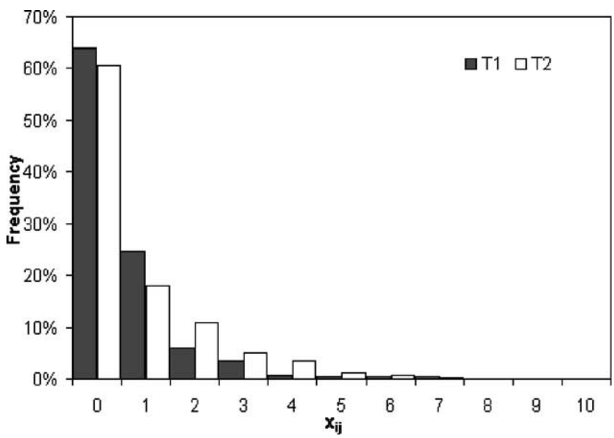

Fig. 7. Distribution of transportation costs (x_{ij}).

Table 3
Total transportation costs, seller profits and social welfare

	Treatment 1	Treatment 2
Σx_{ij}	995	1413
$\Sigma \Pi_j$	13,360	8761
$\Sigma \Pi_i$	3827	7238
Social welfare	17,187	15,999

Apart from these hypotheses which are directly derived from the theoretical framework, our experimental design is appropriate for addressing four additional questions.

Q1. How does flexibility of product re-design affect observed behavior?

Flexibility of product re-design is a central feature of our experiment, which is not addressed in the theoretical model. As we will see in the following lines, flexibility in product design affects several aspects of the observed behavior. Descriptive statistics are provided in Table 2.

First of all, it is worth observing that, in treatment 1, sellers and buyers locate closer to the center of the line ($L=11$) as compared to the locations obtained in treatment 2 (Figs. 3 and 4). In fact, a Kolmogorov–Smirnov test confirms the significance of distributional differences across treatments for both buyer (K–S: $z=5.104$) and seller (K–S: $z=2.370$) locations. However, on aggregate, buyer-subjects have exhibited similar behavior across treatments with respect to their SL's (as formally confirmed by a Mann–Whitney test with $z=0.327$). Therefore, differences in buyer locations are motivated by differences in seller locations and not by the degree to which buyers have adopted strategic locations in the two treatments.

The most important difference across treatments concerns seller differentiation (D) and prices (p_i), presented, respectively, in Figs. 5 and 6. Treatment 2 produces higher product differentiation and, hence, higher prices (MW, $z=-3.327$ and -2.646, for product differentiation and prices, respectively). Therefore, the possibility of more frequent location changes offers sellers a setup in which they tend to differentiate significantly more and set significantly higher prices. Also, the adoption of higher degrees of product differentiation by seller-subjects in treatment 2 is largely responsible for two more results concerning market efficiency and profits. First, the average transportation cost paid by individual buyers in each period (see Fig. 7) is significantly lower in treatment 1 than in treatment 2 (MW, $z=-4.066$). Second, average seller profits are higher and buyer surplus is lower in treatment 2 than in treatment 1 (MW, $z=-2.877$ and -2.876, respectively). These two results can also be obtained comparing total transportation costs and subjects' earnings across treatments (see Table 3). However, total social welfare in treatment 1 is significantly higher than in treatment 2 (MW, $z=-2.877$). Given that SL are similar across treatments,

Table 4
Z-values corresponding to a Mann–Whitney test comparing price differences across treatments, for a given level of differentiation between suppliers

D	0	1	2	3	4	5	6	7	10
Z-value	**−3.26**	**−3.29**	**−4.43**	−0.84	0.20	−1.28	−1.21	**−4.38**	0.33

Entries in bold characters indicate statistical significance.

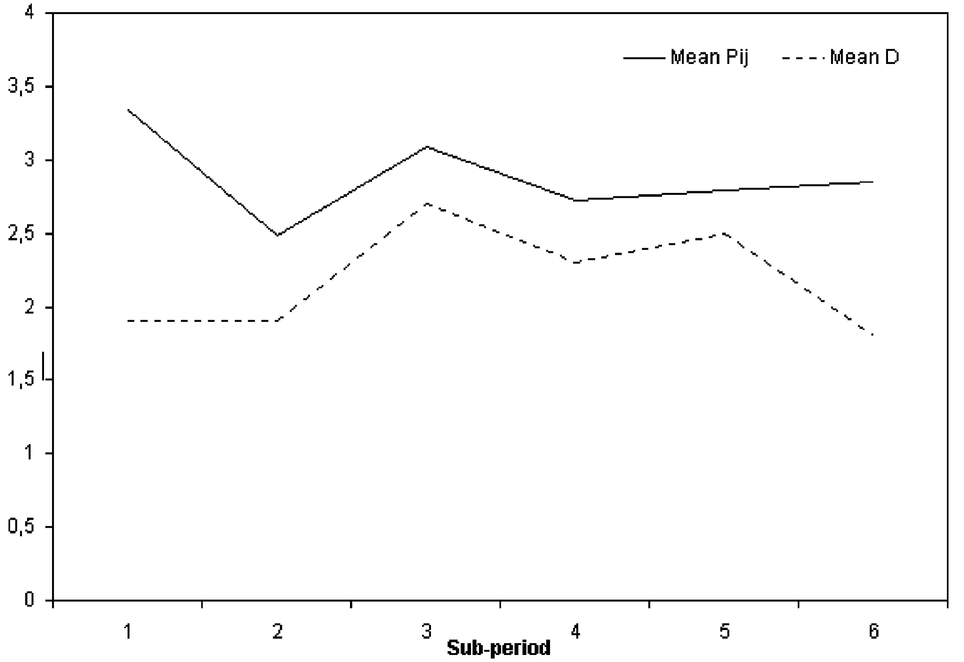

Fig. 8. Evolution of average price levels and differentiation over time (treatment 1).

this result indicates that, smaller degrees of differentiation in treatment 1 have caused lower dispersion of buyers in the area of seller locations, leading to lower transportation costs and, thus, higher levels of social welfare. Therefore, a clear cut result is obtained concerning the incompatibility between private and social desirability of policies and strategies favoring flexibility (understood as the ability of frequent changes) in product re-design.

In Table 4, prices collected from the two treatments are compared, holding product differentiation between sellers constant. Significant differences are obtained for low levels of product differentiation (0, 1, 2), and for seller locations differing by 7. In these cases, for a given degree of differentiation, prices obtained in treatment 2 are significantly higher than prices in treatment 1.

It is not easy to explain this phenomenon, unless we refer to a similar finding in the experiments by Barreda et al. (2000), according to which, prices tend to decline over each sub-period during which locations are kept fixed.[23] In the experiments reported here, this declining trend of prices does not vary across treatments. Therefore, price differences across treatments can be partly explained by the fact that the declining trend in treatment 1 lasts longer than it does in treatment 2.[24]

[23] In that paper, the result was confirmed by the estimates of a simple econometric model, showing that this phenomenon is more intense in the presence of low degrees of product differentiation.

[24] This should not be taken to contradict or substitute the explanation of lower prices for lower differentiation reported on H3, whose testing is based on data obtained within each treatment (with the same length of sub-periods during which locations are kept fixed).

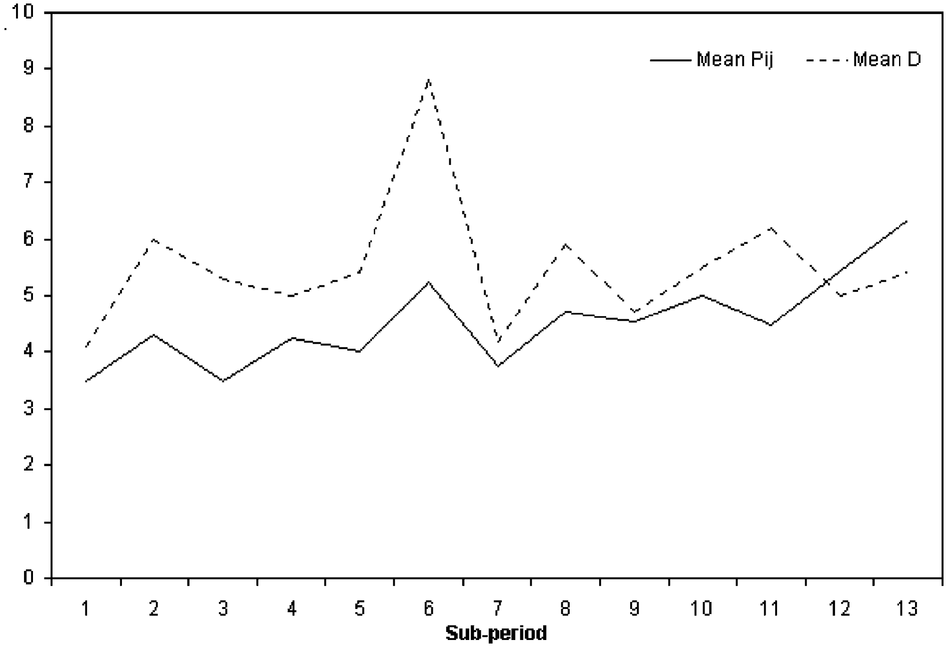

Fig. 9. Evolution of average price levels and differentiation over time (treatment 2).

Q2. Does buyer behavior follow any other pattern than single period utility maximization?

An interesting feature of buyer behavior is what we label as *buyer loyalty*, understood as a systematic tendency of a buyer to purchase significantly more often from one of the sellers than from the other. A formal definition of this specific notion of loyalty is based on a χ^2-test which has been performed at the 1% level of significance for each buyer to distinguish between those who have bought (nearly) equally often from either seller and those exhibiting a systematic tendency to purchase more often at one of them. Results indicate that 24 buyers in treatment 1 and 12 buyers in treatment 2 (33.3% and 17.15%, respectively) have behaved in a systematically loyal way towards one of the two sellers. Despite wisdom from textbook Microeconomics relating customer loyalty to an inelastic demand with respect to price changes, enabling the seller to charge higher prices, buyer loyalty here should be seen as an attitude adopted by buyers wishing to reward sellers who have charged them low prices in the past. Such an attitude is clearly reflected on the negative correlation between loyalty[25] and prices in treatment 1.[26]

Q3. Is there evidence of learning?

As observed in Barreda et al. (2000) for uniform (equidistant) buyer locations, pure price equilibria fail—generally speaking—to exist and calculating a perfect equilibrium

[25] The observed values of the statistic used to perform the χ^2-test mentioned above, have been used as the proxy for each buyer's degree of loyalty.

[26] Spearman correlation value = – 0.661.

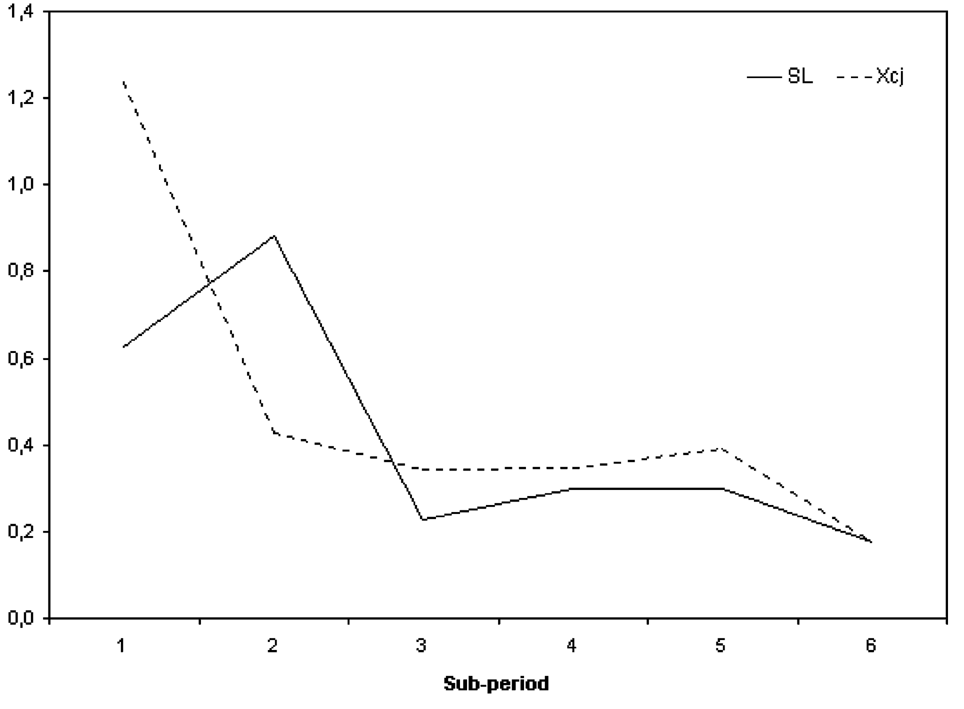

Fig. 10. Evolution of average SL and x_{cj} over time (treatment 1).

requires specific assumptions concerning players' attitudes towards risk. Nevertheless, it is worth mentioning that our setup leaves little space for learning reflected on differences in the behavior of subjects along different periods of a session. The use of a discrete space for both location and pricing strategies makes it straightforward for all subjects to calculate the effects of any combination of their actions and those of their rivals on their earnings at any stage of the game.[27] Therefore, a *learning* result, which is usually reported in oligopoly experiments[28] with continuous pay off functions, is not obtained here. Accordingly, price and differentiation strategies remain, on average, invariant over the 25 periods of the game (see Figs. 8 and 9). An important implication of this result on the lack of learning dynamics is that the reported differences across treatments cannot be explained with learning differences due to a different number of repetitions of the location decision.

However, contrary to other magnitudes, the degree to which buyers choose *strategic* locations (Figs. 10 and 11) changes over time in both treatments. Learning to locate in a less strategic way by adopting an individualistically strategic but socially naive behavior

[27] This should not be taken to imply that the corresponding location and price equilibria are straightforward to compute. Contrary to first-sight intuition, continuous variables leading to easy-to-compute pure strategy equilibria require precise calculations with non-integer numbers. Instead, discontinuous (and especially integer) strategic variables resulting in not-so-easy-to-compute mixed strategy equilibria imply simple numerical calculations in order for the payoff consequences of a given strategic profile to be predicted.

[28] García-Gallego (1998); Rassenti et al. (2000); García-Gallego and Georgantzís (2001).

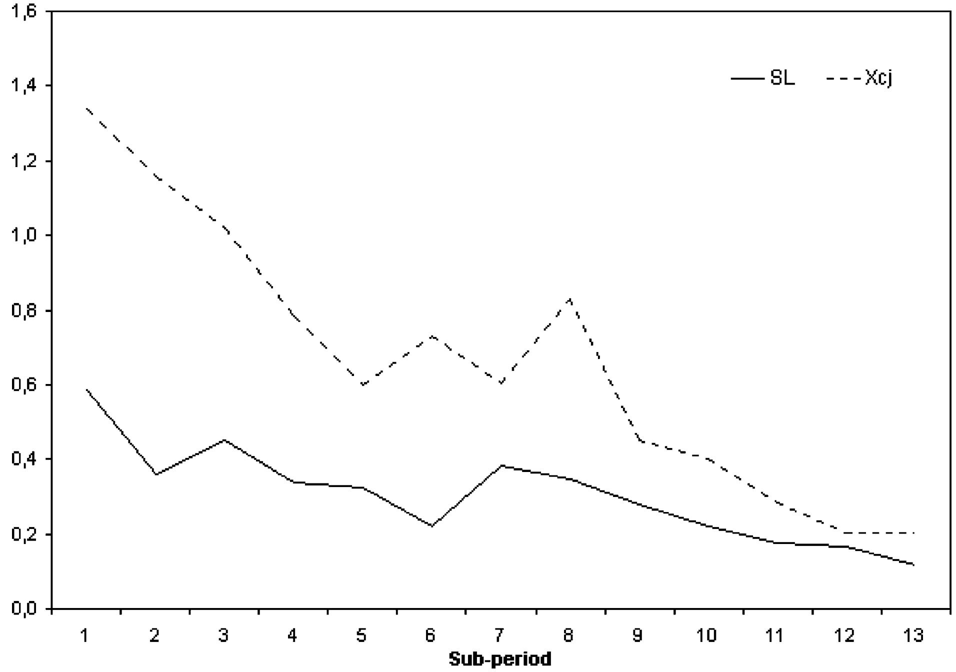

Fig. 11. Evolution of average SL and x_{cj} over time (treatment 2).

works against the buyers' population interest as a whole. The literature on *learning by observing successful others*[29] might give us a hint on what happens here. A strategic buyer locating in the middle between sellers may compare his earnings with those of individualistic (or socially naive) buyers who locate near sellers in the same period and realizes that his strategy is *wrong*. After several repetitions of a similar situation, *some* buyers who were previously behaving in a socially strategic way would tend to imitate the strategy of more successful (individualistic) *colleagues* choosing a transportation cost-minimizing location.

5. Conclusions

The abstract setup used and the results reported here are applicable to various real world situations, related to contracts, repeated purchases, reputation and even past consumption affecting present choices.

Our results indicate that even a small number of buyers cannot be strategic enough with respect to their longer term strategies, especially in the presence of other buyers whose actions and performance tend to spread the message that a socially intelligent behavior is

[29] See for example Offerman and Sonnemans (1998); Bosch-Domènech and Vriend (1999); Duffy and Feltovich (1999).

individually unprofitable. This cognitive issue has serious consequences for the market equilibrium and the degree of product differentiation. According to our results on flexibility of product re-design, the common phenomenon of rapid product innovation may favor product differentiation and *naive* long run behavior by buyers who become more and more often subject to their suppliers' monopolistic power. Revising the theory of product differentiation in order to account for strategic consumer behavior is clearly a fascinating area of research with both a normative and a positive value. In the future, consumer associations might need to use the lessons learned from simple frameworks like ours in order to guide buyer behavior towards strategies associated with collectively and socially intelligent options.

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Appendix A. Instructions

The purpose of this experiment is to study how subjects take decisions in specific economic contexts. The instructions are simple. Follow them carefully and, depending on your performance, you will receive a quantity of money in cash at the end of the session.

Consider a market for an intermediate good, which can be differentiated according to a characteristic that we will call technological profile. In the market, there are two sellers (*A* and *B*) and seven (potential) buyers (*R*1, *R*2, . . ., *R*7). The latter, who will also be referred to as retailers, are willing to transform a maximum of one unit of the intermediate good into a unit of a final product. In each period, a retailer's profit from buying (and transforming) a unit of the intermediate good is given by:

$$\Pi = 10 - p - x$$

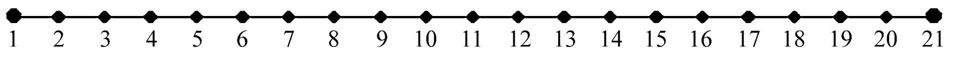
where x is the technological distance (incompatibility) between the retailer's ideal input (his own technological profile) and the one actually purchased (that of the input produced by his supplier). Decisions referring to the choice of technological profile are represented on a straight line as shown and explained below. If the retailer yields a negative payoff from purchasing the product, he will prefer not to buy it at all, earning zero profits.

A supplier selling to $n \in [1, 7]$ buyers at price p earns:

$$\Pi = p \cdot n$$

given that sellers' production costs are zero.

• The market lives for a total of 25 periods (years).
• During the experiment, the decisions will be made according to the following sequence:
  Stage 1 (*Seller location*): Sellers decide simultaneously on the technological profile of their products. This happens at the beginning of the first round and in rounds 5, 10, 15, 20 and 25, (3, 5, 7, . . ., 25 in treatment 2).
  Stage 2 (*Buyer location*): Retailers simultaneously choose their own technological profiles among those available.
  Stage 1 and 2 decisions are reported by referring to each player's choice among 21 points, which are equidistantly placed (at one unit of distance from each other) on a straight line as shown below:
  Stage 3 (*Price setting*): Sellers set prices among the integers from the interval [1, 10], taking into account that their production costs are zero.
  Stage 4 (*Purchasing*): Retailers simultaneously decide whether to buy a unit of the product or not and (in the former of the two cases) which seller to be supplied by.
• Immediately after each stage, decisions are made public to all players.



Each participant's real monetary earnings (in Spanish Pesetas) are calculated from accumulated profits during the session, by applying a 10/1 (real/experimental currency units) exchange rate for buyers and a 5/1 exchange rate for sellers.

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