NET Institute*

www.NETinst.org

Working Paper #05-12

October 2005

Competing Against Simulated Equilibrium Price Dispersions: An Experiment On Internet-Assisted Search Markets

Aurora García-Gallego
Universitat Jaume I

Nikolaos Georgantzís
Universitat Jaume I

Pedro Pereira
Autoridade da Concorrência

José C. Pernías-Cerrillo
LINEEX, Universitat de Valencia

* The Networks, Electronic Commerce, and Telecommunications ("NET") Institute, http://www.NETinst.org, is a non-profit institution devoted to research on network industries, electronic commerce, telecommunications, the Internet, "virtual networks" comprised of computers that share the same technical standard or operating system, and on network issues in general.

Competing against simulated equilibrium price dispersions: An experiment on Internet-assisted search markets*

AURORA GARCÍA-GALLEGO†
NIKOLAOS GEORGANTZÍS‡
JOSÉ C. PERNÍAS-CERRILLO§
PEDRO PEREIRA¶

In a four-treatment experiment, we test some of the hypotheses in García-Gallego et al. (2004) concerning competition among a number of firms of which some (or all) are indexed by a price-comparison engine facilitating buyers' search process. In this paper, we isolate individual behavior from noise due to other players' actions and learning, facing each subject with simulated rivals whose prices are extracted from mixed strategy equilibrium distributions. We find systematic deviations from both theoretical distributions and previous data obtained in sessions where all players were human. Specifically, departures of experimental data from the corresponding theoretical predictions are enhanced in this setting as compared to our previous research in which all agents were represented by human players. This suggests that the divergence between theoretical and observed price reported there should not be attributed to noisy learning and strategic uncertainty due to subjects' interaction with other players. Furthermore, economic tests on players' risk attitudes oganize pricing behavior in meaningful, although not always compatible, ways.

Keywords: Risky Decision Making, Internet, Price-Comparison Search Engines, Mixed Strategy Equilibrium, Experimental Economics.

JEL Codes: C91, D43, D83, L13.

*The authors gratefully acknowledge financial support by the NET Institute.
†LEE/LINEEX and Economics Department, Universitat Jaume I, Castellón (Spain); e-mail: mgarcia@eco.uji.es; phone: 34-964387161.
‡LEE/LINEEX and Economics Department, Universitat Jaume I, Castellón (Spain); e-mail: georgant@eco.uji.es; phone: 34-964728588.
§LINEEX, Universitat de Valencia (Spain); e-mail: jcpernias@ya.com
¶Autoridade da Concorrência, R. Laura Alves, nº 4, 7º, 1050-138 Lisboa (Portugal); e-mail: jppereira@oninetspeed.pt; phone: 21-7802498; fax: 21-7802471.

1. INTRODUCTION

A *Search Engine* is a program that accesses and reads Internet pages, stores the results, and returns lists of pages, which match keywords in a query. *Price-Comparison search engines*, also known as shopping agents or shopping robots, are a class of search engines, which crawl commercial Internet sites. In addition to addresses from vendors, they also collect and display other information like prices, or return policies.

Presumably, the larger the number of vendors whose price a search engine lists on its site, and that thereby consumers can easily compare, the more competitive the market becomes. However, there are several technical reasons for search engines to cover only a small subset of the Internet, and to collect and report information biased in favor of certain vendors. The technology-induced tendency, for search engines to have incomplete and biased coverage, is reinforced by economic reasons. Search engines are profit-seeking institutions, which draw their income from vendors, either in the form of placement fees, sales commissions, or advertising.

Well before automated price-comparison search engines appeared on the Internet, economists had recognized the importance of buyers' search costs for the functioning of oligopolistic markets. For example, models like Varian (1980), Burdett and Judd (1983) or Stahl (1989) demonstrate that any arbitrarily small search cost could yield monopoly pricing by competing sellers. Obviously, there are alternative approaches in the literature which assume buyer heterogeneity as far as search costs are concerned. In the presence of buyer heterogeneity mixed price equilibria may emerge. Such equilibria are often used as the theoretical counterpart of empirical evidence on persistent price dispersion. An interesting special case of such heterogeneity is one in which for a fraction of the consumer population search is costless, whereas the remaining population have identical positive search costs. Under this assumption, models like the one in Stahl show that mixed strategy equilibrium price distributions range from monopoly to competitive (Bertrand) levels as the fraction of zero search cost buyers varies from 0 to 1.

Recently, the use of the Internet and the existence of price-comparison search engines largely characterize the properties of the search process followed by individual buyers. Specifically, buyers may be heterogeneous depending on whether they gather price information on the Internet or not. This fact is tested by empirical results reported by Iyer and Pazgal (2000). Furthermore, search engines may offer incomplete or even biased coverage of competing firms' prices, as reported in Kephart and Greenwald (1999).

Baye and Morgan (2001) from a theoretical perspective, as well as Brynjolfsson and Smith (2000) from an empirical point of view, confirm the prediction of persistent price dispersion in Internet markets, even in the presence of homogeneous products.

From an experimental perspective, in a setup similar to ours but assuming complete coverage, Morgan et al. (2005) study the case of a consumer population consisting of Internet searchers and captive clients. Some systematic deviations between theoretical and experimental results are attributed by the authors to uncontrolled idiosyncratic features of their subjects. However, biases of price-comparison search engines and the effect of incompleteness of the price index were first explored in García et al. (2004), GGPP hereafter. In that paper, we propose a partial equilibrium search model, related to Burdett and Judd (1983) and Varian (1980), to discuss the implications of price-comparison search engines providing consumers with incomplete and biased information. It is assumed that there is a *Price-Comparison* search engine, which in the benchmark case has complete coverage, i.e., lists the prices of all vendors present in the market. There is a finite number of identical vendors. There is a large number of consumers of two types. *Shoppers* use the price-comparison search engine, and buy at the lowest price listed by the search engine. *Non-Shoppers* buy from a vendor chosen at random. Vendors choose prices. In equilibrium, vendors randomize between charging a higher price and selling only to non-shoppers, and charging a lower price to try to sell also to shoppers.

Parallel to GGPP, Cason and Datta (2005) experimentally study price dispersion in a model in which buyer search is costly and firms' strategic spaces include advertising. Some systematic failures of observed strategies to converge towards the theoretical predictions are explained as the result of noise created by simultaneously interacting human subjects learning in and about their market environment. Cason and Datta (2006), simulate buyers' optimal strategies in order to isolate behavior on the supply side from uncontrolled effects caused by human action on both sides of the market. This strategy somehow relates to our present design in which all but one firms' behavior are simulated by the server in order to isolate purely idiosyncratic features of individual decision making from uncontrolled beliefs subjects may hold on others' risk preferences and actions as well as from the noise created by others' simultaneous actions and learning.

In this study, we use the search model in GGPP to discuss individual pricing behavior in the presence of price comparison search engines providing consumers with complete or incomplete but unbiased information on the prices available in the market. In GGPP, the model was tested in a series of experimental sessions, in which random matching and strategic interaction among a number of human subjects created an environment in which some risk-related elements of human behavior were controlled, while others were not. In fact, given that the predictions of the theoretical model accounted for equilibrium price dispersion assuming risk neutrality of all the agents involved, some deviations between theoretical predictions and the experimental results were partially offered an explanation by our subjects' risk attitudes, which significantly deviated from risk neutrality.

The present study extends the GGPP analysis in two different ways.

First, we aim at studying individual behavior in isolation of factors concerning the behavior of "others" and subjects' uncontrolled beliefs with respect to rival risk preferences and thus pricing behavior. In order to do that, we run experimental sessions in which rather than using interacting human agents, we face each subject with a market in which the behavior of "others" is simulated and corresponds to realizations of a random variable distributed according to equilibrium price distributions. This is an important step towards a better understanding of individual behavior in the presence of mixed strategy equilibrium play in isolation of other uncontrolled sources of uncertainty related with the subject-matching protocol and the typology of human behavior or subjects' beliefs regarding such typology.

A second extension of the design in GGPP is proposed with respect to the parallel test used in order to identify our subjects' risk attitudes. In GGPP we use a single test of risk attitudes: the lottery panel test introduced in Sabater and Georgantzís (2002), which was found to produce a two-dimensional description of risk attitudes leading to the construction of two significant explanatory variables (a continuous and a dichotomous one) for the observed pricing behavior. However, given the fact that the aforementioned test is rather new, our previous results are difficult to compare with other tests of risk attitudes and their relation to decision making in strategic environments. In fact, it would be a rather surprising coincidence that a single test of risky behavior could capture the whole spectrum of human attitudes towards uncertain decisions. Therefore, in this study, we propose a more complete test of risky decision making, by introducing (apart from the aforementioned lottery-panel test) a more standard economic test inspired in Holt and Laury (2002, 2005) and two psychometric ones due to Zuckerman (1978) and Torrubia et al. (2001).

2. THEORETICAL FRAMEWORK

We briefly discuss the features and results of the theoretical setting in GGPP.

Consider an electronic market for a homogeneous search good that opens for 1 period. There are: 1 price comparison search engine, $n \geq 3$ vendors, which we index through subscript $j = 1,\ldots,n$, and many consumers. The *Price-Comparison Search Engine*, lists the firms contained in its *Index*, and the prices they charge.

Denote by k, the number of vendors the price-comparison search engine indexes. We will refer to k as the *Size of the Index*. The search engine has *Complete Coverage* if it indexes all vendors present in the market: $k = n$. If $k < n$, the search engine indexes each of the n vendors with the same probability: k/n.

There is a unit measure continuum of risk neutral consumers. Each consumer has a unit demand, and a reservation price of 1. There are 2 types of consumers, differing only with respect to whether they use the price-comparison search engine. *Non-Shoppers*, a proportion λ in $(0,1)$ of the consumer population, do not use the price-comparison search engine, perhaps because they are unaware of its existence, or perhaps because of the high opportunity cost of their time. The other consumers, *Shoppers*, use the price-comparison search engine.

Consumers do not know the prices charged by individual vendors. Shoppers use the price-comparison search engine to learn the prices of vendors. If the lowest price sampled by the price-comparison search engine is no higher than 1, shoppers accept the offer and buy; in case of a tie they distribute themselves randomly among vendors; otherwise they reject the offer and exit the market. Non-shoppers distribute themselves evenly across vendors, i.e., each vendor has a share of non-shoppers of $1/n$. If offered a price no higher than 1, non-shoppers accept the offer and buy; otherwise they reject the offer and exit the market.

Vendors are identical and risk neutral. Marginal costs are constant and equal to zero. Vendors know the functioning rules of the search engine. They know the probability with which they are indexed, but do not observe the identity of the indexed vendors, before choosing prices.

Denote by $\Pi_j(p)$, the expected profit of vendor j when it charges price p on $\mathbb{R}_0^+$. A vendor's *strategy* is a cumulative distribution function over prices, $F_j(\cdot)$. Denote the lowest and highest prices on its support by $\underline{p}_j$ and $\bar{p}_j$.[1] A vendor's *payoff* is its expected profit.

A *Nash equilibrium* is a n-tuple of cumulative distribution functions over prices, $\{F_1(\cdot),\ldots,F_n(\cdot)\}$, such that for some $\Pi_j^\star$ on $\mathbb{R}_0^+$, and $j = 1,\ldots,n$, $\Pi_j(p) = \Pi_j^\star$, for all p on the support of $F_j(\cdot)$, and $\Pi_j(p) \leq \Pi_j^\star$, for all p.

Denote by τ the type of the search engine, and let 'c', mean *Complete Coverage*, and 'u' mean *Unbiased Incomplete Coverage*. Then, τ belongs to $\{c,u,\}$. We will use superscripts 'c'

1. It is well known that this game has no equilibrium in pure strategies.

and 'u' to denote variables or values associated with the cases where the search engine has that type. Denote by ϕ_j^τ the probability of firm j being indexed, such that $\phi_j^\tau = k/n$. Denote by $\hat{p}_{-j}$ the minimum price charged by any indexed vendor other than vendor j, and denote by $\hat{m}_{-j}$ the number of indexed vendors that charge $\hat{p}_{-j}$. Ignoring ties, the expected profit of a vendor that charges $p \leq 1$ is:

$$\Pi_j(p) = p\frac{\lambda}{n} + p(1-\lambda)\phi_j^\tau[1-F(p)]^{k-1}. \tag{1}$$

Denote by l_j^τ the lowest price vendor j is willing to charge to sell to both types of consumers when the search engine has type τ, i.e., $l_j^\tau[\lambda/n + (1-\lambda)\phi_j^\tau] - \lambda/n \equiv 0$.

Then, it is shown that, in equilibrium:

$$p\frac{\lambda}{n} + p(1-\lambda)\phi_j^\tau[1-F_j^\tau(p)]^{k-1} = \frac{\lambda}{n}. \tag{2}$$

All vendors are indexed with positive probability (including the extreme case of 1 when complete coverage is in place). Hence, they face the trade-off of charging a high price and selling only to non-shoppers, or charging a low price to try to sell also to shoppers, which leads them to randomize over prices.

Then, the price distribution for the case in which the market consists of n vendors, and the price-comparison search engine has an unbiased index of size $k \leq n$, is identical to the price distribution for the case in which the price-comparison search engine has *Complete Coverage*, $k = n$, and the market consists of k vendors: $F^u(\cdot; n, k) = F^c(\cdot; k)$.

As discussed in more detail in GGPP, an unbiased decrease in the size of the index has two impacts. First, for indexed vendors, the decrease in the size of the index reduces the number of rivals with which a vendor has to compete to sell to shoppers from $k-1$ to $k-2$. This increases the probability that an indexed vendor will have the lowest price, $(1-F^u)^{k-1}$, which increases the *Volume of Sales effect*. The first impact leads vendors to shift probability mass from higher to lower prices. As a consequence, the price distribution shifts to the left. Second, the decrease in the size of the index reduces the probability that a given vendor is indexed from k/n to $(k-1)/n$, which reduces the *Volume of Sales effect*. The second impact leads vendors to raise the lower bound of the support, and to shift probability mass from lower to higher prices. As a consequence, the price distribution rotates. The total impact of an unbiased decrease in the size of the index is to cause the price distribution to rotate counter clock-wise.

The increase in the lower bound of the support, $l^u(k) < l^u(k-1)$, raises the expected price paid by shoppers. However, the average price paid in the market remains constant and equal to λ. This implies that the expected price by non-shoppers decreases. Recall that vendors now charge lower prices with a higher probability. Shoppers and non-shoppers have conflicting interests with respect to *Unbiased Incomplete Coverage*, as compared with *Complete Coverage*. Shoppers prefer a large to a small unbiased index, and non-shoppers prefer a small to a large unbiased index.

Under *Unbiased Incomplete Coverage*, the equilibrium price distribution does not depend on the number of vendors in the market, $F^u(\cdot; n, k) = F^u(\cdot; n+1, k)$. The probability with which a vendor is indexed, k/n, depends on the number of vendors. Besides, each vendor's share of non-shoppers, λ/n, also depends on the number of vendors.

Given that $F^u(\cdot;n,k) = F^c(\cdot;k)$, comparing the price distributions under *Unbiased Incomplete Coverage*, $F^u(\cdot;n,k)$, and under *Complete Coverage*, $F^c(\cdot;n)$, is equivalent to comparing $F^u(\cdot;n,k)$ and $F^u(\cdot;n,n)$, i.e., is equivalent to analyzing the impact of an increase in the size of the index, under *Unbiased Incomplete Coverage*. Thus, compared with *Complete Coverage*, *Unbiased Incomplete Coverage* causes the price-comparison to rotate counter-clockwise, which increases the expected price paid by shoppers and decreases the expected price paid by non-shoppers.

3. EXPERIMENTAL DESIGN

We run four treatments labeled according to the numbering followed in GGPP. Thus, treatments T1, T2, T4 and T5 reported here refer to a 2x2 design resulting from the combination of two values of $n \in \{3,6\}$ with two values of $k/n \in \{2/3,1\}$. In terms of the theoretical model, the design can be used to test the model's hypotheses concerning the size of the market under complete coverage by comparing a *complete coverage triopoly* (T1) *to a complete coverage hexapoly*, (T4). Furthermore, by comparison of T1 to T2 and T4 to T5, we can test the model's hypotheses concerning the completeness of the index. In fact, both incomplete coverage treatments are run with a 2/3 probability of a seller being indexed by the search engine. Thus, in treatment 2 we use $k = 2$ and in treatment 5 we set $k = 4$.

Contrary to the experiments in GGPP, in which a number of interacting human agents were randomly matched every period of the session, in this study, we face each subject with simulated subjects whose behavior is extracted from the corresponding mixed strategy equilibrium distribution. In this way, we isolate individual behavior from noisy interaction and learning by other players. As observed by Cason and Datta (2006), the overlapping of noises and errors occurring due to human agents' action and interaction should be mitigated by inducing (simulated) optimal behavior on some part of the market.

The prices set by robot players were randomly extracted from the theoretical distributions using the transformation method (Press et al., 1992). The experiment was run using a specific software programmed in Java. Each subject participating in treatments T1 and T2 is faced in each period with 2 simulated players, whereas each subject in treatments 4 and 5 is faced with another 5 simulated players. In order to guarantee that obseved heterogeneity can be genuinely attributed to differences across individuals we have maintained the actual realizations of the simulated players fixed within each treatment. Subjects were told that the objectives pursued by "others" were identical to those induced to each one of them according to the instructions.[2] In that sense, strategic interaction among human players and simultaneous learning by them does not affect individual decision making, as each subject competes in a market in which other's behavior corresponds to mixed strategy equilibrium play.

Like in GGPP, our design includes implementing Sabater and Georgantzís' (2002) lottery panel methodology as a parallel experiment, designed to capture our subjects' attitude towards risk. Subjects are offered the 4 panels of lotteries presented in table 1. Each lottery involves a probability q of earning a monetary reward of X Euros, and a probability $1-q$ of earning 0 Euros. Each one of the 4 panels is constructed using a fixed certain payoff, $c = 1$ Euro, above

2. An English translation of the Instructions to the subjects is provided in the appendix.

TABLE 1

Panels of lotteries

Panel 1

q	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
X €	1.00	1.12	1.27	1.47	1.73	2.10	2.65	3.56	5.40	10.90
Choice										

Panel 2

q	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
X €	1.00	1.20	1.50	1.90	2.30	3.00	4.00	5.70	9.00	19.00
Choice										

Panel 3

q	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
X €	1.00	1.66	2.50	3.57	5.00	7.00	10.00	15.00	25.00	55.00
Choice										

Panel 4

q	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
X €	1.00	2.20	3.80	5.70	8.30	12.00	17.50	26.70	45.00	100
Choice										

which expected earnings, qX, were increased by a ratio h times the probability of not winning, $1-q$, as implied by the formula: $qX = c + h(1-q)$. That is, an increase in the probability of the unfavorable outcome is linearly compensated by an increase in the expected payoff. We use 4 different risk return parameters, $h = 0.1, 1, 5, 10$, implying an increase in the return of risky choices as we moved from one panel to the next. By inspection, the farther right the subject chooses, the less risk averse he is, whereas risk neutral (risk loving) subjects would choose $q = 0.1$ in all panels. In fact, it can be checked that an expected utility maximizing subject with utility $U(X) = X^{1/t}$ would choose the lottery with probability $q = (1-1/t)(1+c/h)$, which, apart from the aforementioned intuitively expected outcome, also predicts that the subject should choose riskier lotteries as we move from panel 1 to panel 4. Thus, for risk-averse subjects, their sensitivity to the attraction implied by a higher h can be approximated by the difference in their choices across subsequent panels.

An alternative test of risk attitudes was used in order to obtain a more complete picture of our subjects' risk attitudes. We have implemented the Low Payment binary lottery choice task presented in Holt and Laury (2002, table 1) using the same nominal rewards expressed in Euros. The test is based on binary choices among a set of lottery pairs constructed to elicit a subject's switching point from a safer to a riskier option. Both this and the lottery panel test were implemented with real rewards in a *recruiting session* organized a day before the main experiment. During the recruiting session, a questionnaire-based psychometric test was also

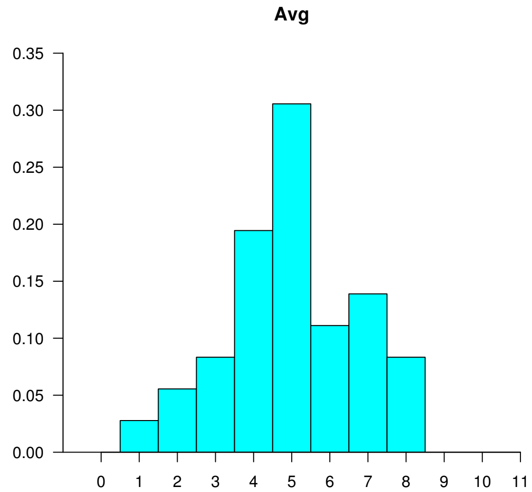


FIGURE 1
Average panel choice histogram.

TABLE 2
Risk Measure Correlations

	Avg	HL	Z	SR
HL	0.2866			
Z	0.1162	0.1400		
SR	0.1899	0.1557	−0.0738	
SP	0.1820	0.1137	0.1622	0.6431

run. The test combined Zuckerman's (1978) Sensation Seeking Scale and a psychometric test of Sensitivity to Rewards and Punishments[3]. The former is a four-subscale assessment of a subject's attraction (or repulsion) to risky activities. The latter is a two-subscale assessment of a subject's attraction to rewards and repulsion towards punishment.

4. RESULTS

4.1. Risk attitudes

Figure 1 presents an histogram on our subjects' choices in the lottery panel test averaged across the four panels. Figure 2 contains the corresponding average choice histogram for data obtained in GGPP. Figure 3 contains histograms corresponding to subjects' choices in each one of the four panels. Figure 4 presents the corresponding histograms for data obtained in GGPP. A weak but systematic tendency is observed according to which our subjects have, at a population level,

3. The test can be found in Torrubia *et al.* (2001).

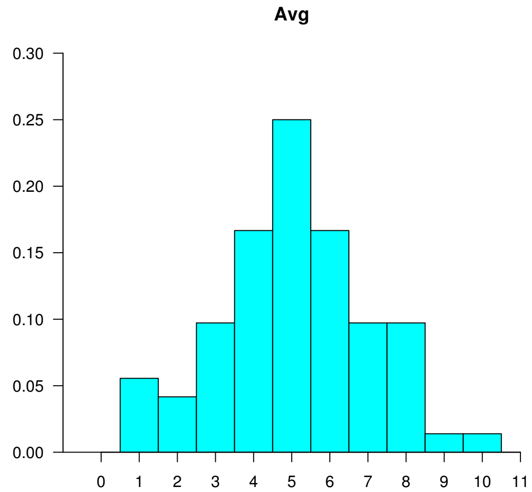
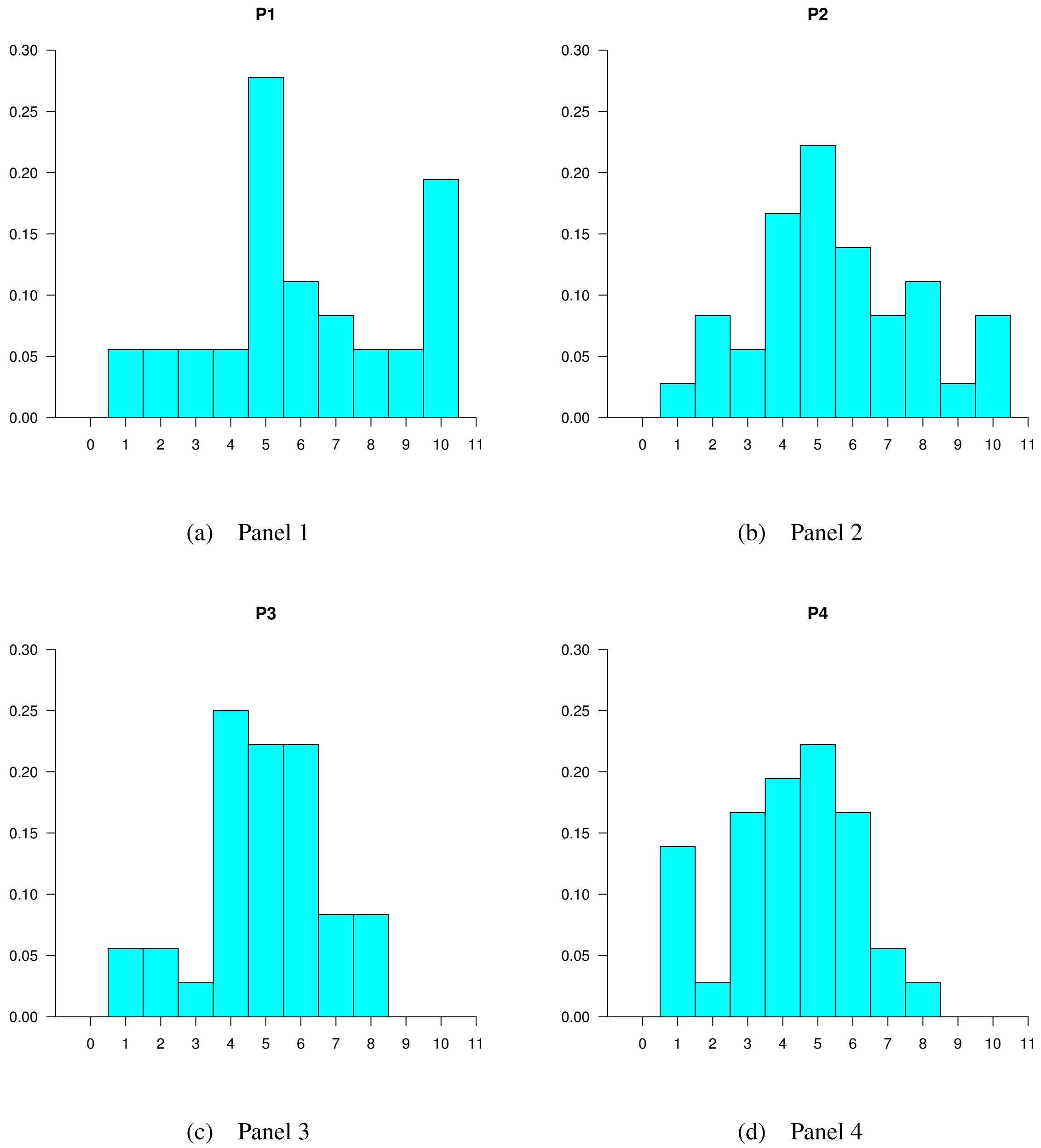


FIGURE 2
Average panel choice histogram (GGPP).

chosen riskier lotteries as the return to risk is increased from panel 1 to panel 4.[4] Choices peak on the $50\% - 50\%$ lottery in 7 out of the 8 histograms.

Figure 5 presents an histogram on results obtained from the Holt and Laury (2002) test. Figures 6 and 7 contain respectively results obtained from Zuckerman's (1978) test and its four subscales (Z1–Z4). Finally, histograms on the sensitivity to rewards (SR) and punishments (SP) are provided in figure 8. Table 2 contains correlations between attitude measures obtained in the *recruiting session.* Except for the well documented correlation (0.64) between sensitivities to punishments and rewards, only the correlation between the Holt and Laury (2002) lotteries and the lottery panel test lies close to the 0.3 threshold. This indicates that risk attitudes revealed within the economic domains are the only ones that should be expected to be (weakly) correlated as shown in Figure 9. Furthermore, an even higher correlation of the Holt and Laury (2002) test is obtained with choices in the first of the four panels, whose rewards lie closer to those of the aforementioned binary choice test (Figure 10).

4. A thorough discussion on the violation of this pattern at an individual level is provided in Georgantzís *et al.* (2003).



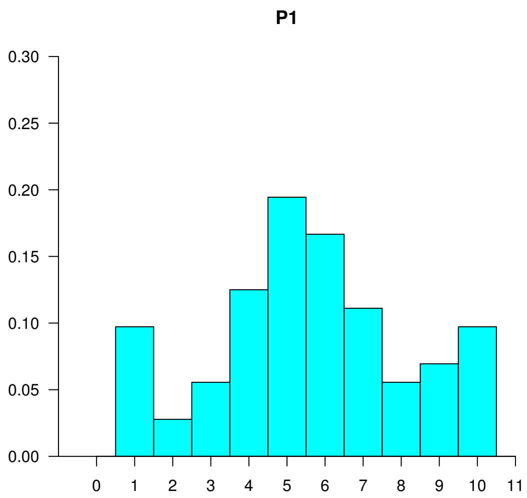
(a) Panel 1

(b) Panel 2

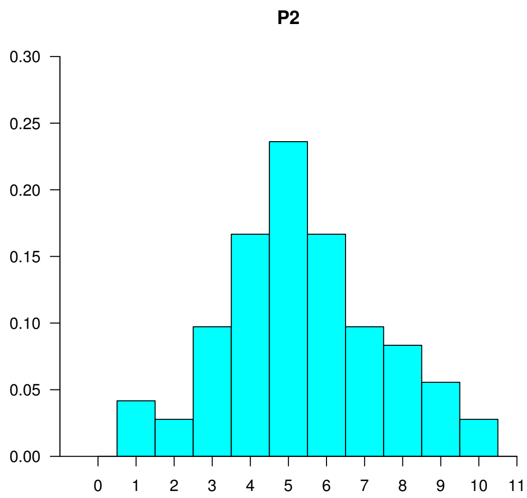
(c) Panel 3

(d) Panel 4

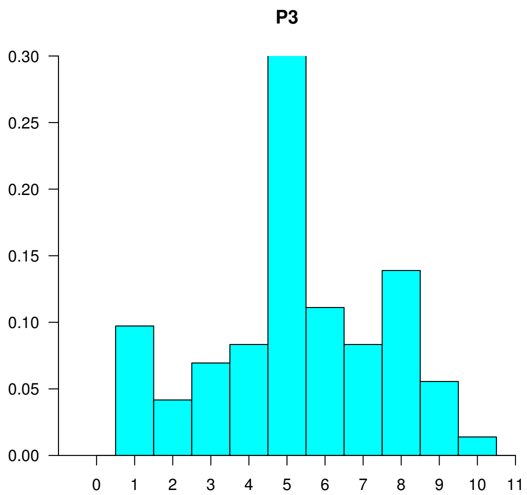
FIGURE 3
Panel choice histograms.



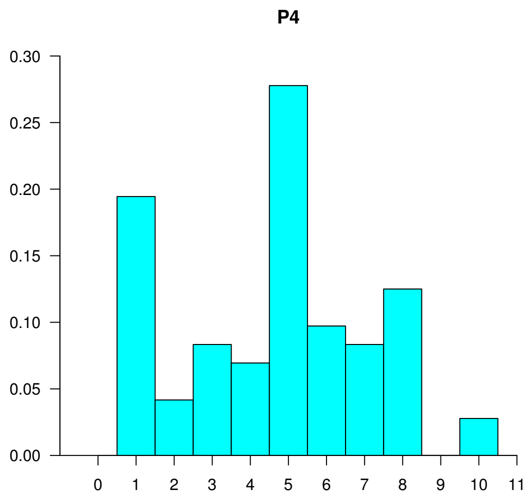
(a) Panel 1



(b) Panel 2



(c) Panel 3



(d) Panel 4

FIGURE 4
Panel choice histograms (GGPP).

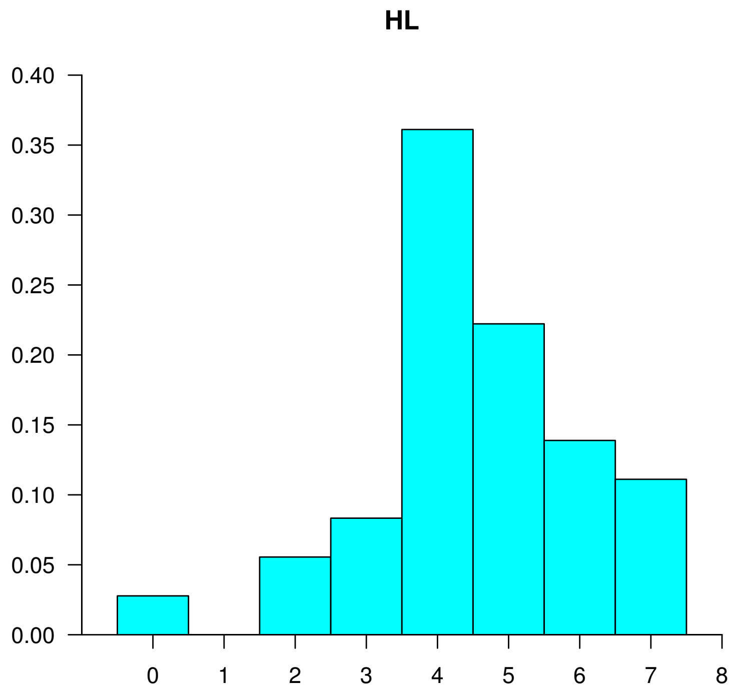


FIGURE 5
Holt-Laury measure histogram.

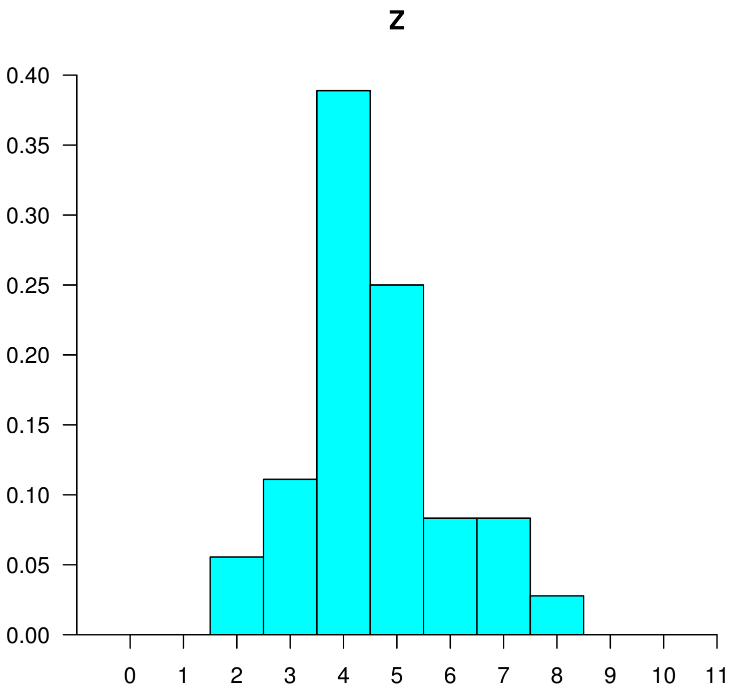
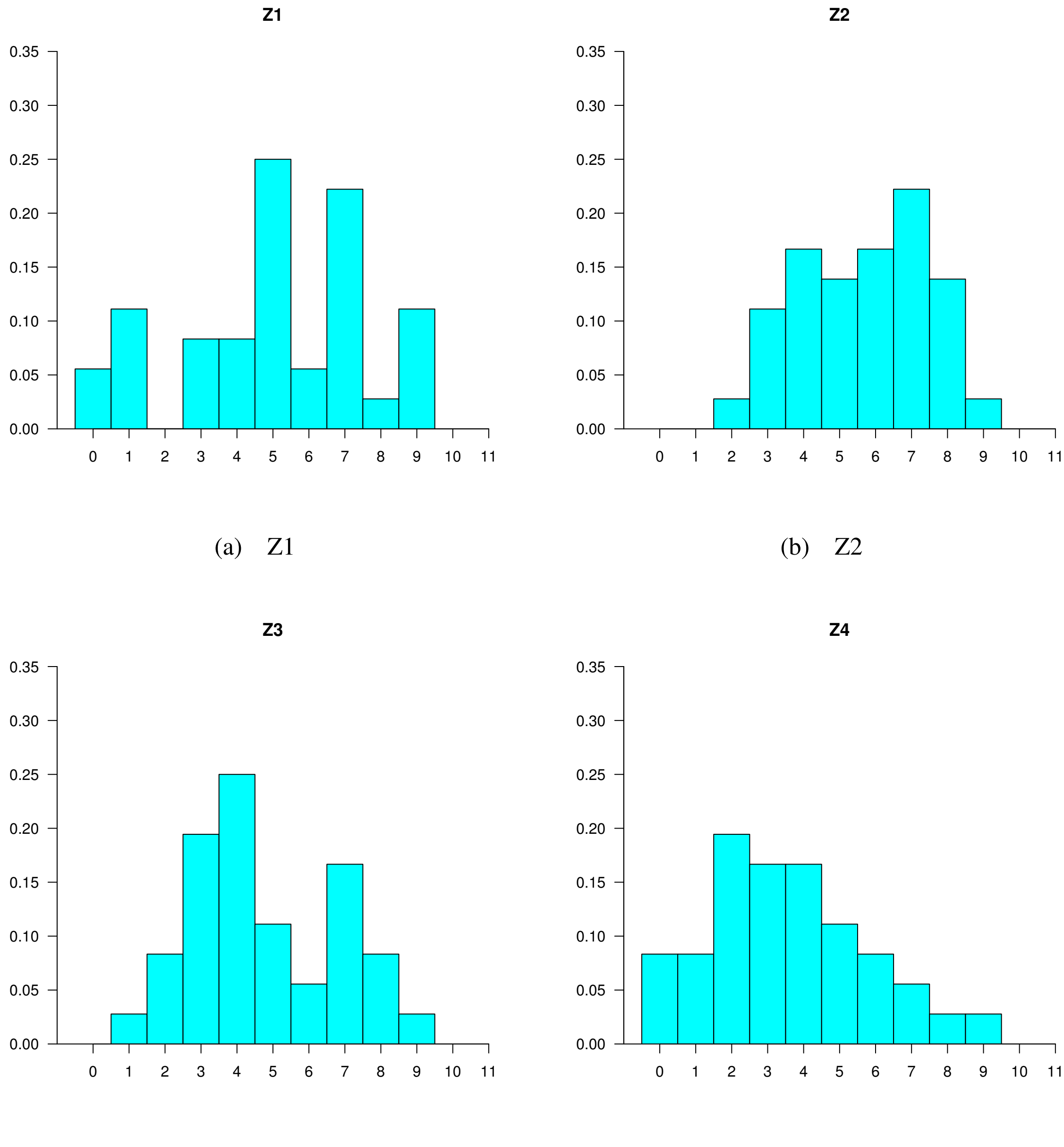


FIGURE 6
Average Z's histogram.

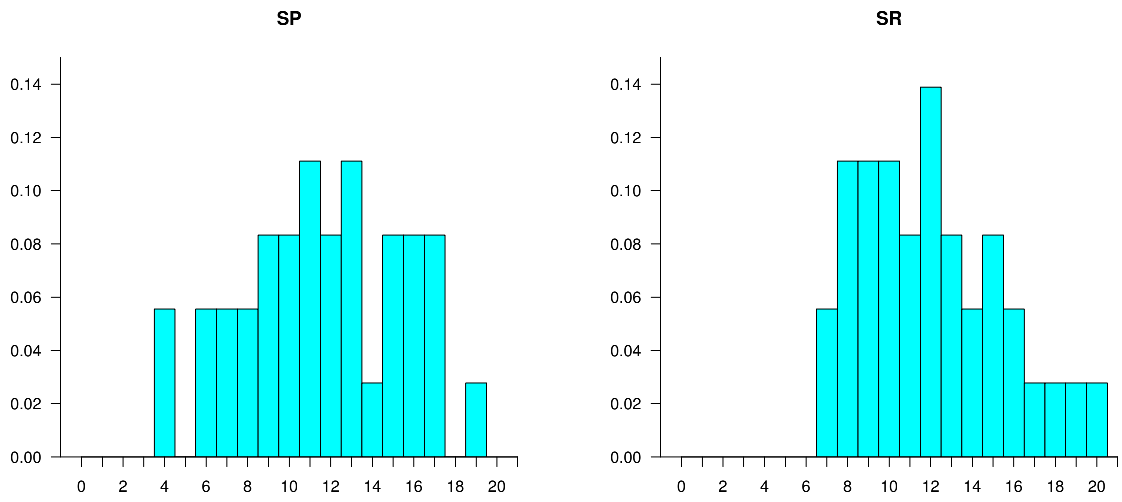


(a) Z1 (b) Z2

(c) Z3 (d) Z4

FIGURE 7

Z's histograms.



(a) SP (b) SR

FIGURE 8
SP and SR histograms

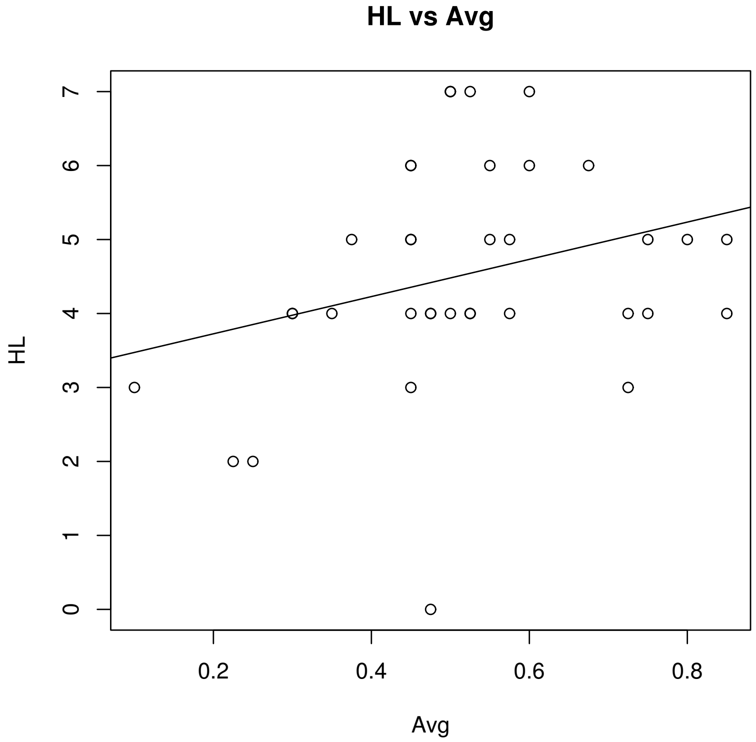


FIGURE 9
Regression of HL on Avg.

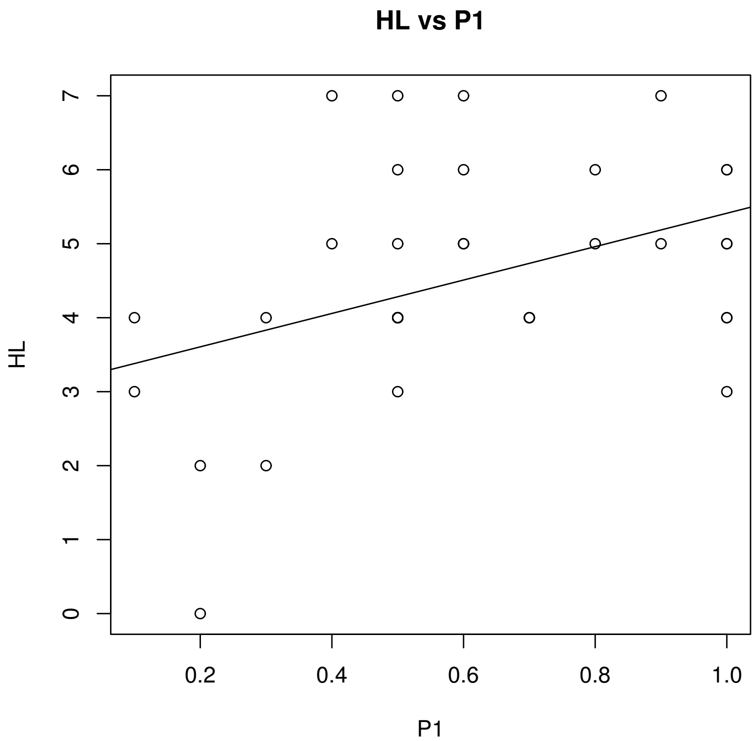
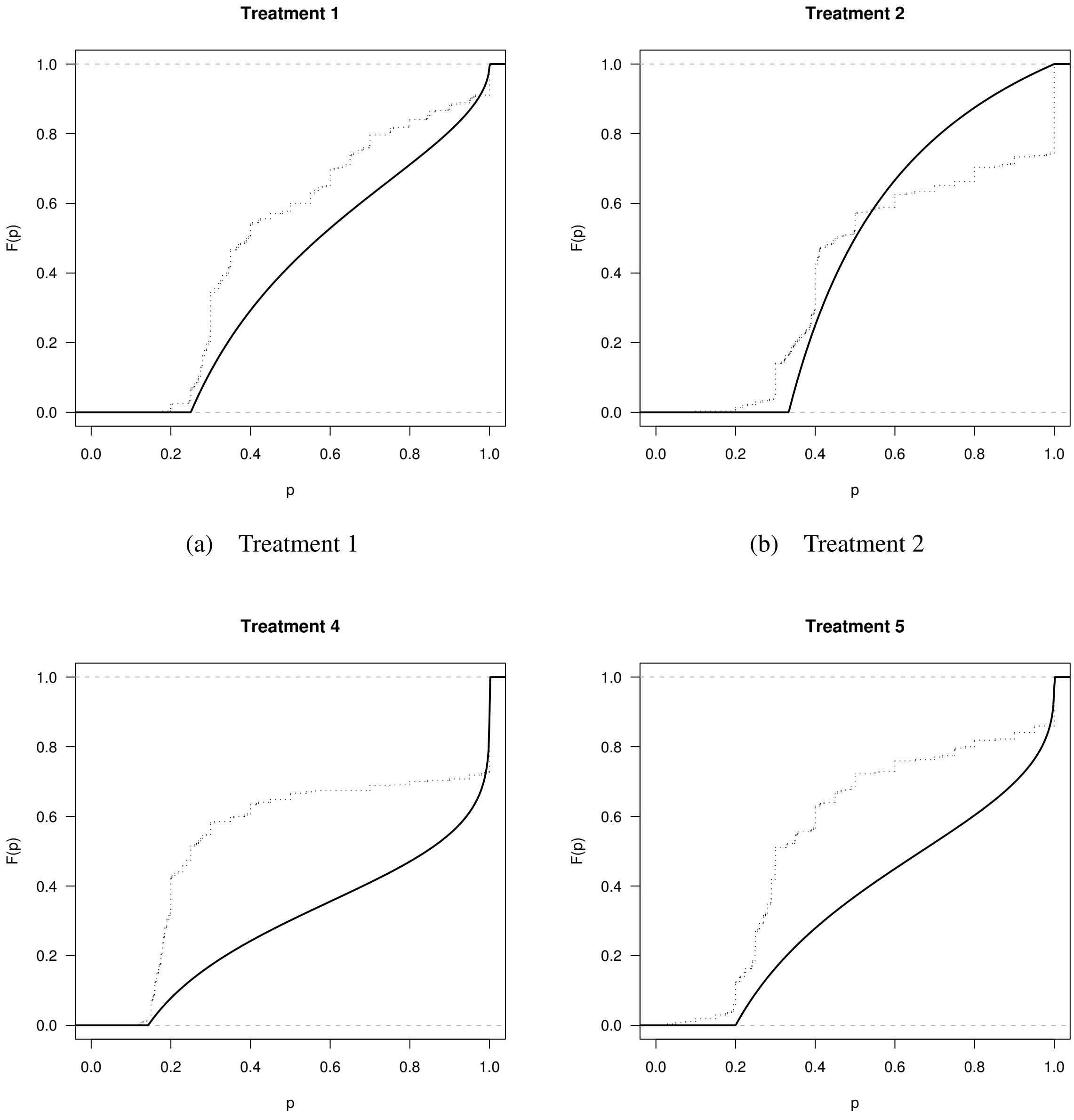


FIGURE 10
Regression of HL on P1.



(a) Treatment 1 (b) Treatment 2

(c) Treatment 4 (d) Treatment 5

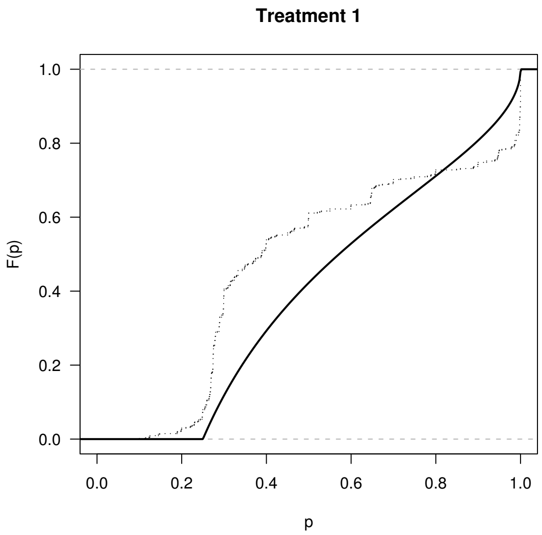
FIGURE 11

Empirical vs. theoretical cumulative price distributions.

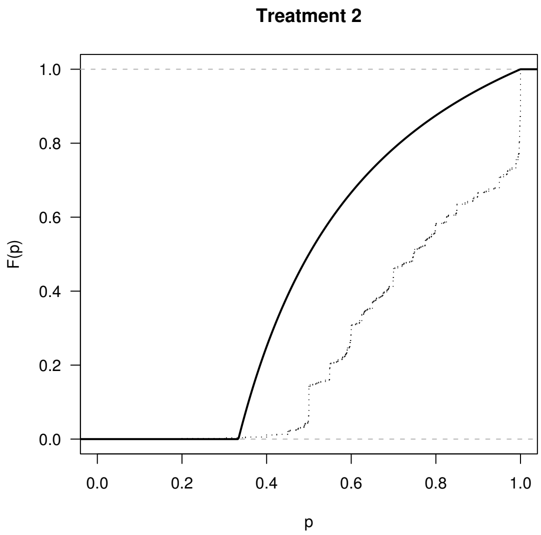
4.2. Pricing behavior

We discuss the basic features of the observed pricing behavior in comparison with previous experiments in which all firms were represented by human subjects. In all cases, observed cumulative distributions are plotted against the corresponding theoretical predictions.

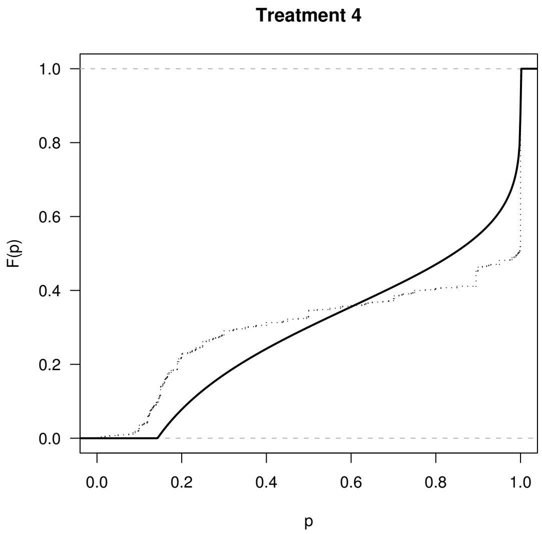
Figures 11 and 12, respectively compare the cumulative price distributions obtained here and in GGPP with the corresponding theoretical equilibrium distributions. Table 3 presents statistics of the price distributions obtained in the sessions with simulated "others" and human agents alone against the corresponding theoretical predictions. Generally, speaking, competing against simulated equilibrium play does not seem to systematically reduce the gap between predicted and observed behavior. In fact, in treatments with six sellers in the market (T4, T5)



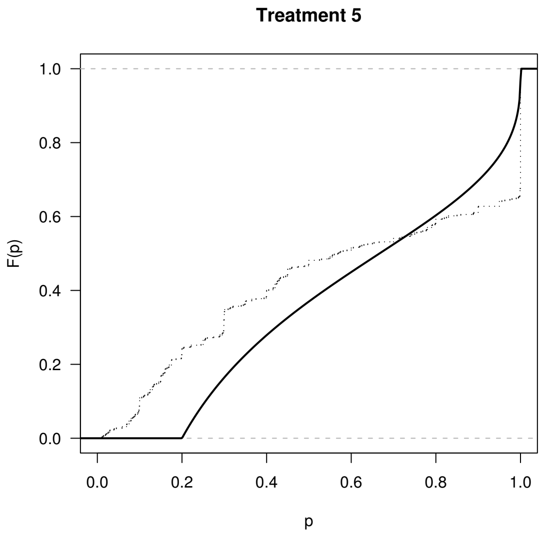
(a) Treatment 1



(b) Treatment 2



(c) Treatment 4



(d) Treatment 5

FIGURE 12

Empirical vs. theoretical cumulative price distributions (GGPP).

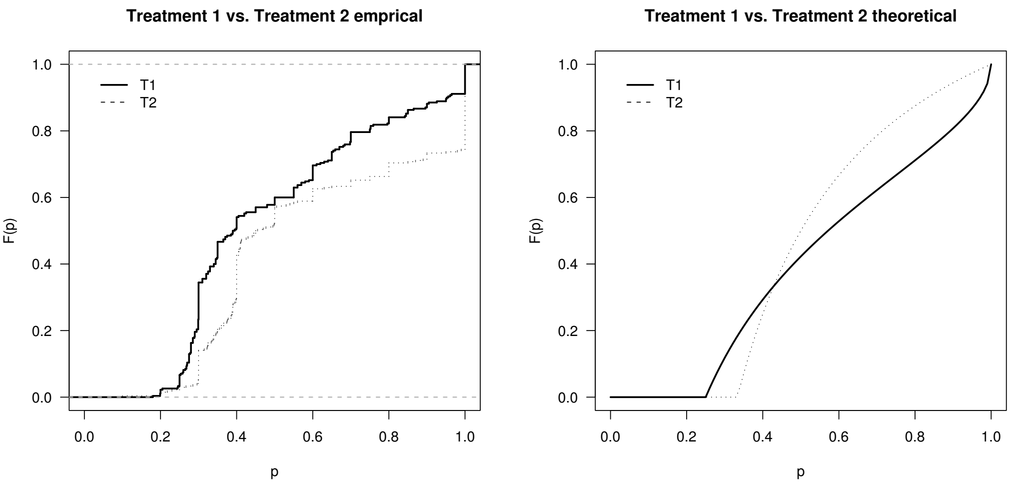
TABLE 3

Price distributions statistics

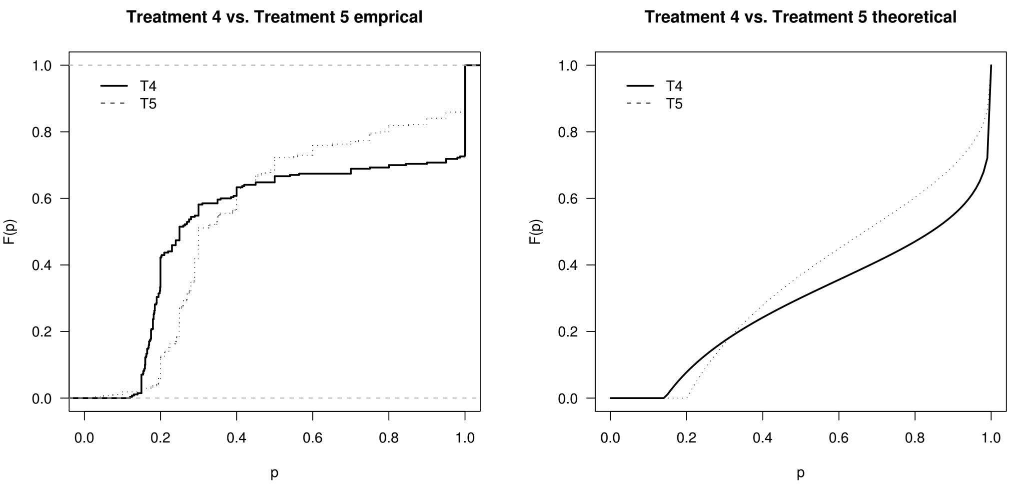
	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	StdDev
Treatment 1							
Theoretical	0.2500	0.3721	0.5714	0.6046	0.8421	1.0000	0.2481
All human	0.1000	0.2750	0.3890	0.5351	0.9200	1.0000	0.3033
Simulated	0.1800	0.3000	0.3925	0.5024	0.6700	1.0000	0.2501
Treatment 2							
Theoretical	0.3333	0.4000	0.5000	0.5493	0.6667	1.0000	0.1778
All human	0.2000	0.5968	0.7470	0.7597	0.9900	1.0000	0.1937
Simulated	0.1000	0.3880	0.4525	0.5970	1.0000	1.0000	0.2817
Treatment 4							
Theoretical	0.1429	0.4126	0.8421	0.7081	0.9942	1.0000	0.1429
All human	0.0020	0.2497	0.9940	0.6998	1.0000	1.0000	0.3712
Simulated	0.1200	0.1823	0.2500	0.4721	1.0000	1.0000	0.3601
Treatment 5							
Theoretical	0.2000	0.3721	0.6667	0.6476	0.9412	1.0000	0.2000
All human	0.0100	0.2220	0.5690	0.5923	1.0000	1.0000	0.3683
Simulated	0.0290	0.2500	0.3000	0.4590	0.6000	1.0000	0.2855

the gap is increased in a systematic way: higher density is observed on lower prices. The only clear decrease of the predicted-observed gap is observed in the case of treatment 2.

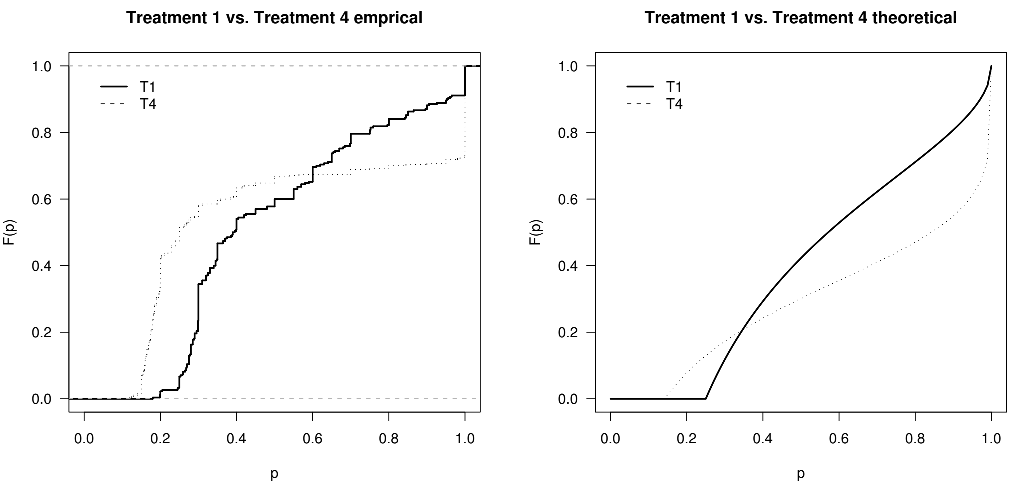
Figures 13 and 14 organize the same graphs in a way which enables us to test the predictive power of the theoretical model's comparative statics. Like in the case of GGPP, the only hypothesis which is systematically confirmed concerns the comparison between T1 and T4 referring to the prediction concerning the number of firms in the market under complete coverage. Thus, the general hypothesis (HG in GGPP) concerning the rotation of price distribution clockwise with increases in the number of firms in the market (Varian, 1980) is robust to the alternative designs implemented here and in GGPP.



(a) Treatment 1 vs 2



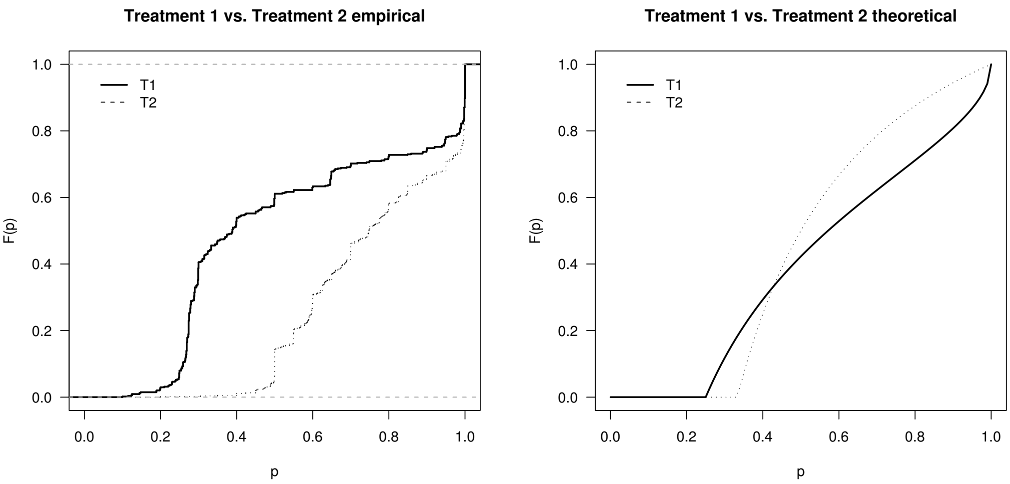
(b) Treatment 4 vs 5



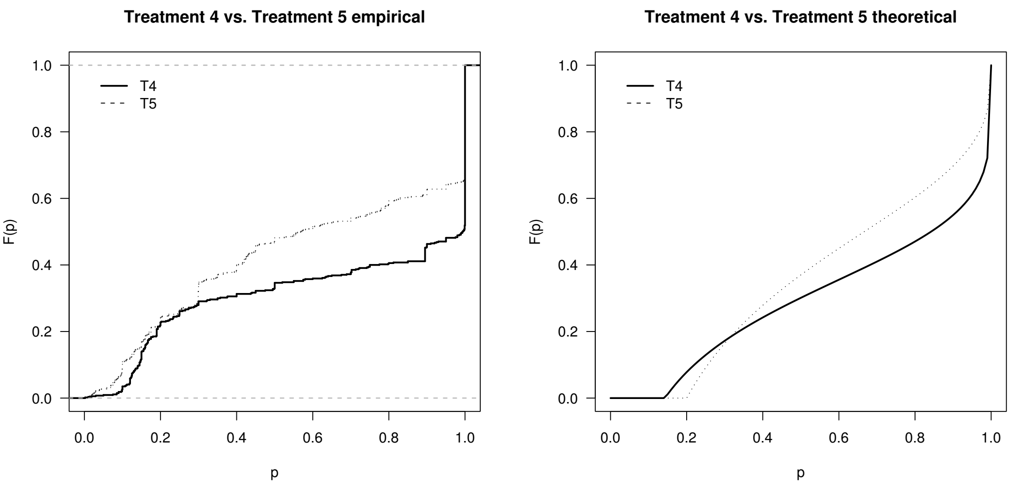
(c) Treatment 1 vs 4

FIGURE 13

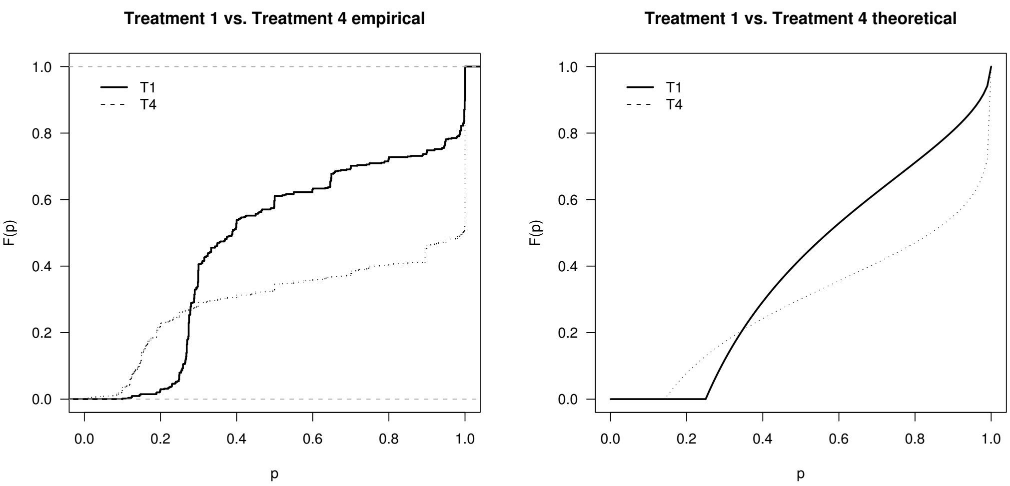
Comparisons of cumulative price distributions.



(a) Treatment 1 vs 2



(b) Treatment 4 vs 5

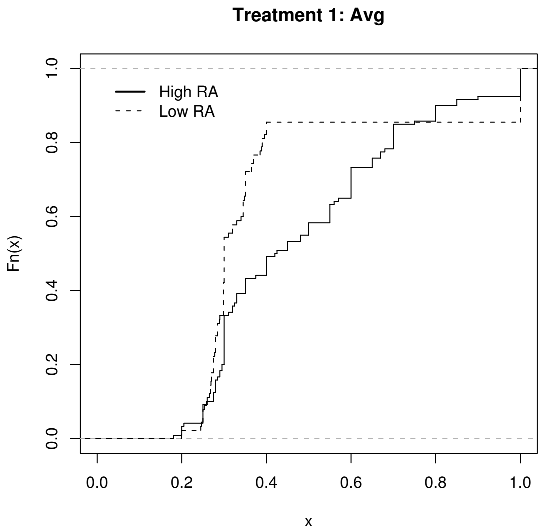


(c) Treatment 1 vs 4

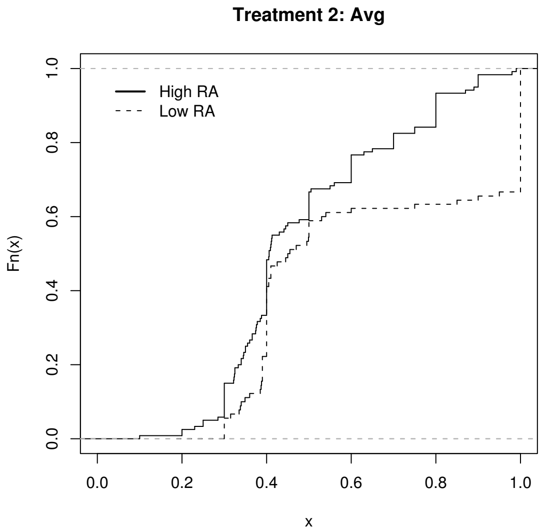
FIGURE 14

Comparisons of cumulative price distributions (GGPP).

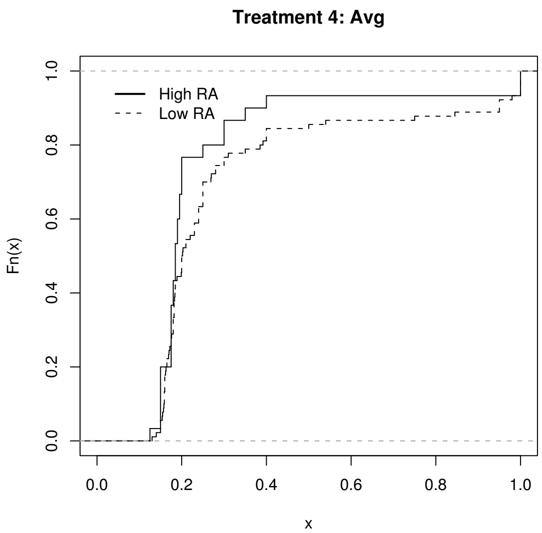
4.3. *Risk and pricing behavior*



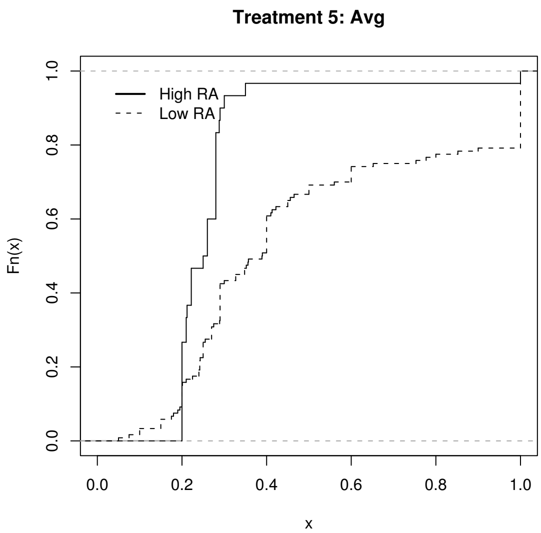
(a) Treatment 1



(b) Treatment 2



(c) Treatment 4

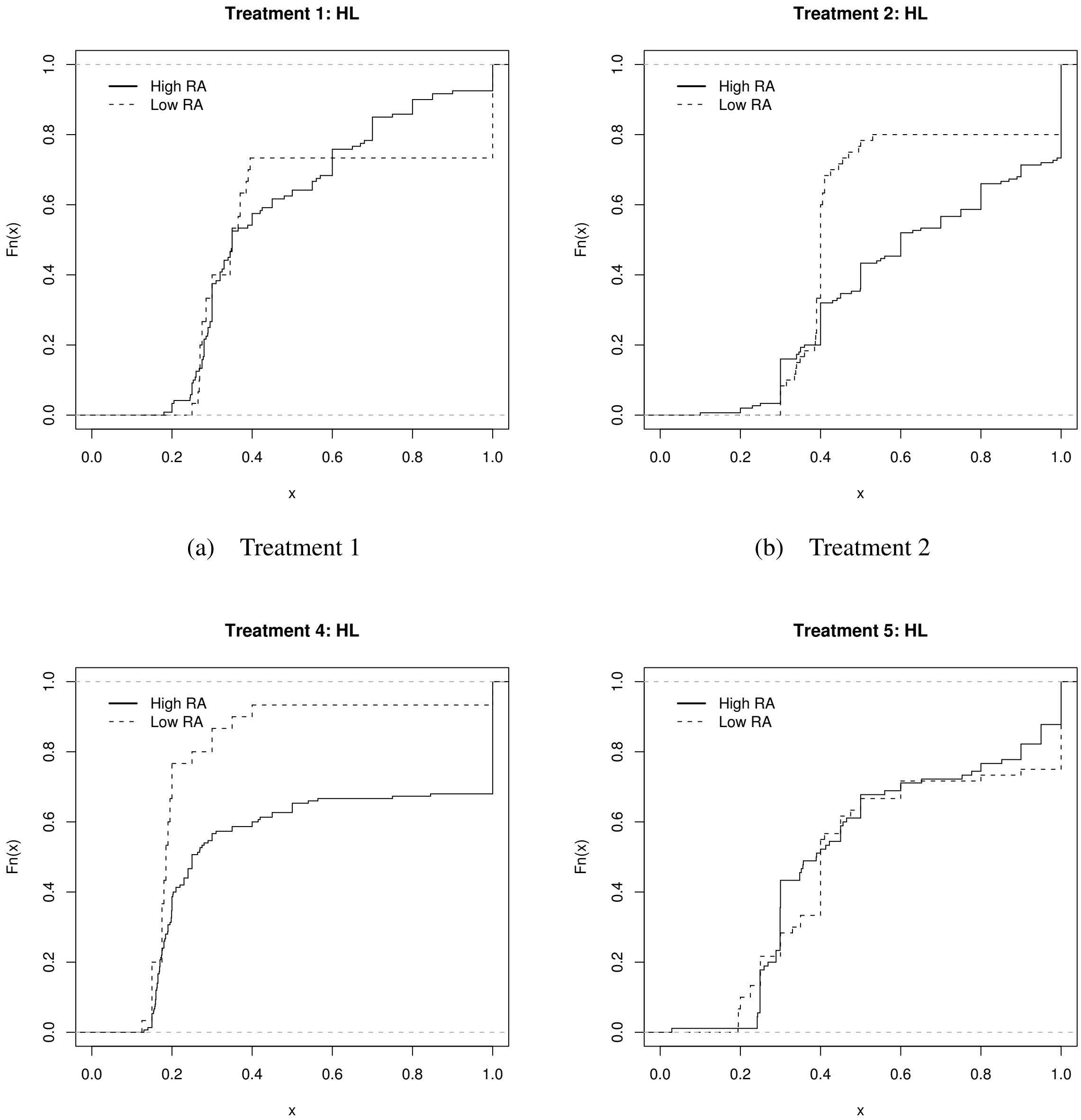


(d) Treatment 5

FIGURE 15

Price distributions by degree of risk aversion: Avg.

Unlike GGPP, in which a single measure of risk attitudes was used, we can compare here the two economic domain-related tests with respect to their role as a criterion for classifying and organizing the observed pricing behavior. In order to do that, we classify the subjects according to their choices in the two tests under three equally sized groups labeled as high, low and medium risk aversion. In order to obtain a clearer result we take the low and high risk aversion ones and compare their corresponding cumulative price distributions. This is done in figures 15 and 16. Both tests seem to indicate that, in treatment 1, low risk aversion subjects set prices with an accumulation point on $p = 1$ leading to cumulative distributions which rotate clockwise with respect to the prices of high risk aversion subjects. Treatment 2 and 4 data are organized in



(a) Treatment 1

(b) Treatment 2

(c) Treatment 4

(d) Treatment 5

FIGURE 16

Price distributions by degree of risk aversion: HL.

totally different ways by classifications under the two alternative tests, as the lottery panel test predicts that low risk aversion subjects' prices have more density on higher prices (especially on $p = 1$), while the Holt and Laury (2002) lotteries predict just the contrary. Finally, while the Holt and Laury (2002) test cannot distinguish between behavior by low and high risk aversion subjects in treatment 5, the lottery panel test predicts that low risk aversion subjects' prices in treatment 5 have a higher density on higher prices. In fact, the prediction that highly risk averse subjects set lower prices is also consistent with the corresponding result reported by GGPP on session in which all agents were represented by human subjects. The consistency of the prediction of the lottery panel test for treatments 4 and 5 offers a possible explanation for the systematic deviation between observed and predicted behavior in these treatments as reported in the comment on figure 11. That is, the observed higher density on lower prices may be the result of behavior by highly risk averse subjects.

5. CONCLUSIONS

We report results from an experiment aimed to extend our previous work on pricing behavior in markets with Internet-assisted consumer search. The richer description of subjects' attitudes towards risk elicited in environments within the economic domain and the isolation of individual behavior form uncontrolled, "other-regarding" beliefs and behavior have produced new insights on the relation between individual decision making and strategic interaction in settings leading to equilibrium price dispersion.

The present design extends the GGPP experiment in two different ways. First, we aim at studying individual behavior in isolation of factors concerning the behavior of "others" and subjects' uncontrolled beliefs with respect to rival risk preferences and thus pricing behavior. In order to do that, we have run sessions in which rather than using interacting human agents, we have faced each subject with a market in which the behavior of "others" is simulated and corresponds to realizations of a variable distributed according to equilibrium price distributions. This is an important step towards a better understanding of individual behavior in the presence of mixed strategy equilibrium play in isolation of other uncontrolled sources of uncertainty related with the subject-matching protocol and the typology of human behavior or subjects' beliefs regarding their rivals' types.

Second, we have used psychometric and economic tests to elicit our subjects preferences towards risk. We find that the latter can be used to meaningfully organize the observed pricing behavior. However, the resulting taxonomy of risk-related effects on pricing, may differ depending on the test used. This is despite the fact that there is some correlation between the two tests used here, especially in cases in which the stakes are of similar sizes.

However, the lottery panel test rather consistently predicts that both under complete and incomplete coverage of prices in markets with many firms, highly risk averse players set lower prices, which may serve as an explanation of the systematic deviation of observed prices from the theoretical prediction in the sense of first order stochastic dominance. In the presence of few firms and complete coverage of prices by the search engine, both tests agree on the fact that low risk aversion subjects' price distributions rotate clockwise with respect to those posted by highly risk averse subjects.

A. APPENDIX: INSTRUCTIONS OF THE MAIN EXPERIMENT (TRANSLATED FROM SPANISH)

- The purpose of this experiment is to study how subjects take decisions in specific economic contexts. The approximate duration of the session will be of on hour and a half. This experiment is part of a research project which has received public financial support. Therefore, your decision making in this session is going to be of great importance for the success of this research. Follow the instructions carefully. At the end of the session you will receive an amount of money in cash that will depend on your performance during the session. We describe next the economic scenario in which the decision making will take place.

- The environment is an industry characterized by:

  (a) A number of firms which will remain constant through the session. Each firm produces a homogeneous product, and this product is the same for all firms,

  (b) A price comparison search engine like the ones on the Internet,

  (c) 1,200 consumers.

- You are *one* of the firms in the industry. *At the beginning of the session, the number of firms in the industry will appear at your screen.*

- The session will consists of *50 rounds*. Each round you and the rest of the firms in the industry have to decide *the price* at which you want to sell the product. Price is your only decision variable.

- For simplicity, your production costs are zero, so that, each period, your profits will be equal to your revenue (PRICE x *N* of consumers you sell to).

- Each period, the *Price Search Engine* lists the price of *all* (*Treatments 2 and 5*:several but *not all*) firms in the industry. (*Treatments 2 and 5*:*The number of firms which will be part of the search engine will appear at your screen at the beginning of the session.*)

- In particular, the search engine chooses randomly the firms that are going to be part of it in each period, and the prices of that firms will be included in the list.

- Transactions will take place in *UMEX*, our lab's Experimental Monetary Unit.

- Each consumer wants to buy one unit of the product per round. The maximum willingness to pay of each consumer for a unit of the product is 1,000 UMEX. That is, if the price you fix is higher than 1,000 UMEX, no body will buy from you.

- There are two types of consumers. Half of them are consumers who read the list of prices created by price search engine. The other half do not actually read the list of prices of the search engine (maybe because they are not able to do so). The master program of the computer will simulate the consumers' reactions.

- The consumers who read the price list of the search engine will buy, each period, from the firm whose price for that period is the lowest *among all prices included in the price list*, if such price does not exceed 1,000 UMEX. In case of a "tie" (i.e. several firms fix the same minimum price) the consumers are distributed evenly among the firms with the same minimum price.

- The consumers who do not read the search engine's price list will buy ramdomly from any vendor, so that this group of consumers will be distributed evenly among all firms in the industry.

- In each round, the firms you compete with will be randomly selected among the 18 participants of this session. Therefore, the probability of competing with the same firms in 2 different periods is very low.

Feedback

- At the end of each round, you will see on your screen the information of (*Treatments 2 and 5:* of whether you were part of the search engine), your own sales and your earnings for that round.

- All over the session, you will see on your screen a history that includes information about you own sales, your earnings, and the prices fixed by your competitors in the past.

Payoffs

- At the end of the session you will be paid in cash. Your reward will be determined taking into account the earnings you accumulate over 10 (randomly selected) out of the total 50 periods. The exchange rate will be: 1,000,000 UMEX = 12 € (if you are part of a market of 3 firms), or 1,000,000 UMEX = 24 € (if you are part of a market of 6 firms).

Thank you very much for your collaboration. Good luck!

REFERENCES

[1] BAYE, M., R. GATTI, P. KATTUMAN, AND J. MORGAN (2003): Did the Euro Foster Online Price Competition? Evidence from an International Price Comparison Site. Indiana University.

[2] BAYE, M., D. KOVENOCK, AND C. DEVRIES (1992): It Takes Two to Tango: Equilibria in a Model of Sales. Games and Economic Behavior, vol. 4, pp. 493-510.

[3] BAYE, M. AND J. MORGAN (2001): Information Gatekeepers on the Internet and the Competitiveness of Homogeneous Product Markets. American Economic Review, vol. 91(3), pp. 454-474.

[4] BRADLOW, E. AND D. SCHMITTLEIN (1999): The Little Engine that Could: Modeling the Performance of World Wide Web Search Engines. Marketing Science, vol. 19(1), pp. 43-62.

[5] BRYNJOLFSSON, E. AND M. SMITH (2000): Frictionless Commerce? A Comparison of Internet and Conventional Retailers. Management Science, vol. 46(4), pp. 563-585.

[6] BURDETT, K. AND K. JUDD (1983): Equilibrium Price Dispersion. Econometrica, vol. 51, pp. 955-969.

[7] CASON, T. AND S. DATTA (2005): Costly Buyer Search in Laboratory Markets with Seller Advertising, Working Paper, Purdue University.

[8] CASON, T. AND S. DATTA (2006): An Experimental Study of Price Dispersion in an Optimal Search Model with Advertising. International Journal of Industrial Organization. Forthcoming.

[9] CASON, T. N. AND D. FRIEDMAN (2003): Buyer Search and Price Dispersion: a Laboratory Study. Journal of Economic Theory, vol. 112, pp. 232-260.

[10] DIAMOND, P. (1971): A Model of Price Adjustment. Review of Economic Theory, vol. 3, pp. 156-178.

[11] GARCÍA-GALLEGO, A., N. GEORGANTZÍS, P. PEREIRA AND JC. PERNÍAS: (2004), Risk Attitudes and Internet Search Engines: Theory and Experimental Evidence., Working Paper 04-03, NET Institute.

[12] GEORGANTZÍS, N., M. GENIUS, A. GARCÍA-GALLEGO, AND G. SABATER (2003): Testing for Risk-Return Tradeoffs in Individual Decision Making. Working Paper 43/03, LINEEX, Valencia.

[13] GUIMARAES, P. (1996): Search Intensity in Oligopoly. Journal of Industrial Economics, vol. 44, pp. 415-426.

[14] HOLT, C. A. AND S. K. LAURY (2002): Risk Aversion and Incentive Effects. American Economic Review, vol. 92, pp. 1644-1655.

[15] HOLT, C. A. AND S. K. LAURY (2005): Risk Aversion and Incentives without Ordering Effects. American Economic Review, vol. 100, pp. 1-16.

[16] IYER, G. AND A. PAZGAL (2000): Internet Shopping Agents: Virtual Co-Location and Competition. Marketing Science, vol. 22, pp. 85-106.

[17] KEPHART, J. AND A. GREENWALD (1999): Price-Comparison Site Economics. IBM Institute for Advanced Commerce.

[18] LAWRENCE, S. AND C. GILES (1998): Searching the World Wide Web. Science, vol. 280(3), pp. 98-100.

[19] LAWRENCE, S. AND C. GILES (1999): Accessibility of Information on the Web. Nature, vol. 400, pp. 107-109.

[20] MONTGOMERY, A., K. HOSANAGAR, R. KRISHNAN, AND K. CLAY (2001): Designing a Better Price-Comparison Site. School of Industrial Administration.

[21] MORGAN, J., H. ORZEN, AND M. SEFTON (2005): An Experimental Study of Price Dispersion. Games and Economic Behavior. Forthcoming.

[22] PEREIRA, P. (2004a): Do Lower Search Costs Reduce Prices and Price Dispersion? Information Economics and Policy, vol. 17 (1), pp. 61-72.

[23] PEREIRA, P. (2004b): Search and Destroy: Competition between Search Engines and Consumer Prices. Portuguese Competition Authority.

[24] ROSENTHAL, R. (1980): A Model in Which an Increase in the Number of Sellers Leads to a Higher Price. Econometrica, vol. 48, pp. 1575-1579.

[25] PRESS, W. H., AND TEUKOLSKY, S. A., VETTERLING, W. T., AND FLANNERY, B. P. (1992): Numerical Recepes in C. The Art of Scintific Computing, 2nd ed. Cambridge University Press.

[26] SABATER, G. AND N. GEORGANTZÍS (2002): Accounting for Risk Aversion in Repeated Prisoners' Dilemma Games. Journal of Economic Behavior and Organization, vol. 48, pp. 37-50.

[27] SAMUELSON, L. AND J. ZHANG (1992): Search Costs and Prices. Economics Letters, vol. 38, pp. 55-60.

[28] STAHL, D. (1989): Oligopolistic Pricing with Sequential Consumer Search. American Economic Review, vol. 79, pp. 700-712.

[29] TORRUBIA, R., ÁVILA, C., MOLTÓ, J. AND X. CASERAS (2001): The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a Measure of Gray's Anxiety and Impulsivity Dimensions. Personality and Individual Differences, vol. 31, pp. 837-862.

[30] VARIAN, H. (1980): A Model of Sales. American Economic Review, vol. 70, pp. 651-659.

[31] ZUCKERMAN, M. (1978): Sensation Seeking. In H. London and J Exner (eds.), Dimension of Personality. New York: John Wiley & Sons.