Human Traders across Multiple Markets: Attracting Intra-marginal Traders under Economic Experiments

Jung-woo Sohn
College of Information Sciences and Technology
The Pennsylvania State University
University Park, PA 16802, USA
+1-814-863-2480
jwsohn@ist.psu.edu

Anthony M. Kwasnica
Smeal College of Business
The Pennsylvania State University
University Park, PA 16802, USA
+1-814-863-0542
kwasnica@psu.edu

Tracy Mullen
College of Information Sciences and Technology
The Pennsylvania State University
University Park, PA 16802, USA
+1-814-865-6425
tmullen@ist.psu.edu

ABSTRACT
We conducted human-subject market experiments to check the effects of charging different types of market fees on human trader's market selection behavior across multiple markets. In alignment with previous findings using software trading agents, a market charging lump-sum registration fees attracted intra-marginal or high-value human traders, while, extra-marginal traders, or low-value traders, were more likely to select a market charging a fixed-rate profit fee. The experiment data suggests that human trader behavior might also have been influenced by criteria such as loss aversion or potential risk averseness.

Categories and Subject Descriptors
J.4 [**Social and Behavioral Sciences**]: *Economics*
I.2.11 [**Distributed Artificial Intelligence**]: *Intelligent agents*

General Terms
Design, Economics, Experimentation, Human Factors, Verification

Keywords
Multiple markets, competing markets, market selection strategy, trading agent, CAT tournament, JCAT, economic experiment, human behavior, market design

1. INTRODUCTION
In a highly interconnected and online world, traders increasingly face the problem of selecting the best market for their buying or selling activities from several available marketplaces. A seller might choose to sell her IBM stocks in New York Stock Exchange (NYSE) in US or she can list them on the Bombay Stock Exchange (BSE) in India. [2]

However, as Cai et al. [1] points out, there exist little research on the market selection behaviors of a trader. Under this multiple market scenario, markets can have different prices and exchange rules (such as fee charges) as well. Clearly, a trader wants to go to the market where she can maximize her profit among several different marketplaces.

The CAT tournament and JCAT market simulation platform [3] is specifically interested in this kind of scenario where traders can have more than one choice for market selection and markets compete against each other. Results from the CAT tournament and JCAT market simulation platform, include work by Niu et al. [3] suggesting that attracting intra-marginal traders[1] is a key factor in trader market selection behavior when multiple markets are competing against each other. By attracting larger numbers of intra-marginal traders competing markets can often acquire more profit, larger market share, and have a higher chance of matching traders successfully.

Niu et al. [3] also report that a market charging a registration fee, basically a lump-sum fee charged to the trader when entering the market for a trading period, tends to attract intra-marginal traders and drive out extra-marginal traders. On the other hand, Niu et al. also report that charging a profit fee, essentially a fixed-rate fee charged on the profit made in a trading period, tends to attract extra-marginal traders. We consistently identified the same results with the PSUCAT market specialist as well. [6]

In this study, we aim to extend these findings to human traders, focusing on the registration fee and profit fee effect in attracting intra-marginal traders. While simulations with intelligent software agents is known to be an effective tool to analyze complex systems such as markets, we seek to assess if there is a gap between the human market selection behavior and that of software agents. In particular, we wish to (1) check if human traders market selection behavior is similar to software trading agents and intra-marginal traders are attracted to the registration fee market, (2) more generally compare human trading behavior with that of software trading agents, and (3) draw preliminary implications of how we might model human trader market selection behavior in

[1] Intra-marginal traders can be defined as buyers willing to pay higher price than market equilibrium price. (or sellers willing to sell at lower price than market equilibrium price) Conversely, extra-marginal traders are defined as buyers who want to pay lower price than market equilibrium price (or sellers willing to sell only at higher price than market equilibrium price)

software trading agents by modifying existing market selection algorithms and charging policies. For this purpose, we conducted controlled economic experimental sessions with human traders under similar setup as in the CAT tournament.

In our study, it is found that the market selection models and the findings from the JCAT simulations align well with the economic experiment results with human traders. However, there may be other factors to consider such as possible loss-aversion in human traders and their potential risk-averseness when locating a trading partner.

2. PROBLEM DESCRIPTION

2.1 Trader Market Selection under Multiple Market Scenario

The objective of a trading agent in a market can be simply summarized as the maximization of the total trading profit. To make a trading profit, a trader has to find a trading partner and successfully transact, i.e. a buyer needs a seller and a seller needs a buyer. Under the multiple market scenarios a trader also needs to determine which market will be a *better* place to make more money from trading.

To do this, a trader must consider the effect of market policies (e.g., charging policy, shout accepting policy, clearing policy, and pricing policy) on trader payoffs. Our work limits the scope of market policy to charging policy and primarily addresses the effect of trader market selection behavior across two markets, one with a registration fee and one with a profit fee. Clearly traders will prefer a market charging policy that results in a lower fee, assuming of course that the two markets provide equal chances to find a good trading partner.

Recall that a registration fee can be defined as a lump-sum fee that a market charges when a trader enters the market for a trading period. As a simple illustrative example, consider the entrance fee for an amusement park; once the fee is paid, you can remain in the park the whole day riding the rides for free. Similarly, once a trader pays the registration fee of $1, for example, he or she is allowed to spend the entire trading period in the market.

On the other hand, a trader does not need to pay any entrance fee when the market charges profit fee. The trader is free to enter the market for a trading period. However, if the trader makes a trade, then the market charges for a fixed-rate fee calculated on the net profit. For example, suppose the market charges 10% of the profit fee and the trader earned $20 for the trading period. Then the profit fee market charges $2 which is 10% of $20 profit when the trading period is over.

2.2 Market Selection in CAT Tournament

The default trader market selection strategy adopted in CAT tournament and JCAT market simulation platform is based on N-Armed bandit algorithm where traders select the market with the highest profit history in the exploitation state and randomly select between markets in the exploration state. The exploitation and the exploration stages are randomly mixed between $1 - \varepsilon$ and ε. In CAT tournament, ε is set to 0.1 as default; 90% of time traders look for the market with the highest profit history so far and 10% of time traders randomly select from the available markets.

2.3 Experimental Prediction under Competitive Equilibrium Setting

A prediction model based on competitive equilibrium and price-taker assumptions is built up to configure experimental parameters and to estimate or predict experiment results in advance of running actual experimental sessions. The competitive equilibrium and price-taker assumptions are typically adopted as a preliminary prediction for economic experimental designs and we tried to apply the technique to our experiment with sealed-bid auction matching for simplification purpose.

Starting from previous work [5] with game-theoretic analysis, we assumed that traders will end up in one of the Nash equilibrium states given the market selection choices for two markets. The typical pattern in the equilibria is that traders tend to pair-up in the *same* market with the trading partner as is in the famous battle-of-the-sex game. Table 1 shows a market selection case when a buyer and a seller select between two free markets. Both traders want to stay together either in market 1 or market 2 to be matched into a transaction, but they obtain zero payoffs when separated since they cannot have any transactions.

Now when there are more than two traders available, they form pairs depending on the degree of their private values; for example, when two buyers B1, B2 have the private values 150, 130, respectivly and two sellers S1, S2 have the private values 50, 70, the traders form pairs such as (B1, S1) and (B2, S2) for their market selections. In short, a trader is willing to stay in the same market as his or her trading partner stays. [5] Table 2 shows the Nash equilibria for this four intra-marginal trader case. Markets are assumed to be clearing-houses.

Table 1. Market selection model for one buyer and one seller with private value 150 and 50. [5]

	Seller selects market 1	Seller selects market 2
Buyer selects market 1	**(50, 50)**	(0, 0)
Buyer selects market 2	(0, 0)	**(50, 50)**

Table 2. Nash equilibria for market selection behaviors with four intra-marginal traders. All markets clear at p*=100

	Market 1	Market 2
NE case 1	(B1, S1), (B2, S2)	
NE case 2	(B1, S1)	(B2, S2)
NE case 3	(B2, S2)	(B1, S1)
NE case 4		(B1, S1), (B2, S2)

With the profit fee fixed to 10% for convenience, we tried to find appropriate registration fee level for experiments which triggers the separation effect in market selections between intra-marginal and extra-marginal traders.

We assumed that human traders will first consider one of the Nash equilibria under two *free* markets for their possible market selection decisions. Then they apply the effect of the registration fee (and profit fee) to the Nash equilibria found and check which Nash equilibria will actually result in higher net payoffs for them.

In this setup, we also assumed that traders are behaving as price-takers with the market clearing at the competitive equilibrium price of p^*. Depending on their net profit comparison results, we assumed that human traders will prefer certain Nash equilibria to others (or update their decision) under the given the fee policy and their private values.

Table 3 shows the Nash equilibria categorization result with respect to different trader private values, with the registration fee set to 1 and the profit fee set to 10%. It can be seen that intra-marginal traders prefer to select registration fee market more frequently since they obtain more profit and extra-marginals prefer the profit fee market, while buyers with private value 110 and sellers with 90 are indifferent between selecting the registration fee market and the profit fee market, obtaining the same amount of profit for both markets. Because of the high complexity of problem search space, we wrote a simple script to compute the Nash equilibria and the payoffs. Similar tables were constructed for other fee cases such as registration fee 2, 3, and 4, with profit fee fixed at 10%.

Table 3. Trader preferences on Nash Equilibria in market selection. (Registration fee = 1, Profit fee = 10%)

Buyer private value	Seller private value	Buyer prefer RF mkt	Buyer prefer PF mkt	Seller prefer RF mkt	Seller prefer PF mkt
150	50	2212	956	2212	956
140	60	2212	956	2212	956
130	70	2212	956	2212	956
120	80	2212	956	2212	956
110	90	**956**	**956**	**956**	**956**
100	100	956	2212	956	2212
90	110	956	2212	956	2212

Table 4 is the summary for the *indifference* points where traders are indifferent between choosing registration fee market and profit fee market for other combinations of registration fee and profit fee. In other words, traders obtain the same profit whichever market they choose when the registration fee and profit fee are set to those listed in Table 4.

Table 4. Trader private values predicted to be indifferent between two markets

(RF, PF)	(1, 10%)	(2, 10%)	(3, 10%)	(4, 10%)
private value	buyer:110 seller: 90	buyer:120 seller: 80	buyer:130 seller: 70	buyer:140 seller: 60

3. EXPERIMENTAL RESULTS

3.1 Experimental Setup

Our experiment setup aimed to replicate typical CAT tournament setting and our previous JCAT simulations but with one major difference. In our original experiments, we typically used 100 buyers and 100 sellers. Given the budget constraints for human subject payments in cash, we needed to reduce the number of traders into 11 buyers and 11 sellers, or 22 human traders per session. Human subjects were mostly undergraduate students who signed up from an e-mail list for announcing economic experiments.

For the software trading agents, their private values were randomly drawn from the same uniform distribution [50, 150]. Similarly, we assigned specific private values to our human traders from the interval [50, 150] as shown in Figure 1.

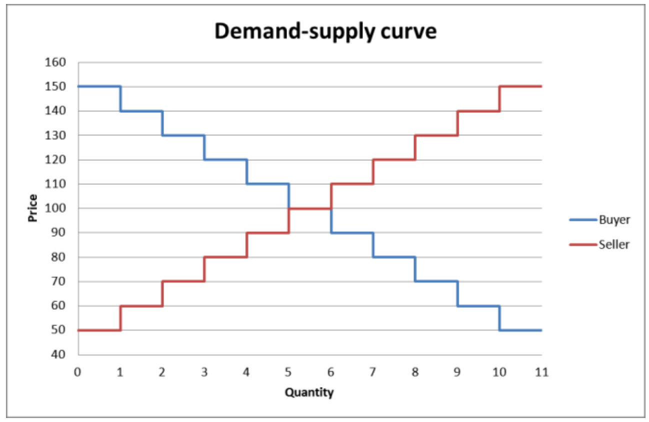


Figure 1 Demand-supply curve for human trading experiment

During each experiment, participants had one practice training sessions where the score did not count. Each experiment consisted of about 35 trading periods, where each period lasted about 1 minute. A trader first selected a market to trade in and then made bids or asks in that market for the trading period. A trader was allowed to buy or sell one unit of good (or endowment) for one period. The experiment was composed of the following periods: (1) a tutorial period on how to make market selection and actual bidding (2) one practice period without payment (3) four market-assigned periods for tutorial purpose (4) two free market periods for baseline (5) actual trading periods with different registration fee and profit fee treatments.

Traders were free to place bids (or asks) and accept available bids (or asks) as well. Clearing policy was set to continuous double auction (CDA) where both buyers and sellers were allowed to place bids or asks simultaneously. CDA is also a typical setup for economic auction experiments. A total of seven experiments were conducted. Data in this paper were collected from four experiments, with the treatment drawn from (registration fee, profit fee) = (1, 10%), (2, 10%), (3, 10%), (4, 10%).

Subjects were paid in proportion to the trade payoffs for the entire experiment session plus a show-up fee of $5.

3.2 Experiment Result

Figure 2 shows the trader market selection results collected from the experiment, with the registration fee (RF) and the profit fee (PF) set to (RF, PF) = (1, 10%), (2, 10%), (3, 10%), (4, 10%). The graph shows the separation patterns for traders with intra-marginals selecting RF market more frequently and extra-marginals prefer PF market. Note the predicted *indifference* points where traders with particular private values are indifferent between selections between the two different markets as listed in Table 3.

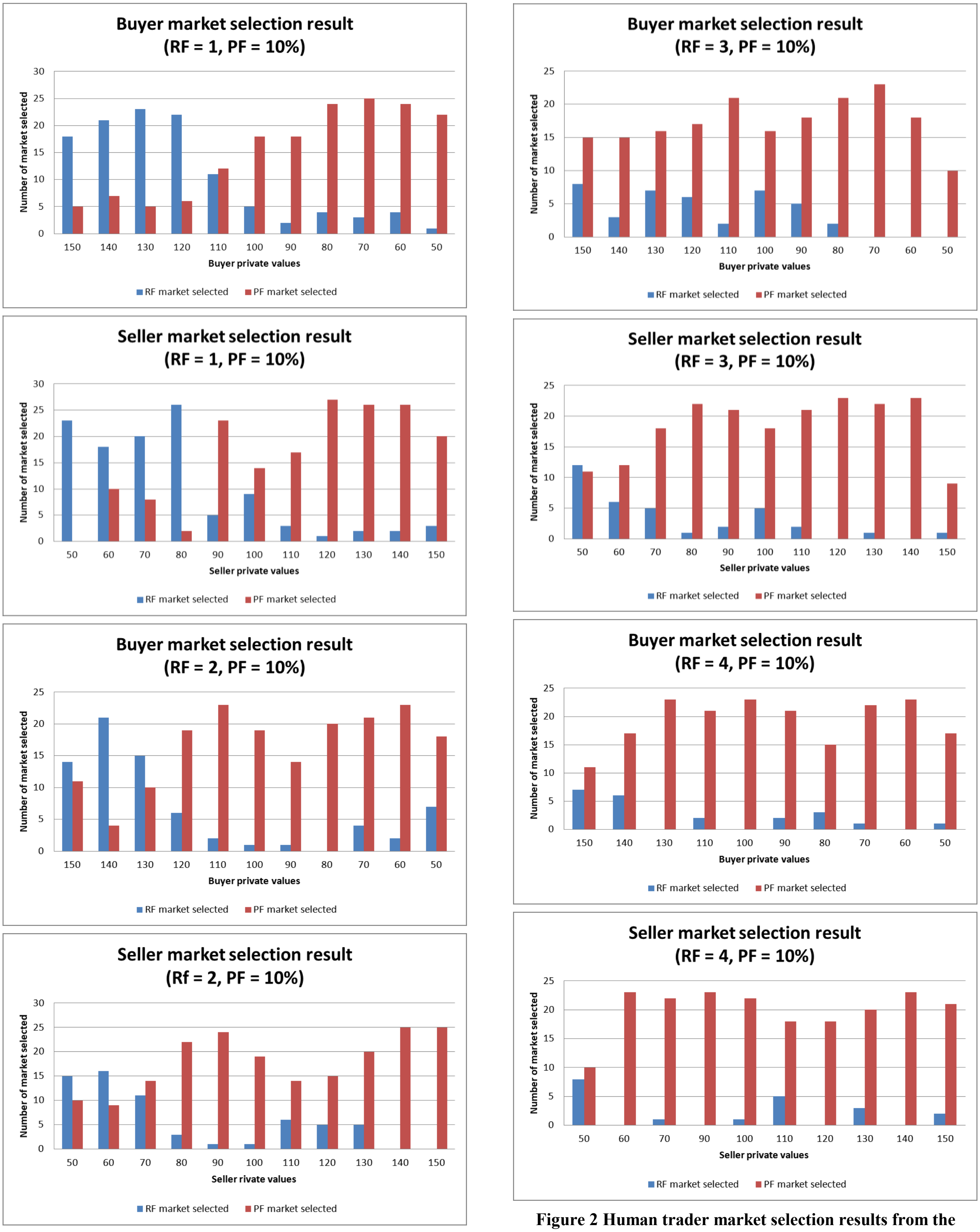


Figure 2 Human trader market selection results from the experiment

4. EXPERIMENTAL DATA ANALYSIS

4.1 Hypothesis Test

In order to check the registration fee effect, we started from applying a simplified, first-pass statistical test to the experimental data. First, we want to see whether the registration fee has any effect on market selection behaviors of the human subjects by setting up a null hypothesis. When the market selection decision from a human trader is not affected by the registration fee, his or her probability for selecting the registration fee market *p* will become 0.5 (regardless of their trader private values)

$$H_0: p = 0.5$$

In case of intra-marginal traders, the null hypothesis can be rewritten as

$$H_0: p = 0.5,\ H_1: p > 0.5$$

Similarly for extra-marginal traders, the null hypothesis will be

$$H_0: p = 0.5,\ H_1: p < 0.5$$

The market selection behavior can now be modeled as a simple coin-flipping binomial distribution with $B(n, p)$ in which the random variable is the number of the registration fee market selection cases out of *n* total market selections. Clearly, the market selection outcomes cannot be considered as independent trials since trader's current market selection might have been affected by his or her past market selection history. However, we tried to apply modeling with binomial distribution for a simple, first-pass modeling approach. In addition, independence assumption actually weakens trader learning in market selection; with independence, traders can be assumed to start from scratch every time they make a market selection decision. Rejecting null hypothesis under this assumption implies that traders are still affected by registration fee effect even when traders are assumed to be less intelligent by resetting their memory every time they make a market selection decision.

In order to apply hypothesis test technique to the experiment data, $B(n,p)$ is approximated to the normal distribution of $N(np, np(1-p))$. Table 4 and 5 shows the test results for the market selection data. Bold typeface denotes cases where p-values for buyers are lower than the significance level of 5%. p-values marked with * denotes significant cases where *p* is more than 95%.

For the case with the registration fee and the profit fee set to 1 and 10% respectively, the p-values show that the null hypothesis is rejected for the intra-marginal buyers with private values 150, 140, 130, 120 and the intra-marginal sellers with private values 50, 70, 80 under the significance level of 5%. This identifies that human traders were affected with their market selection decision by the given registration or profit fee schedule.

One interesting pattern from the result as the registration fee increases is that there were more instances of significant p-value results for traders switching to the profit fee market than the registration fee market. (more significant p-values denoted with * than with bold typefaces) While further analysis with trader payoffs is needed, it might imply that registration fee has the effect of driving out extra-marginal traders (and also driving out low-value intra-marginals who thinks the registration fee is too much for them) According to Gintis [4], this might be an instance of loss-aversion characteristic typical for human agents; when extra-marginal traders stay in the profit fee market, they do not lose any money even when they do not have any successful transaction at all. However, extra-marginal human traders might risk net negative profit when they stay in registration fee market without having any successful transactions at all; they have to pay the registration fee. Suppose human traders are prone to loss-aversion, they will be less likely to go to the registration fee market to avoid losses.

Table 5. P-values for buyer market selection outcomes

Buyer private value	RF = 1 PF = 10%	RF = 2 PF = 10%	RF = 3 PF = 10%	RF = 4 PF = 10%
150	**0.003357**	0.2742531	0.9278	0.671639
140	**0.004075**	**0.0003369**	0.997661*	0.830596
130	**0.000335**	0.1586553	0.969716*	0.97725*
120	**0.001248**	0.9953388*	0.989095*	0.95075*
110	0.582586	0.9999867*	0.999963*	0.97725*
100	0.996643*	0.9999715*	0.969716*	0.95075*
90	0.999827*	0.9996054*	0.996643*	0.908789
80	0.999921*	0.9999961*	0.999963*	0.966081*
70	0.999984*	0.9996631*	0.999999*	0.97725*
60	0.999921*	0.9999867*	0.999989*	0.96228*
50	0.999994*	0.9860966*	0.999217*	0.671639

Table 6. P-values for seller market selection outcomes

Seller private value	RF = 1 PF = 10%	RF = 2 PF = 10%	RF = 3 PF = 10%	RF = 4 PF = 10%
50	**8.1E-07**	0.1586553	0.417414	0.671639
60	0.065285	0.0807567	0.92135	0.830596
70	**0.011671**	0.7257469	0.996643*	0.97725*
80	**2.87E-06**	0.9999277*	0.999994*	0.95075*
90	0.999665*	0.9999979*	0.999963*	0.97725*
100	0.851427	0.9999715*	0.996643*	0.95075*
110	0.999127*	0.9631809*	0.999963*	0.908789
120	1*	0.9873263*	0.999999*	0.966081*
130	0.999997*	0.9986501*	0.999994*	0.97725*
140	0.999997*	0.9999997*	0.999999*	0.96228*
150	0.999804*	0.9999997*	0.994294*	0.58793

4.2 Maximum Likelihood Estimation of Selecting the Registration Fee Market

With the statistical significance information from the experiment data, we can now estimate the actual probability of p_{est} to select the registration fee market with respect to trader private values. We used maximum likelihood estimation (MLE) technique to estimate the parameter p_{est} from the assumed distribution of $B(n, p)$. Again, i.i.d (independent and identically-distributed) assumption is important for maximum likelihood estimation and dependency problems might possibly arise in the trader market selection behavior from one trading period to another. Therefore, we are considering the use of MLE technique only to have a first-pass, big-picture view on the experimental data.

When the market selection behavior X_i follows the binomial distribution of $B(n, p)$, the likelihood function for a human trader to choose the registration fee market *k* times (out of *n* total periods) can be written as follows.

$$L = f(x_1, x_2, \ldots, x_n) = \prod f(x_i) = p^k (1 - p)^{n-k}$$

Given the data from the experimental outcome, p will maximize the likelihood function L. Taking the first-order derivate of L and setting it to zero, we have

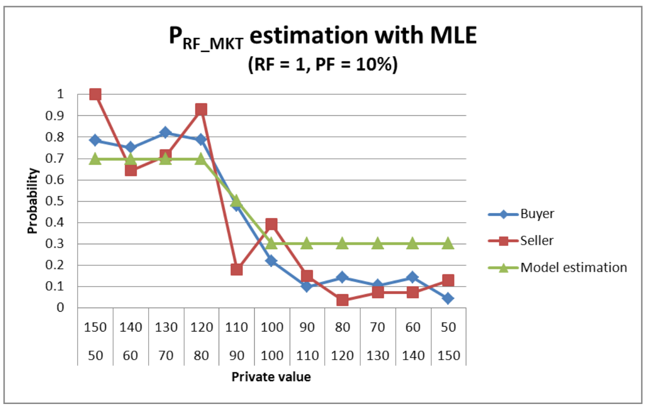
$$k\,p^{k-1}\,(1-p)^{\,n-k} - (n-k)\,p^{k}\,(1-p)^{\,n-k-1} = 0$$

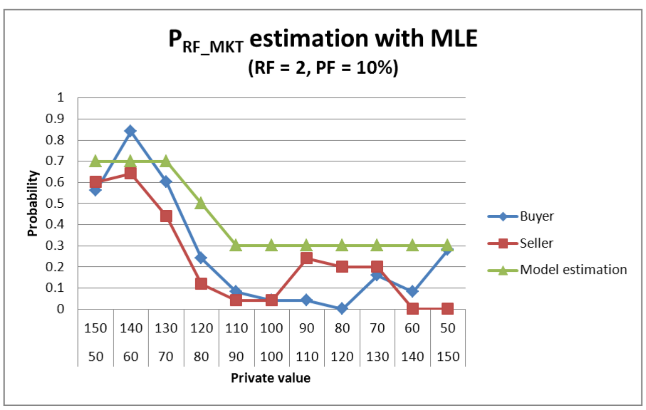
$$p^{k-1}(1-p)^{n-k-1}(k-np) = 0$$

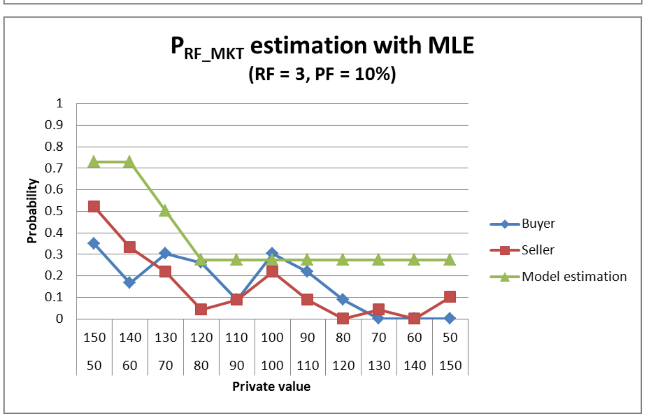
Therefore, the optimal p that maximizes the likelihood function L is

$$p_{est} = k / n$$

Figure 3 shows the plot of p_{est} for different (RF, PF) treatments. It can be seen that the maximum likelihood estimate of p_{est} follows the pattern predicted by our competitive-equilibrium based model; intra-marginal traders are more likely to select the registration fee market and extra-marginals are more likely to stay away from the registration fee market.







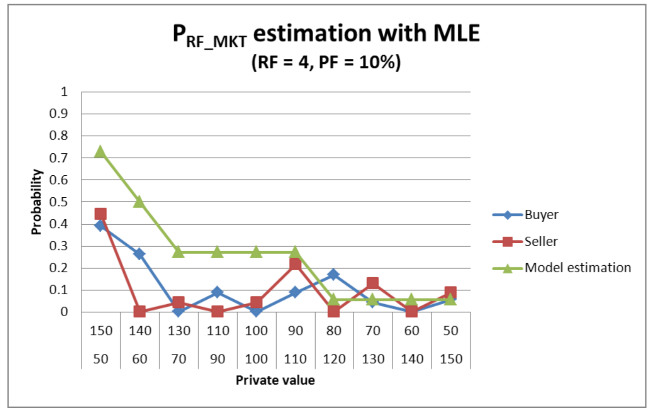


Figure 3. MLE estimation of the probability to choose RF market with respect to trader private values

5. DISCUSSION

First, one interesting finding from Figure 3 is that human traders might leave the registration fee market earlier than model prediction as the registration fee goes up. When RF = 1, human intra-marginal traders are more likely to select the RF market than the model prediction of the probability 0.6982. When RF = 2, human intra-marginal traders exhibit a similar probability for choosing the RF market as is predicted in the model. But when RF is increased to 3 or 4, they become less likely to stay in the RF market and switch to the PF market. This occurs earlier than the model prediction.

While there might be several factors affecting this phenomena, we speculated that one reason may be that human traders exhibit risk-averse characteristics when finding a trading partner, causing them to make an early switch to the PF market and possibly find a trading partner more easily. We plan to conduct further analysis on this by further analyzing the payoff data and trading partner match information.

Second, there is an asymmetry between the probability of intra-marginal traders choosing the RF market and the probability for extra-marginal traders to choose the PF market. Intra-marginal traders rarely select the RF market more than 80% as shown in Figure 3 and this probability goes down as the RF increases. However, the probability of extra-marginal traders choosing the PF market often achieves 90% (100% - 10%) or more. Also, the model prediction shows symmetry between the two market selection probabilities; for example, when RF = 1, the model plot shows symmetry around 0.5, with the probability plot values starting from 0.7, going down to 0.5, and then to 0.3.

As discussed shortly in the previous p-value analysis part, this might be related to loss-aversion in human traders where traders want to avoid earning net negative payoffs. It should be noted that this loss aversion can be categorized as anomaly in human behavior which cannot be easily captured by rational decision-making agent models. [4]

There were other possibilities of anomaly or semi-rational behaviors observed in the experiments. While not listed in this paper, the experiment data also shows that human traders do not go to the fee-charging market when one market is free of charge and the other market charges fees. (such as RF = 1, PF = 0%) The original software trader market selection strategy based on the N-armed bandit algorithm might not capture this easily; it needs to build up payoff history to learn that free market is better than fee-charging market. However, human traders tend to go directly to free market from the start.

Finally, there is some anomalous behavior that shows that human traders are slightly more likely to choose the RF market when trader private values are around [100, 70] for buyers and [100, 120] for sellers with theoretical market clearing price p^* of 100. We leave this as another future research work suspecting possible anomaly from human trading behaviors bidding around 100.

In addition, we are also considering extending the current simple MLE technique to a logit regression, to discover a potential new market selection model. Checking which variables are explanatory for market selection behaviors will be interesting. There are also other observations that need further investigations: some human traders stayed at one market regardless of the fee schemes. Under this situation, checking the market selection behavior of the other trading partner (or how she learns her partner is in the different market) can be an interesting work since it might suggest the process how traders learn about ongoing market situations. Finally, sellers had larger payoffs in one experiment session even when the number of buyers and sellers were equal. Investigating on how buyers were able to get more payoffs in this particular case and possibly exploit on seller payoffs is left as another future research work.

6. ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from Seed Grant Program, College of Information Sciences and Technology, The Pennsylvania State University. We also thankfully acknowledge the use of economics laboratory facility from Laboratory for Economics Management and Auctions (LEMA), Smeal College of Business, The Pennsylvania State University. This study is approved by IRB #30912, The Office for Research Protections, The Pennsylvania State University.

7. CONCLUSION

In this preliminary study, we tried to extend the finding for trader market selection behavior modeled from CAT tournament findings and JCAT market simulation platform into economic experiment with real human traders. The experimental results show that the findings align well with the previous market selection behavior results from software agent simulations. When the market charges registration fee, intra-marginal traders were selecting the registration fee market more frequently. On the other hand, extra-marginal traders went to the profit fee market more frequently and avoid the registration fee market. We were able to identify this with simple statistical technique such as binomial distribution, hypothesis testing, and the maximum likelihood estimation of market selection probabilities. We hope that our preliminary finding can contribute to the refinement of software trading agent design, especially market selection strategies under multiple market scenarios.

8. REFERENCES

[1] Cai, K. Niu, J. and Parsons, S. On the Economic Effects of Competition between Double Auction Markets. In *Proceedings of the Tenth Workshop on Agent-Mediated Electronic Commerce (AMEC X)*, Estoril, Portugal, May 2008

[2] Hasbrouck, J., 1995, *One Security, Many Markets: Determining the Contributions to the Price Discovery*, Journal of Finance, Vol. 50 (4), pp. 1175, Waverly Press Inc., New York.

[3] Niu, J., McBurney, P., Gerding, E. and Parsons, S., 2008, *Characterizing Effective Auction Mechanisms: Insights from the 2007 TAC Market Design Competition*. In Proceedings of the 7th International Conference on Autonomous Angents and Multi-Agent Systems, Estoril, Portugal

[4] Gintis, H. *Beyond Homo economicus: evidence from experimental economics*, Ecological Economics, Volume 35, Issue 3, December 2000, Pages 311-322, ISSN 0921-8009, DOI: 10.1016/S0921-8009(00)00216-

[5] Sohn, J-W., Lee, S., and Mullen, T. *Attracting Intra-marginal traders across multiple markets*, IJCAI-09 Workshop on Trading Agent Design and Analysis (TADA-09), Pasadena, CA, July 2009, pp 91-96

[6] Sohn, J-W., Lee, S., and Mullen, T., *Impact of Misalignment of Trading Agent Strategy across Multiple Markets*, The First Conference on Auctions, Market Mechanisms and Their Applications (AMMA 2009), Boston, MA, May 2009.