Price Competition between Price Setting Middlemen in the Laboratory Setting*

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Abstract

This paper investigates how middlemen would compete on ask and bid prices with one another in the laboratory setting. We conducted a series of experiments of two-person games to check whether people offered the competitive price set. Although it is reported in a number of experiments that most people do not play games perfectly competitively if they are repeatedly played by the same two person, in our experiments, from fifteen to fifty percent of subjects offer the most competitive alternatives even if the game is repeatedly played by the identical pair. This suggests that the trading rules press them to offer the most competitive prices This result suggests the competitiveness of discount ticket shops.

1 Introduction

Middleman is important for markets because (s)he is an economic agent who purchaces from suppliers for resale to buyers and helps buyers and sellers meet and transact. (S)he creates and manages markets by seeking out suppliers, finding and encouraging buyers, selecting bid and ask prices, and holding inventories to provide liquidity or availablity of services and goods, and so on. However, General Equilibrium Theory (GET) and Industrial Organization Theory have not seriously examined the role of a price-setting middleman.[1]

From 1980's, Market Micro Structure (MMS) Theory, which takes the role of middleman into account, emerged. Spulber (1996, 1999, 2002), Gehrig (1993), and Rust and Hall (2003) focus how price-setting middleman makes prices and competes for each other, reduces uncertainty and, helps buyers and sellers meet and transact. The nature

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[1]Actually, a lot of papers investigate the behavior of retailers in terms of Game Theory. Although, most of them do not think that middleman creates and manages markets.

of middleman is in common with their models; middleman sets a bid price and buys a commodity from a supplier, then sells it to a buyer at a higher ask price.

Additionally, the viewpoint of MMS theory is similar to Kirzner's market process theory. In Kirzner (1973) and (1997), he emphasizes the role of arbitragers. To buy and resell a commodity and make more profit than the opponents, they outbid them, compete with each other, and finally prices near to the competitive level. This function is important for changing a disequilibrium to the market equilibrium[2]. Evidently, they are the middlemen assumed in MMS theory and the present study.

Before introducing our experiments, it will be useful to discuss recent experiments about price competition. For example, Dufwenberg and Gneezy (2000) examines the relationship between the number of competitors and the theoretical solution. The target model is the standard Bertrand competition,[3] subjects know the number of rounds and the demand and cost conditions, and the opponent changes in every round. As a result, they find that the number of subjects who offer the competitive price increases as the number of competitors increases. Especially, in case of two competitors, no subjects offer the market price. Abbink and Brandt (2002) conducts experiments to study price competition under constand but uncertain cost structure. They find that market prices decrease significantly as the number of competitors increases but stay above the competitive level. Ortmann (2003) conducts classroom experiments on Bertrand price competition.

Dufwenberg et al. (2002) introduces the price floor (minimum price) and examine whether subjects choose the minimum price when the number of competitors is two. They find that the average price falls significantly under the price floor treatment.

The aim of this paper is to investigate whether middlemen offer the competitive prices as bid and ask prices in the laboratory setting as a result of the price competition. Especially, we want to examine the effect of information and experience on subjects' behaviors, which is an open question in Ogawa et al. (2003), and to compare our results with some previous experimental results. Stahl (1988) and Spulber (1999) examine price competition between middlemen in terms of the two-stage game; in the first stage, middlemen offer bid prices simultaneously, and then the high-priced middleman buy commodity and offer an ask price in the second stage. We used this framework and conducted a series of experiments. We focus the situation where two middlemen compete for each other by offering bid and ask prices. Our number of competitors is the same as Dufwenberg et al. (2000).

Let us summarize experimental results. As we wll see, our experimental settings have some factors that promotes collusion. Nevertheless, the number of pairs whose winning prices are the competitive ones is significantly higher than Dufwenberg and Gneezy (2000), and Dufwenberg et al. (2002). This result suggests that the trading rule promotes subjects to offer the competitive prices.

This paper is organised as follows; the next section introduces the experimental design. Then we show and compare the experimental results with other ones. Finally we discuss the facotrs which affects our results.

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[2]In his view, the realization of equilibrium is an open question in GET, and he asserts market process theory explains the realization and is a complement of GET.

[3]These experiments assume that firms are producers, while we assume firms are middlemen. Plott and Url (1982) is an experimental study about the intertemporal arbitrage by middleman.

2 Experimental Design

2.1 Theoretical Prediction

In this experiment, the subjects are asked to choose bid and ask prices. In the first stage, a subject offers a bid price simultaneously. If he purchases inputs, he can set an ask price in the second stage. Otherwise, he waits for the next round. In the second stage, only the subject who have a commodity can sell it. If both middlemen have a commodity, they chose ask prices simultaneously. Then the lowest-bidded middleman sells first. The other middleman faces the residual consumers and sells a commodity to them. Middleman-1 one's profit is determined as follows.

$$\pi_1 = p_1 q_{D1} - w_1 q_{S1}, \tag{1}$$

where p_1, w_1, q_{D1}, and q_{S1} represent the ask price, the bid price, the number of demand units, and the number of supply units, respectively. Especially,

$$q_{S1} = \begin{cases} 0 \text{ if } w_1 < w_2 \\ S(w_1)/2 \text{ if } w_1 = w_2 \\ S(w_1) \text{ if } w_1 > w_2 \end{cases} \tag{2}$$

$$q_{D1} = \begin{cases} 0 \text{ if } q_{S1} = 0 \\ D(p_1) \text{ if } p_1 < p_2, \text{ and } q_{S1} \geq D(p_1) \text{ or if } q_{S2} = 0, \text{ and } q_{S1} \geq D(p_1) \\ q_{S1} \text{ if } p_1 < p_2, \text{ and } q_{S1} < D(p_1) \text{ or if } q_{S2} = 0, \text{ and } q_{S1} < D(p_1) \\ q_{S1} \text{ if } p_1 > p_2 \text{ and } q_{S1} < D(p_2) - q_{S2} \\ D(p_2) - q_{S2} \text{ if } p_1 > p_2 \text{ and } q_{S1} > D(p_2) - q_{S2}. \end{cases} \tag{3}$$

If $p^R \leq p^W$, this game has a unique sub-game perfect Nash equilibrium (SPNE), where p^R and p^W indicate the sales-revenue-maximizing ask price and the Walrasian price, respectively. In SPNE, both middlemen set the competitive price as the bid and ask prices.[4] Especially, if supply and demand functions are liner, suppose, $S(w) = cw$ and $D(p) = a - bp$, respectively. a, b, and c are all positive. The market price is apparently $p^W = b/(a+c)$. p^R is equal to $a/2b$. To satisfy $p^R \leq p^W$, we need $c \leq b$.

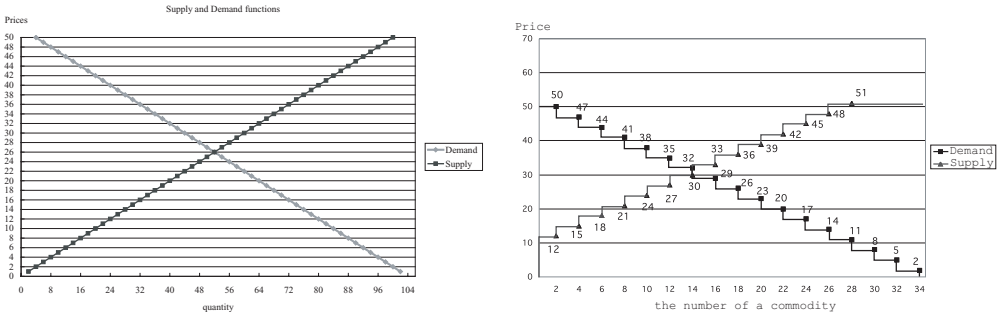
Fact1: Suppose $p^R \leq p^W$. In SPNE, both firms offer the competitive price as bid and ask prices, and get zero profit.

In this paper, we conducted Liner-Function Treatments (LFT) and Step-Function Treatments (SFT). Figure 1 (a) shows that supply and demand functions, which are $S(w) = 2w$ and $D(p) = 104 - 2p$, respectively, under LFT. Thus, they satisfy $p^R \leq p^W$

Another price set is (26,26).[5] If monopolistic middleman maximises his own profit, (s)he offers (39,13). We call here monopolistic profit set.

[4] The detailed proof is shown in Spulber (1999), ch. 3 pp. 65-66 and Stahl (1988).

[5] Although (26,25) belongs to the competitive price ranges, it is not best response. We exclude it from the competitive price set.



(a) Supply and Deamnd Functions under LFT (b) Supply and Deamnd Functions under SFT

Figure 1: Supply and Demand Functions

Fact2: Under LFT, SPNE is the competitive price set: (27,25) and (26,26), where a and b indicates ask and bid prices, respectively.

Figure 1 (b) describes supply and demand functions used under SFT. Those under SFT are step-functions and SPNE is different from the competitive price set. Of course $p^R = 53/2 \leq p^W \in [32, 30]$. Supply and demand are approximate to $S(w) = 2w/3 - 6$ and $D(p) = -2p/3 + 106/3$, respectively.

Fact3: Under SFT, SPNE is (35,29) and different from the competitive price set, (32,30), (32,31), and (32,32).

Let us explain why (35,29) is SPNE. When both middlemen choose SPNE, each profit is 36. If one of them chooses the competitive price set, his profit is at most 28. Thereby, middlemen do not have the incentive to choose the competitive price set. However, (35,29) is no more SPNE when the number of competitors is more than three.

The competitive price set is (32,32), (32,31), and (32,30). Particularly, (32,31) and (32,30) are Nash equilibria. The monopolistic profit set is (41,21).

2.2 Experimental Procedure

LFT and SFT consist of Treatment-1 (T-1), Treatment-2 (T-2), and Treatment-3 (T-3). Under T-1, subjects did not know the detail of supply and demand functions or undergo the experience of any other Treatments. Under T-2, they knew the detail of supply and demand functions and have already experienced T-1 or T-3. Under T-3, they knew the detail of supply and demand functions but did not undergo the experience of any other Treatments. The experiment was conducted at the Kyoto Sangyo University Experimental Economics Laboratory (KEEL) from October, 2002 to February, 2004. Subjects had not experienced price competition experiments yet.

	T-1-1	T-3-1	T-3-2	T-3-3
number of pairs	13	9	10	13
number of rounds	103	103	103	114
max total profit	6337	15960	24744	30044
min total profit	-8444	385	-909	-5746
average	2959.85	6861.84	6627.33	8314.07
variance	13101778.86	15876172.47	45775929.13	75442736.61
	T-2-1	T-2-2	T-2-3	T-2-4
number of pairs	13	9	10	13
number of rounds	107	83	98	101
max total profit	31608	22484	32744	48330
min total profit	2622	3700	4050	3002
average	10519.00	10700.47	10080.90	13450.22
variance	74855986.80	43683783.71	92317605.49	100192855.87

Table 1: The OverView under LFT [7]

In total 90 subjects under LFT and 126 subjects under SFT participated in this study; see Tables 1 and 2.

In each session all the students enter the KEEL, they receive an instruction, and are told that they would get 2000 yen for showing up (about 16 dollars at the time of the experiment) and additional monetary reward contingent on the total performance in the experiment.[6] The contingent part is calculated from $0.07(0.4)*\sum_{i=1}^{2}$ Total $\text{Profit}_{\text{Treatment-}i}$ under LFT (SFT).

Under LFT and SFT, before T-3 or T-2 starts, subjects cope with questions to understand the supply-demand structure.

Let us explain the common settings under all treatments. First, the number of rounds is more than eighty. Second, subjects play the game with an identical opponent but do not know who is the opponent. Finally, subjects get the following information in every round; their own bid price and inputs, and the opponent's bid price the opponent's ask price, their ask price, their sales and their profit.

The differences between LFT and SFT are the shapes of functions and the ten-round training. Under LFT, subjects played the training rounds. They knew the number of the training rounds. The opponent under these rounds is different from the one under T-i(i $\in$ [1,2,3]).

2.3 Collusive Factors

There are four collusive factors in our experiment. First, under all treatments, the opponent is the same throughout a treatment, while the opponent is randomly matched in every round in Dufwenberg and Gneezy (2000), Abbink and Brandt (2002), and Dufwenberg et al. (2002). By playing a game with the identical opponent thorughout a treatment, a subject can easily cooperate with each other. Secondly, our subjects did not knew when a treatment ended. This setting make it easy for them to cooperate with each other, since the game structure comes close to the infinitely repeated game.

[6] When the total performance is negative, only showing up fee is paid.

[7] T-1-1 and T-2-1 are conducted in order. T-3-i and T-2-i+1 are conducted in order.

	Treatment1-1	Treatment1-2	Treatment1-3	Treatment1-4
number of pairs	11	13	7	13
number of rounds	103	102	104	103
max total profit	3961	1982	4496	4148
min total profit	-10203	-2761	-1637	-11625
average	-126.77	217.54	1513.25	-928.96
variance	10139436.85	1674217.62	3113343.67	16588388.76
	Treatment2-1	Treatment2-2	Treatment2-3	Treatment2-4
number of pairs	11	13	7	13
number of rounds	107	109	108	107
max total profit	7636	10722	8800	7661
min total profit	516	654	907	-2968
average	3372.05	4105.46	5253.31	3183.73
variance	3419055.19	5491465.70	7635767.16	7283718.76
	Treatment2-5	Treatment3-1	Treatment3-2	
number of pairs	10	9	10	
number of rounds	101	129	114	
max total profit	5083	10067	3941	
min total profit	-628	-4462	-1856	
average	2049.3	3090.72	766.05	
variance	3163590.85	8942654.09	2153211.73	

Table 2: The OverView under SFT [8]

Thirdly, the number of competitors is always two. In two-person game, cooperation can be easy. Finally, as mentioned above, SPNE is not the competitive prices under SFT. If subjects act rationally as the backward induction expects, they do not offer the competitive price. Thus this setting prevents them from offering the competitive price.

3 Results

3.1 OverView

Let us give an overview of the results. Under LFT and SFT, subjects' average total profit is the highest under T-2. The difference is significant at the 5 per cent level for all cases; see Tables 1 and 2. The maximum total profit and the minimum total profit under T-2 is the highest among three treatments under LFT and SFT.

This profit difference comes from mostly of the burden of dead inventory; $q_S - q_D$. Because subjects under T-1 do not know the supply or demand, they search for the profitable price sets first. During searching, they often suffer from dead inventory. Whereas those under T-2 and T-3 know the supply and demand functions in advance and may choose prices not to suffer from dead inventory. Moreover, those under T-2 have already experienced T-1 or T-3. The experience increases profit.

We see from Table 3 that the variances of prices are smaller under T-3 treatments than under most of T-2 treatments. See Table 4. Under SFT, the variances of T-2 treatments are smaller than those of T-1 treatments. That of T-3-1 is close to those of

[8] T-1-i and T-2-i, T-3-2 and T-2-5 are conducted in order.

Treatment	1-1	2-1	2-2	2-3	2-4	3-1	3-2	3-3
ask	0.329	0.142	0.453	0.432	0.578	0.293	0.387	0.343
bid	0.442	0.084	0.558	0.508	0.547	0.246	0.457	0.650

Table 3: variance of average winning prices throughout LFT

Treatment	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4	2-5	3-1	3-2
ask	1.00	1.07	1.35	2.34	0.60	0.24	0.53	0.55	0.29	1.11	0.33
bid	1.14	1.73	1.68	4.32	0.49	0.24	0.60	0.46	0.21	1.20	0.16

Table 4: variance of average winning prices throughout SFT

T-1 treatments, while that of T-3-2 is close to those of T-2 treatments.

3.2 Convergence

To classify the results under LFT, we check the results by checking last 30 rounds. We call these rounds check rounds. We use two criteria; loose and tight. Loose criterion is 60 %; if a pair chose some price set (the competitive price set) in more than 60% of check rounds, the decision making of this pairs is classified into some category, while tight criterion is 80%.

We classify the pairs under LFT into following four patterns. A pair is classified into C-1-LFT if more than 60 % (loose criterion) or 80 % (tight criterion) of the winning bid and ask prices in the check rounds belong to the competitive price set. A pair is classified into C-2-LFT if more than 60 % (loose) or 80 % (tight) of the winning bid and ask prices in the check rounds belong to the monopolistic price set. A pair is classified into C-3-LFT if more than 60 % (loose) or 80 % (tight) of the winning bid and ask prices in the check rounds belong to another price set. Otherwise, a pair is classified into C-4-LFT.

Loose criterion	T-1	T-2	T-3
competitive price(%)	53.85%	48.89%	56.25%
monopolistic price(%)	0.00%	6.67%	0.00%
other convergence(%)	0.00%	6.67%	0.00%
fluctuation(%)	46.15%	37.78%	43.75%
Tight criterion	**T-1**	**T-2**	**T-3**
competitive price(%)	46.15%	48.89%	43.75%
monopolistic price(%)	0.00%	6.67%	0.00%
other convergence(%)	0.00%	6.67%	0.00%
fluctuation(%)	53.85%	37.78%	56.25%

Table 5: Classification Result under LFT

C-1-LFT Convergence to the competitive price sets,

C-2-LFT Convergence to the monopolistic price set,

C-3-LFT Convergence to another price set.

C-4-LFT Non Convergence.

Loose criterion	T-1	T-2	T-3
competitive price(%)	34.09%	27.78%	57.89%
monopolistic price(%)	0.00%	14.81%	0.00%
SPNE(%)	4.55%	20.45%	18.52 %
other convergence(%)	15.91%	12.96%	5.26%
fluctuation(%)	45.45%	25.93%	15.79%
Tight criterion	T-1	T-2	T-3
competitive price(%)	29.55%	20.37%	42.11%
monopolistic price(%)	0.00%	5.56%	0.00%
SPNE(%)	2.27%	7.41%	15.79%
other convergence(%)	11.36%	3.70%	0.00%
fluctuation(%)	56.82%	62.96%	42.11%

Table 6: Classification Result under SFT

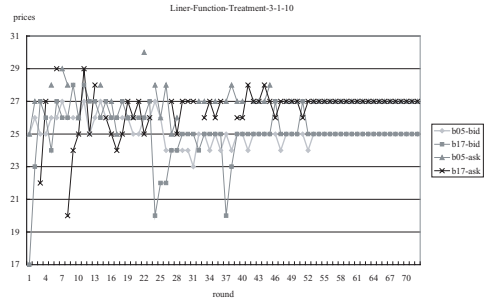
Figure 2 (a), (c) and (e) are typical cases of convergence to the competitive price set, to the monopolistic price set, and to another price set, under LFT respectively. From (a), subjects compete with one anothor in the early rounds. (c) shows that both subjects understand the structure of this game and intend to offer the monopolistic price set. (e) shows that both of them offer (30,22) and sprit profit into two.

Table 5 indicates the classification results under LFT. Under every treatment, the result of loose (tight) criterion shows that more than 45 (40) % of the pairs offer the competitive price. There does not seem to be the difference of the distribution among treatments when we apply the loose criterion. Applying the χ^2 test, we do not find the difference between LFT-1 and LFT-2, LFT-2 and LFT-3, LFT-3 and LFT-1. We find the same result in the tight criterion.

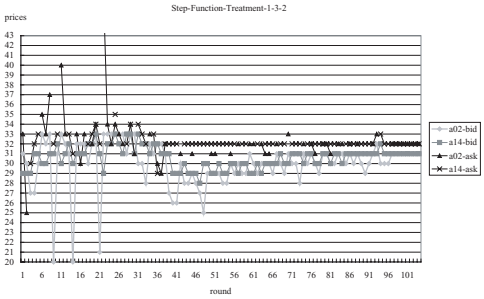
From this analysis, it is reasonable to say that the supply-demand information does not affect the results under LFT. The experience does not affect the results either, although some pairs are classified into C-2 and C-3. Additionally, the change of the criterion does not significantly affect the result, either. This suggests that the competitive price set is robust as the theory predicts.

Result 1: Under LFT, more than 40 % of the pairs' decision makings converge to the competitive price set. The ratio statistically stays unchanged even if various conditions changes.

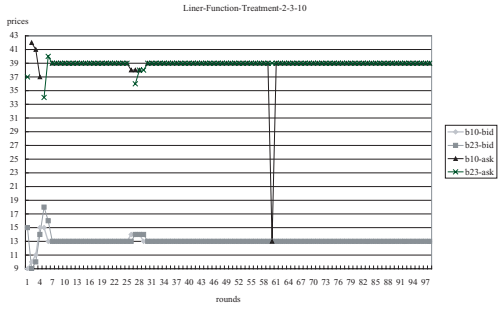
We classify the pairs under SFT into following five patterns. The criteria of "loose" and "tight" are the same as those of LFT. However, the length of check rounds is different from that of LFT. To classifiy the results, we see decision makings from the 70th round to the last round. A pair is classified into C-1 when more than 60 % (loose criterion) or 80 % (tight criterion) of the winning bid and ask prices in the check rounds belong to $(30, 31), (30, 32)$, or $(31, 32)$. Similarly, a pair is classified into C-2 if more than 60 % (loose) or 80 % (tight) of the winning prices in the check rounds belong to $(41, 21)$. A pair is classified into C-3 when more than 60 % (loose) or 80 % (tight) the winning prices in the check rounds belong to SPNE. A pair is classified into C-4 when



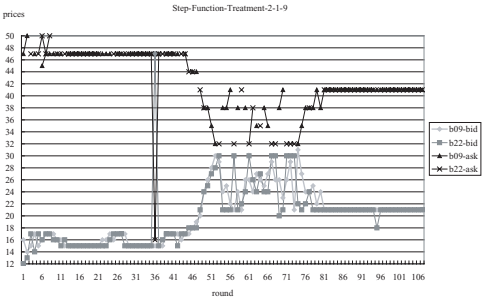
(a) Convergence to the Competitive Price set under the LFT-3



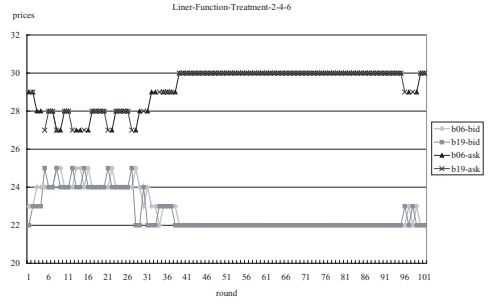
(b) Convergence to the Competitive Price set under the SFT-1



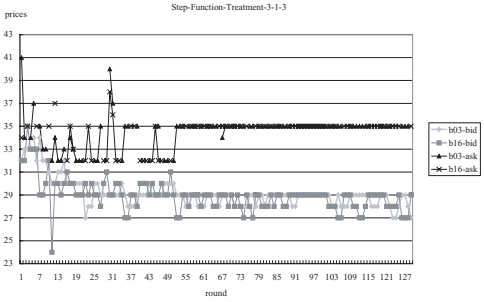
(c) Convergence to the Monopolistic Price set under the LFT-2



(d) Convergence to the Monopolistic Price set under the SFT-2



(e) Convergence to Another Price set under the LFT-2



(f) Convergence to SPNE under the SFT-3

Figure 2: Typical Results

60 % (loose) or 80 % (tight) the winning prices in the check rounds belong to a price set which does not belong to from C-1 to C-3, for example, $(38, 26)$, $(35, 27)$ and so on. Otherwise, a pair belongs to C-5.

C-1-SFT Convergence to the competitive price sets,

C-2-SFT Convergence to the monopolistic price set,

C-3-SFT Convergence to SPNE,

C-4-SFT Convergence to another price set,

C-5-SFT Non Convergence.

Figure 2 (b), (d) and (f) are typical cases of C-1-SFT, C-2-SFT, and C-3-SFT, respectively. (b) shows that subjects compete with one another or search for a profitable price set in early rounds, and then both offer the competitive price set (32, 31) in later rounds. Most pairs classified into C-1 offer (32,31). (d) shows that both subjects offer (47, 15) and earn the bid-ask spread in early rounds. Then, one of them find the most profitable price set, and both offer (41, 21) in later rounds. (f) shows that subjects compete in first 40 rounds and that they choose SPNE in later rounds.

Table 6 indicates the classification results under SFT. First, we check the difference between T-1 and T-3. Applying the χ^2 test, the difference between T-1 and T-3 is significant in 1 % level. In both criteria, the percentages of C-1-SFT and C-3-SFT are much higher under T-3 than under T-1, while the percentages of C-4-SFT and C-5-SFT are higher under T-1 than T-3. This result suggests that informed subjects can easily offer rational price sets.

Second, let us check the difference between T-2 and T-3. In both criteria, the percentages of C-1-SFT and C-3-SFT are much higher under T-3 than under T-2, while the percentages of C-4-SFT and C-5-SFT are higher under T-2 than T-3. This results suggests that experienced and informed subjects can more easily collude with each other than the informed subjects.

The classification result under SFT depends on the criterion unlike the result under LFT. The rates except C-5 significantly decrease as the criterion becomes tighter. Under SFT, the number of subjects who keep on choosing the market prices or SPNE decrease.

Result 2: Under SFT-3, the convergence rate in C-1 is over 50 %. However, various conditions, such as the experience and information, statistically decrease the rate under SFT.

To compare results under LFT with under SFT, we include C-3-SFT into C-4-SFT when we focus the convergence to the competitive price set (the first case). When we focus the stability of Nash equilibrium, we include C-3-SFT into C-1-SFT. Applying the first case, the percentage of C-4-SFT is about 20 % under T-1, 33 % under T-2, and 26 % under T-3 for loose criterion, and about 14 % under T-1, 11 % under T-2, and 16 % under T-3 for tight criterion. In the second case, the percentage of C-1-SFT is about 39 % under T-1, 48 % under T-2 and 79 % under T-3 for loose criterion, and about 32 % under T-1, 28 % under T-2, and 58 % under T-3 for tight criterion.

In the first case, for both criteria, convergence to the competitive price set is stronger under LFT-1 and LFT-2 than SFT-1 and SFT-2, respectively, while convergence to the set under LFT-3 is almost the same as SFT-3.

In the second case, for both criteria, the convergence rate to Nash equilibrium is higher under LFT-1 than under SFT-1. In loose criterion, the rate under LFT-2 is almost the same as the one under SFT-2, whereas, in tight criterion, the former is significantly higher than the latter. The rate is significantly higher under SFT-3 than under LFT-3. Thus, in loose criterion under T-2 and T-3, we can not find the difference in the convergence rate between LFT and SFT. In tight criterion under T-1 and T-3, we can significantly find the difference between two treatments.

Result 3: The competitive price set under LFT is robuster than the one under SFT. The ratio of the informed and/or experienced pairs which offer Nash equilibrium under LFT is close to the one under SFT.

3.3 Comparison With Other Experimental Results

At the end of this section, let us compare our results with other experimental results. In Dufwenberg and Gneezy (2000), and Dufwenberg et al. (2002), when the number of competitors is two, no subjects offer the market price in both experiments except the price floor treatment.[9] Since their experimental settings aim to promote competition (random matching in every round and informing subjects when the session ends), some factors may prevent their subjects from competing with eath other.

In our results, from 13.64 to 57.89 % of the pairs offer the market prices. These ratios are higher than those in other results, although our experimental settings have collusive factors as mentioned above. Thus our experimental settings have some factors which encourage subjects to compete. We will discuss the reason why our experimental settings are competitive in the next section.

Result 4: Under all treatments, the rate of convergence to the competitive price set is significantly higher than those of Dufwenberg and Gneezy (2000)'s and Dufwenberg et al. (2002)'s standard price competitions.

4 Discussion

As a discussion, we examine why our experiments are more competitive than other ones. Then we deal with the effect of the difference betweem LFT and SFT. Finally we discuss some suggestions to the real markets.

There may be two reasons why our experiments are competitive; the bid-ask competition and the threat of the burden of dead inventory acceralete the reduction in ask prices and especially the appreciation in bid prices. Certainly the first factor exists in

[9] No subjects offer the monopolistic price either.

	A (32,31)	B (32,30)	C (35,29)
A (32,31)	7,7	14,0	14,0
B (32,30)	0,14	14,14	28,0
C (35,29)	0,14	0,28	36,36

Table 7: Payoff Matrix under SFT

the ask price competition in other experiments, but these experiments do not examine the bid price competition. If our subjects fail to buy a commodity, they can not participate in the market. Since they hope to take part in the trade and win the opponent especially in early rounds, they offer a high bid price.

Secondly, the burden of dead inventory may happen after they succeed in buying a commodity. In most of price competition experiments,[10] this problem is not considerd, since these experiments assume that firms can immediately produce all the units that they want to sell. On the other hand, the dead inventory is serious in our study. Even if the subjects win the opponent, buy a commodity, but does not sell all the units, they suffer from significant profit loss. They can not offer high ask prices but do ask prices at which they can sell all the units. Thus, because of above mentinoed features, our trading system is competitive even in the case of the two competitors.

A few more remarks are called for under SFT, since some (under SFT-3, more than half) pairs offer the competitive price set although SPNE is away from the competitive price. Let us examine SFT in terms of the normal form game(see Table 7). We can see from this matrix that (A,A), (B,B), and (C,C) are Nash equilibrium. Especially (A,A) and (C,C) are evolutionary stable set (ESS). Figure 3 investigates the game from replicator dynamics. This Figure indicates that most of the initial probabilities converge to (A,A). Moreover we can find that (A,A) risk dominates (B,B), that (B,B) does (C,C) and that (C,C) also does (A,A). Thus no Nash equilibria are risk dominant. In other words, subjects can not select equilibria in terms of risk dominance. The competitive equilibrium (A,A) is not risk dominant but safe since subjects always make (a little) profit by offering A. If subjects hope that they make at leaset positive profit, they will offer the competitive price set. [11]

From the above discussion, we can find the factors which prevent subjects from competing in Dufwenberg and Gneezy (2000) and Dufwenberg et al. (2002). Their experiments assume that products are immediately made, and that firms can produce a good to meet demand. Therefore, firms do not suffer from the burden of dead inventory. They do not make an effort to get a commodity or are not under the threat of the dead inventory. Moreover, when the number of competitors is two, the number effect is weak. Thus, firms do not offer the competitive price even if some facotrs promote competition. [12]

[10] Plott and Url (1982) seems to have the relation wtih this problem. However, their aim is to examine the intertemporal trade by middlemen.

[11] Additionally, some subjects act as the repeated game theory assumes. In the post-experiment questionnaire, they answer that they choose the same value as their opponents in both stages. According to their statement, they aim to collude with each other in the long run.

[12] Dufwenberg and Gneezy's result can be attained because of ten-round experiment. If the number of rounds is larger, more competitive result may be attained. Of course, we never know how something

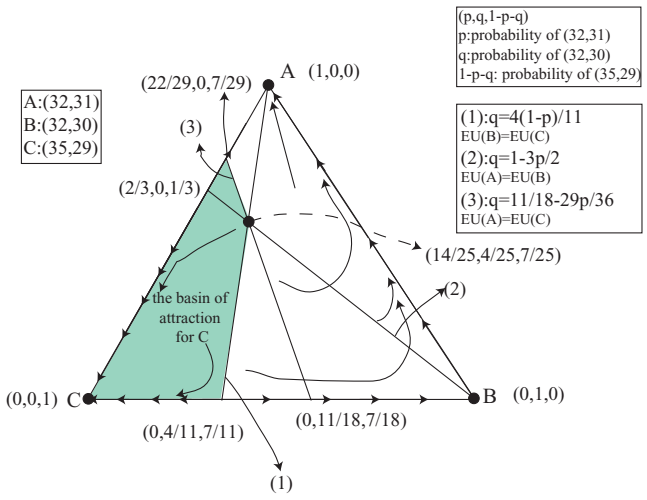


Figure 3: Phase Diagram under SFT

Then let us examine the effect of the shapes of functions. Since SFT has two equilibria, the ratio of the pairs which offer equilibirum is higher under SFT-3 than those under LFT-3. However, the informed and experienced subjects under SFT-2 can easily deviate from the competitive equilibrium because of SPNE. Therefore, the ratio of the competitively priced pairs decreases. Additionally, the fact that most ratios under SFT-2 decrease in the tight criterion indicates that the subjects' decisiom makings are not robust. This suggests that although subjects deviate the competitive price set, they can not choose profitable price sets such as SPNE or the monopolistic price set in a long term.

Finally, we discuss the relation betweenship real markets and our experiments. The essential activities of firms in our study, which has the problem that we do not capture the function of inventory, can be seen in those of retailers, wholesalers, and so on. Discount ticket shops and used-book stores are the closest to our middlemen. Here we briefly examine those in Japan. The discount shops in Japan usually buy tickets and gift certificates from suppliers at about 10 percent discount off the list prices, and then sell them to consumers at about 5 per cent discount off the list prices. The bid-ask spread is very small, since a lot of discount ticket shops compete with each other and tickets are homogeneous. The stiff competition in this industry can be suggested from our experimental results. In our experiments, it is frequently found that two middlemen, whose trading rule is very close to those of discount ticket shops, offer the competitive price set. Of course, as the number of competitiors increases, the competitive price is offered easily. However, our result indicates that the competitive result is atteined by at least two competitors.

Used book stores can also offer bid and ask prices to make profit. The bid-ask spreads of small stores are wider than those of discount ticket shops. This can be explained by the fact that books are heterogeneous. Recently large used book firms

will turn out until we've conducted the longer-round experiment.

emerges in Japan and have market power. They regard books as homogeneous goods and offer bid and ask prices. Since this study deals with the competition for a homogeneous good, the investigation into the small used book stores is difficult but the investigation into the big stores can be effective.

References

[1] Abbink, Klaus and Brandits. Jordi, "Price Competition under cost uncertainty:A laboratory anlysis", University of Nottingham, CeDEX discussion paper, 2002

[2] Dufwenberg, Martin and Gneezy, Martin. "Price Competition and Market Consentration an Experimental Study", *International Journal of Industrial Organization*, vol 18, pp7-22, 2000

[3] Dufwenberg, Martin., Uri Gneezy, Jacob K. Goeree, and Rosemarie Nagel, " Price Floor and Competition", working paper, Stockholm University, 2002

[4] Friedman, Daniel and Sunder, Shyam., *Experimental Methods A primer for economists*, Cambridge University Press, 1994.

[5] Friedman, Daniel, "Equilibrium in Evolutionary Games: Some Experimental Results", The Economic Journal, vol.106, pp.1–25, 1996.

[6] Gehring, Thomas, "Intermediation in Search Markets," *Journal of Economics and Manegement Strategy* 2,97-120 1993

[7] Kazuhito Ogawa, Yuhsuke Koyama, and Sobei H. Oda. "An experimantal approach to market microstructure -search and market efficiency", *Proceedings of The 6th International Conference of COMPLEX SYSTEM 2002*, pp.124–134, 2002.

[8] Kazuhito Ogawa, Kouhei Iyori, and Sobei H. Oda, "Price Competition Between Middlemen: An Experimental Study", *Post-Conference Publication of ISAGA2003*, Springer Verlag, forthcoming.

[9] Kirzner, Israel M., "Competition and Entrepreneurship", University of Chicago Press, 1973

[10] Kirzner, Israel M., "How Markets Work: Disequilibrium, Entrepreneurship and Discovery", Institute of Economic Affairs, 1997

[11] Andreas Ortmann, "Bertrand Price Undercutting: A Brief Classroom Demonstration", Journal of Economic Education, pp.21–26, 2003.

[12] Plott, C. R. and Uhl. J T., "Competitive equilibrium with middlemen: An empirical study.", *Southern Economic Journal*, Vol. 47, pp. 1063–71, 1981.

[13] Rust, J and Hall, G, 2003 Middlemen versus Market Makers: A Theory of Competitive Exchange. *Journal of Political Economy*, vol. 111, no. 2, pp.353-403

[14] Spulber, Daniel F. "Market microstructure and intermediation.", *Journal of Economic Perspectives*, Vol. 10, pp. 135–152, 1996.

[15] Spulber, Daniel F. *Market Microstructure -Intermediaries and the theory of the firm-*., CAMBRIDGE UNIVERSITY PRESS, 1999.

[16] Stahl D O. II, "Bertrand Competition for Inputs and Walrasian Outcomes.", *American Economic Review*, vol.78, pp.189-201, 1988