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Revisiting Marshallian versus Walrasian Stability in an Experimental Market*

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Abstract

We study dynamics in pit market trading by a laboratory experiment. Our exchange economy model contains two types of consumers and two kinds of commodities, and three competitive equilibria exist. The two equilibria with the lowest, and the highest relative prices are beneficial for one type of the consumers, and the intermediate price gives an equitable allocation. The theory of Walrasian tatonnement dynamics predicts that relative prices diverge from the intermediate equilibrium towards the lowest equilibrium or the highest equilibrium depending on initial prices. On the other hand, Marshallian quantity adjustment process leads the total supplied volume to the intermediate equilibrium only regardless of initial states. In order to examine how robust the equilibrium selection is, we conducted a manual experiment of pit market trading with different combinations of ethnicities of subjects in Kenya. Our result shows strong support for the convergence to the intermediate equilibrium, which is unstable in Walrasian tatonnement dynamics and is stable in Marshallian quantity adjustment process.

Keywords: Marshallian Stability, Walrasian Stability, Experiments, Pit Market, Kenya

JEL codes: C92, D51

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1. Introduction

We investigate dynamics adjustment processes in pit market trading by a laboratory experiment. We explore two issues in this paper. The first is the fact finding of natures of disequilibrium and equilibration processes in trading on the floor, or "pit" markets. Historically, such markets have been widely used in actual trading places. In spite of that, studies on dynamic adjustment process in pit markets have been limited, while most scholars have investigated this issue in double auction markets. The key difference between a pit market and a double auction market is whether or not bids and asks as well as prices are public information.[1]

In the experimental economics literature, it has been known that pit market experiment was first conducted by Chamberlin (1948), who wanted to present that the model of perfect competition does not predict well. Smith (1962) used the double auction to show that repeated trades with public information about bids, asks, and trading prices tend to lead markets to perfectly competitive prices. In our experiment of pit markets (not *double auction* as in Smith, 1962) with repeated trades, different from Chamberlin (1948), bids and asks were known to the buyer and the seller only in each trade, and what were publicly revealed to markets are quantities agreed to exchange. We conducted the experiment repeatedly by setting the initial holdings to be constant in each period of a sequence of experiment to observe tendencies of market prices. We had a conjecture that the sequence of market prices would converge to a competitive equilibrium because buyers and sellers can freely trade as many times as they want then information about exchange rates will become public gradually.

The second issue is the extent to which theoretical models based on adjustment help with understanding this trading pit process. Almost all dynamic models of perfect competition are formulated with the Walrasian tatonnement, which is the only system that manipulates a market price by raising a price when the commodity is excessively demanded and lowering a price when the commodity is excessively supplied. The dynamic stability of an experimental market is usually analyzed as if the process of equilibrium price discovery is the Walrasian tatonnement even when it is obviously not. Existing experimental results from continuous double auctions suggest that data of movement in market prices are highly consistent with the Walrasian tatonnement (Smith 1962; Anderson et al., 2004; Crockett et al., 2010). To our best knowledge, there is no such evidence with experimental results from trading pit which support any theory of dynamics in markets. We expected that the Walrasian adjustment process would work

[1] We would like to give special thanks to Charles Plott for pointing out this issue.

because a market price goes up whenever the commodity is excessively demanded and the price falls whenever the commodity is excessively supplied regardless of styles of trading. We thus actually conducted an experiment of trading pit to investigate what kind of dynamics of market prices appears.

The model to experiment is an exchange economy with two types of consumers and two kinds of commodities in which three competitive equilibria exist. One type of consumers initially own the more of the first good, and the less of the second good, than the other type of consumers have. The same type of consumers are all rationed identical commodity bundles of endowment. We choose the second good as the numeraire, the price of which is always fixed to be one, and focus on the behavior of the relative price of the first good. In our model, the supply and demand curves intersect at three points, namely, there are three equilibrium prices. The lowest relative price is beneficial for the type of consumers having more of the second good, and the highest relative price is advantageous to the type of consumers having more of the first good. The intermediate price gives an "equitable" allocation.

According to the Walrasian dynamics, relative prices diverge from the intermediate equilibrium towards the lowest equilibrium or the highest equilibrium depending on initial prices. It means that the market mechanism causes an income inequality and the "invisible hand" leads the economy to an efficient but inequitable state. We thus have strong interest in conducting an experiment of our exchange model with multiple equilibria. We simply conjectured that trading outcomes would converge to one of the extreme equilibria because they are stable in Walras' sense. However, our results obtained in Kenya show strong support for the convergence to the intermediate equilibrium on average. Thus, our observations tell that pit market trading does not cause large inequalities of income or welfare. This is the opposite result that the theory of Walrasian stability predicts.

We therefore investigate our model with another dynamic stability concept of a market mechanism called the Marshallian adjustment process[2], in which sellers increase supplies when the supply price is higher than the demand price and decrease them when the supply price is lower than the demand price. It then turned out that, in our model, the stability of each equilibrium is different in Walras' and Marshall's sense. It means that the lowest and highest equilibria are stable in Walras' sense but unstable in Marshall's sense, and the intermediate equilibrium is unstable in Walras' sense but stable in Marshall's sense. Our experimental results of trading pit show that the market prices

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[2] Our first debt is to Shyam Sunder, who suggested us to check Marshallian stability of equilibria for our model.

converged to the intermediate equilibrium, which is unstable in Walras' sense and stable in Marshall's sense. Shapley and Shubik (1977) is a pioneering work that presents a simple exchange economy model with multiple competitive equilibria. Different from the current study, they investigated the Walrasian stability of the three equiribria, but did not discuss the Marshallian stability.

The paper is organized as follows. In Section 2, we present the model of an exchange economy with three competitive equilibria which we used to conduct our experiment. We also discuss the Walrasian stability and the Marshallian stability of each equilibrium. In Section 3, we explain the design and procedures of our experiment. Namely, we describe how we transformed the theoretical model into the experiments. In Section 4, we analyze the results of the experiment to find tendencies of the data and effects of our scientific controls. Discussions are provided in Section 5. Finally, Section 6 is for concluding remarks.

2. An Exchange Economy with Multiple Equilibria

We consider the following exchange economy model with two kinds of commodities called X and Y and two types of consumers named 1 and 2. The utility functions of consumers 1 and 2 are of "Leontief-nested" types in the following forms:

$$U_1(x_1, y_1) = a_1 \min[g_1(x_1), y_1] + b_1 \text{ and}$$
$$U_2(x_2, y_2) = a_2 \min[g_2(x_2), y_2] + b_2 \qquad (2.1)$$

In the experiment, we set $a_1 = 52.58$, $b_1 = 669.96$, $a_2 = 50$, $b_2 = 695.07$,

$$\begin{aligned} g_1(x_1) &= x_1/9.8 && \text{if } x_1 \in [0, 6.2] \\ &= 10x_1 - 6.2(10.5 - 1/9.8) && \text{if } x_1 \in [6.2, 7.5] \\ &= x_1/9.8 + 1.3(10.5 - 1/9.8) && \text{if } x_1 \in [7.5, 14.9] \\ &= 10.5x_1 - 13.6(10.5 - 1/9.8) && \text{otherwise;} \end{aligned}$$

and

$$\begin{aligned} g_2(x_2) &= x_2/9.1 && \text{if } x_2 \in [0, 7.35] \\ &= 11.3x_2 - 7.35(11.3 - 1/9.1) && \text{if } x_2 \in [7.35, 8] \\ &= x_2/9.1 + 0.65(11.3 - 1/9.1) && \text{if } x_2 \in [8, 17.45] \\ &= 11.3x_2 - 16.8(11.3 - 1/9.1) && \text{if } x_2 \in [17.45, 18.45] \\ &= x_2/9.1 + 1.65(11.3 - 1/9.1) && \text{otherwise.} \end{aligned}$$

The individual endowment of consumer 1 is given by $(\bar{x}_1, \bar{y}_1) = (25,1)$ and the individual endowment of consumer 2 is $(\bar{x}_2, \bar{y}_2) = (5,29)$.

Figure 1 displays this economy in an Edgeworth box. The solid (resp. dashed) piecewise linear line denotes consumer 1's (resp. consumer 2's) "offer curve," derived by varying prices and asking the consumer how much she would like to trade to maximize her utility at each price. Notice that the offer curves are given by $y_1 = g_1(x_1)$ and $y_2 = g_2(x_2)$, because the utility maximization points are the loci of the verteces of the L-shaped indifference curves. There are three competitive equilibrium allocations denoted by the points of intersection of the two offer curves: A = (7.00, 9.01), B = (12.01, 14.74), and C = (15.48, 21.13) in terms of agent 1's consumption bundle. Figure 1 can be also regarded as demonstrating symmetric equilibrium outcomes in a market with n traders on each side when all traders of the same type take the same action.

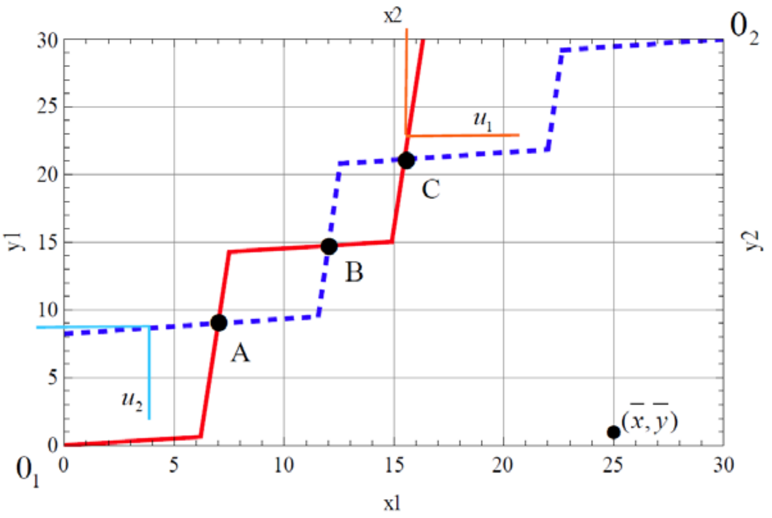

Figure 1. Exchange Economy with Three Competitive Equilibria

Figure 2 represents a diagram of the demand and supply curves for good *X* which are derived from our two-good economy model.[3] Notice that the supply curve is downward-sloping. The intuitive reason is as follows. Suppose that the price for *X* relative to good *Y*, *Px/ Py*, decreases. Then the income of consumer 1 who initially has a

[3] We only need to focus on trades of good *X* because, based on the Walras' law, the market of good *X* is clear when that of good *Y* is clear. Notice that Walras' law holds in our model since the utility functions of all consumers satisfy local nonsatiation.

large amount of X becomes smaller. Because consumer 1's utility function is of a Leontief type, there is no substitution effect and a large income effect. Therefore, consumer 1's demand for X decreases, implying that the supply (endowment minus demand) of X by consumer 1 increases. Since consumer 1 is the only supplier of X, the supply for X increases when the relative price for X decreases.

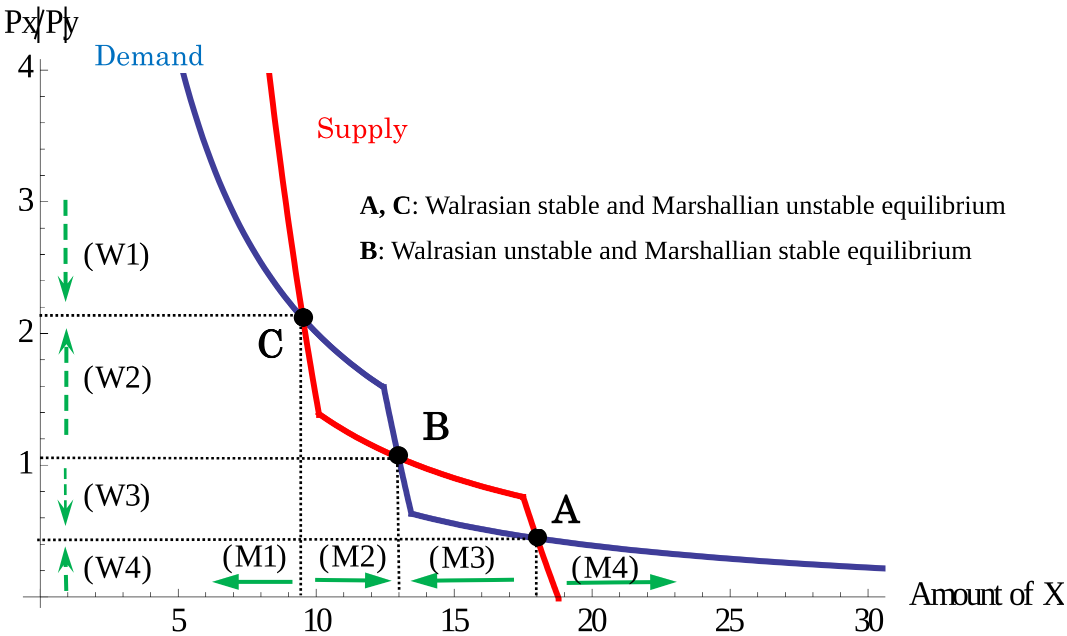

Figure 2. Local Walrasian and Marshallian Stability of Three Competitive Equilibria in a Demand-Supply Diagram.

Figure 2 shows three equilibria at which the demand and supply curves intersect: A = (x_A, p_A) = (18.00, 0.44), B = (x_B, p_B) = (12.99, 1.06), and C = (x_C, p_C) = (9.52, 2.11). There are two well-known concepts of local stability of a competitive equilibrium: Walrasian and Marshallian stability. These concepts give opposite answers to the question of whether each of the three equilibria is locally stable or unstable. First of all, let us consider Walrasian dynamics of price adjustment process, which works off equilibrium in the market. According to this dynamics, if the relative price of *X*, $p = Px/ Py$, is lower than p_A (higher than p_C), the demand for *X* is larger (smaller) than the supply for X, so that p increases (decreases). If p lies between p_A and p_B (between p_B and p_C), the demand for X is smaller (larger) than the supply for X, so that p decreases (increases). Therefore, the equilibrium B is locally unstable in Walras' sense, whereas the other two equilibria A and C are both locally stable in Walras' sense.

Next let us examine Marshallian dynamics of quantity adjustment process. According to this dynamics, if the quantity of X, x, is larger than x_A (smaller than x_C), the demand price at x is higher (lower) than the supply price at x, so that x increases (decreases). If x lies between x_A and x_B (between x_B and x_C), the demand price at x is lower (higher) than the supply price at x, so that x decreases (increases). Therefore, the equilibrium B is locally stable in Marshall's sense, whereas the other two equilibria A and C are both locally unstable in Marshalls' sense.[4]

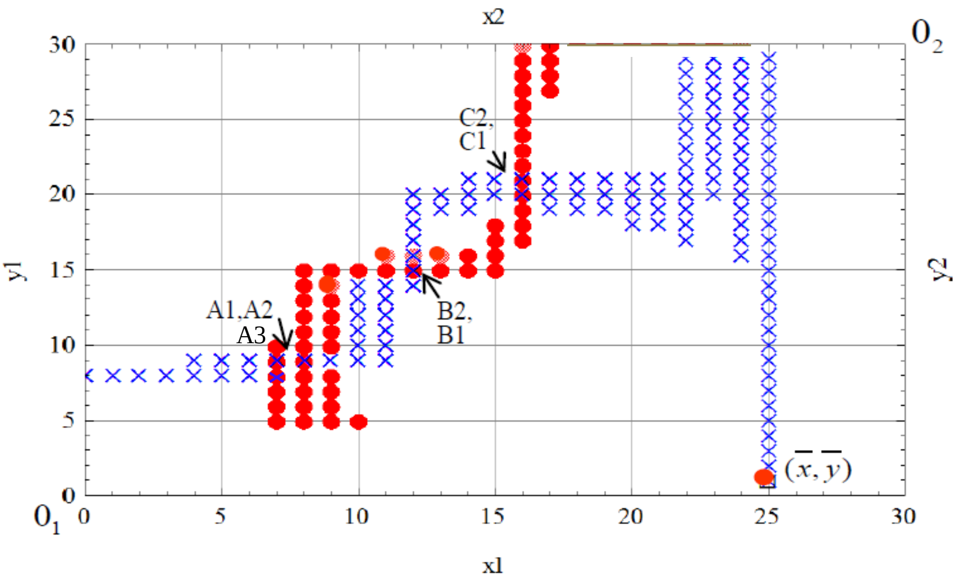

Figure 3. Discrete Version of the Exchange Economy

In our experiment, subjects chose integers as trading units, not real numbers as in usual theory. Therefore, it is important to consider a discrete version of the exchange economy corresponding to the experimental setting to make a rigorous theoretical prediction. Figure 3 shows this discrete exchange economy in an Edgeworth box. The locus of circles (●) (resp. multiplication signs (´)) denotes consumer 1's (resp.

[4] See Appendix 1 for the formal definitions of local stability and instability of equilibrium according to Walrasian price adjustment process and those according to Marshallian quantity adjustment process.

consumer 2's) offer curve, which is thick, in the discrete economy. The two offer curves intersect at seven points indicating competitive equilibria. In terms of consumer 1's consumption bundles, these equilibria are given by A1 = (7, 8), A2 = (7, 9), A3 = (8, 9), B1 = (12, 15), B2 = (12, 16), C1 = (16, 20), and C2 = (16, 21) together with the corresponding equilibrium price ratios P_X / P_Y = 0.39, 0.44, 047, 1.08, 1.15, 2.11, and 2.22, respectively.

Moreover, we prohibited subjects from trading commodities at which the price ratio P_X / P_Y, the trading ratio of Y to X (= (Amount of Y)/(Amount of X)), was less than 1/4 = 0.25. For $P_X / P_Y < 1/4$, there are several competitive equilibria other than the above seven equilibria. In Figure 3, we omit these equilibria and focus on the seven equilibria close to the three equilibria in Figure 1 of the usual Edgeworth box.

Table 1 summarizes the equilibrium predictions. The equilibria A1, A2, and A3 with low relative prices of commodity *X*, P_X / P_Y, are beneficial for type 1 consumer having more of commodity *Y*, while the equilibria C1 and C2 with high relative prices of commodity *X* is advantageous to type 2 consumer having more of commodity *X*. In this sense, these four equilibria are not equitable. From the viewpoint of stability, these four equilibria are locally stable in Walras' sense, but locally unstable in Marshall's sense.

Table 1: Theoretical Predictions about Discrete Equilibria

	Allocation					Payoff	
	Type 1 (x1, y1)	Type 2 (x2, y2)	Price	Walrasian Stability	Mashallian Stability	Type 1 U1	Type 2 U2
A1	(7, 8)	(23, 22)	0.39	stable	unstable	1091	1745
A2	(7, 9)	(23, 21)	0.44	stable	unstable	1143	1745
A3	(8, 9)	(22, 21)	0.47	stable	unstable	1143	1739
B1	(12, 15)	(18, 15)	1.08	unstable	stable	1445	1445
B2	(12, 16)	(18, 14)	1.15	unstable	stable	1445	1395
C1	(16, 20)	(14, 10)	2.11	stable	unstable	1722	1136
C2	(16, 21)	(14, 9)	2.22	stable	unstable	1669	1136

On the other hand, the equilibria B1 and B2 with intermediate prices give allocations that generate the minimal difference between the payoffs to the two types of consumers.

We say that the equilibrium and allocation are fair. In particular, each type receives the same equilibrium payoff at B1. They are locally unstable in Walras' sense, but locally stable in Marshall's sense. There are trade-off between local Walrasian stability and "equity" of the competitive equilibria, whereas local Marshallian stability and allocation equity are compatible.

3. The Experimental Design and Procedures

The experiment was conducted at the University of Nairobi in Kenya during August 10-12 of 2010. We recruited subjects from three ethnic groups (i.e., Luo, Kikuyu, and Kalenjin) to attend the experiment.[5] The subjects were students at major Kenya universities such as the University of Nairobi, Kenyatta University, Moi University, Egerton University, Mount Kenya University, Kimathi University College of Technology, and Jomo Kenyatta University of Agriculture and Technology. No subject had prior experience in market experiments. The number of subjects from each of the three ethnic communities was 40 for a total of 120 distinct subjects. For each ethnic group, 20 subjects played the role of type 1 consumer and another 20 subjects did the role of type 2 consumer. Their roles were fixed throughout the experiment.

Each subject participated in two sessions. In the first session they played with subjects from the same ethnic group and in the second session they played with those from a different ethnic group. In each session, there were 10 subjects who played the role of type 1 and 10 subjects who played the role of type 2. The subjects who played the same role in each session were always from the same ethnic group. As a result, a total of 12 sessions was conducted. Table 2 presents the details of these sessions. In the table, The roles of type 1 and type 2 that subjects played are indicated by the numbers 1 and 2, respectively, and *L*, *Ki*, and *Ka* refer to Luo, Kikuyu, and Kalenjin subjects, respectively. For example, L1-L2 and L1*-L2* refer to the sessions in which Luo subjects of type 1 played with Luo subjects of type 2, refer to the session in which Luo subjects of type 1 played with Kikuyu subjects of type 2, etc. In addition, it should be noted that the subjects participated in the experiment changed every day. For example, the Luo subjects in L1-l2 session on the first day differed from those in L1*-L2* session on the third day, and the Kikuyu subjects in Ki1-Ki2 session on the first day differed from those in

[5] We investigated whether ethnicity affects subjects' trading behavior in another study (see Shimomura and Yamato (2012)). However, there are several differences in both the experimental design and procedures between that study and the current one (see detailed discussions in Section 5).

Ki1*-Ki2* session on the second day, etc.

Table 2. Time schedule of the experiment

	8/10/2010	8/11/2010	8/12/2010
AM	L1-L2: 20 subjects	Ka1-Ka2: 20 subjects	Ka1*-Ka2*: 20 subjects
	Ki1-Ki2: 20 subjects	Ki1*-Ki2*: 20 subjects	L1*-L2*: 20 subjects
PM	L1-Ki2: 20 subjects	Ka1-Ki2*: 20 subjects	Ka1*-L2*: 20 subjects
	Ki1-L2: 20 subjects	Ki1*-Ka2: 20 subjects	L1*-Ka2*: 20 subjects

Notes: The roles of type 1 and type 2 that subjects played are indicated by the numbers 1 and 2, respectively. *L*, *Ki*, and *Ka* refer to Luo, Kikuyu, and Kalenjin subjects, respectively.

The procedure in each session was exactly the same. At the beginning of a session, each subject received one experimental instruction, one record sheet, one payoff table and one name tag.[6] The name tag of each subject indicated her team name (A, B, C, …, or T) and her identification number (1 or 2). Ten subjects (A-J) played the role of type 1, and ten subjects (K-T) played the role of type 2. Each subject was given pink cards and/or white cards in an envelope. One pink card was one unit of commodity X, and one white card was one unit of commodity Y. We explicitly noticed to every subject that she was not allowed to reveal any information regarding her payoff table or endowed color cards to any other subject.

Then, the subjects walked around a relatively large laboratory room and found a subject to trade. We prohibited any subject from trading any amount of commodity X or Y more than what they held. In addition, as explained in the previous section, the trading ratio of Y to X should be greater than or equal to 1/4 = 0.25 to exclude undesirable equilibrium allocations. We told the subjects to trade commodity X for Y or Y for X when two subjects reached an agreement. After writing the trading results in their record sheets, the subjects reported them to the experimenter. The following information on the results was entered into the computer and displayed publicly through a projector: the team name giving commodity X, the amount of the traded X, the team name giving Y, the amount of the traded Y, and the trading ratio of the commodities (= Y/X). This was the end of one trade. The subjects had 10 minutes for each period and they were allowed to trade as many times as they wanted within the time limit. For the next trading partner, the subjects could choose any subject as they wanted. That is to say that the next partner might be the same as or different from one of the subjects they had already traded. After each period, the

[6] The experimental instruction and payoff tables are provided in Appendix 2 and Appendix 3, respectively..

subjects went back to their seats and the experimenter collected all commodity cards. This was the end of one period.

At the beginning of the next period, the subjects received the same materials as those of the previous period. In particular, holdings of commodities were reset at the end of the previous period and each subject held the same endowment as that at the beginning of the previous period. After a 2-minute break, the next period started. One session had 5 periods, which means that the above steps were repeated 5 times.

Earnings of each subject or team depended on the final payoff that she or her team earned in one randomly selected period from the experiment. This period was chosen by a random device after the experiment. The two sessions in which each subject participated required approximately 3 hours and half to complete in total. The mean payoff per subject was 3026 Ksh (One US dollar approximately exchanged for 80 Ksh in August of 2010). The maximum payoff among the 120 subjects was 3865 Ksh, and the minimum payoff was 2068 Ksh.

4. Experimental Results

In this section, we are going to exhibit whether our experimental results support the Walrasian adjustment process or the Marshallian adjustment process based on the discussions on the ratio of the three equilibria, the average distances to the fair equilibrium, price movement, and final holdings of commodity X.

Table 3 provides the ratios of the three equilibria (i.e., A2, B1, and C1) bundles and the ratios of bundles near these three equilibria in the end-of-period holdings of X and Y. These ratios are also presented in Figure 4 to help understanding visually.[7] The bundles near A2, B1, and C1 are defined as being within 1 unit of A2, B1, C1 for each commodity. For example, the bundles of near B1 for type 1 (i.e., (12,15)) are (11, 14), (11, 15), (11, 16), (12, 14), (12, 15), (12, 16), (13, 14), (13, 15), and (13, 16), and the bundles of near B1 for type 2 (i.e., (18,15)) are (17, 14), (17, 15), (17, 16), (18, 14), (18, 15), (18, 16), (19, 14), (19, 15), and (19, 16). There were 120 subjects and each subject who was assigned to be either type 1 or type 2 participated in 2 experimental sessions in which each session consisted of 5 periods. Hence, the number of the end-of-period bundles for each type subjects is 600. Among these bundles, as shown from Table 3 and Figure 4, both ratios of the fair equilibrium B1 bundle and the ratios of bundles near B1 were respectively much

[7] In Figure 4, Panel I is for the ratios of the three equilibria bundles and Panel II is for the ratios of bundles near these three equilibria.

higher than those of A2 (resp. C1) and those near A2 (resp. near C1) for either type 1 subjects or type 2 subjects. This result is strongly supported by the test of proportions. All the p values are smaller than 0.001 in any cases.

Table 3. Ratios of Three Equilibria Bundles to All Final Holdings

	Type 1	Type 2	Both types
A2	0.17% (=1/600)	0.33% (=2/600)	0.25% (=3/1200)
Near A2 (±1)	0.50% (=3/600)	1.00% (=6/600)	0.75% (=9/1200)
B1	7.83% (=47/600)	6.33% (=38/600)	7.08% (=85/1200)
Near B1 (±1)	27.83% (=167/600)	27.33% (=164/600)	27.58% (=331/1200)
C1	1.00% (=6/600)	0.17% (=1/600)	0.58% (=7/1200)
Near C1 (±1)	2.67% (=16/600)	0.67% (=4/600)	1.67% (=20/1200)

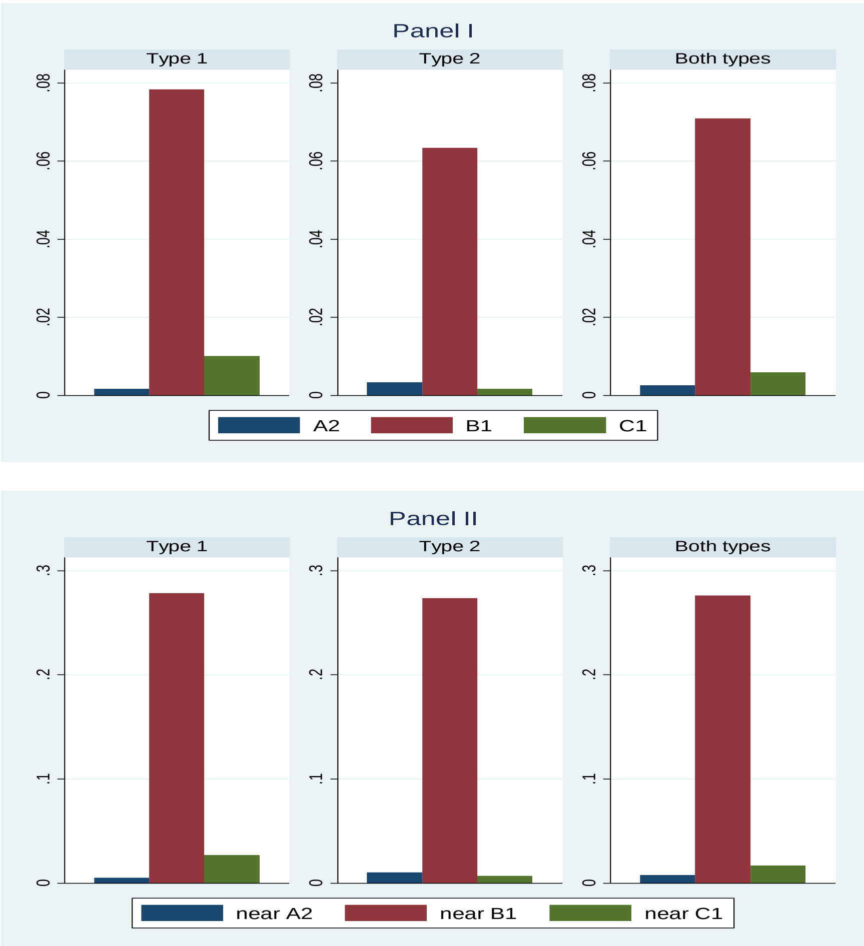

Figure 4. Ratios of Three Equilibria Bundles to All Final Holdings

Figure 5 shows the average distances from subjects' end-of-period holdings to the fair equilibrium B1 consumption bundle.[8] As indicated clearly from the figure, the average distances to B1 decreased as the period went by for both types of subjects. A panel data regression of the variable *Distance* on the variable *Period* was run to test whether this decrease is statistically significant. We found that the coefficient of *Period* was negatively significant at 0.1% level in either type-separated case or type-pooled case, which confirms that the decreasing tendency in Figure 5 is significant.

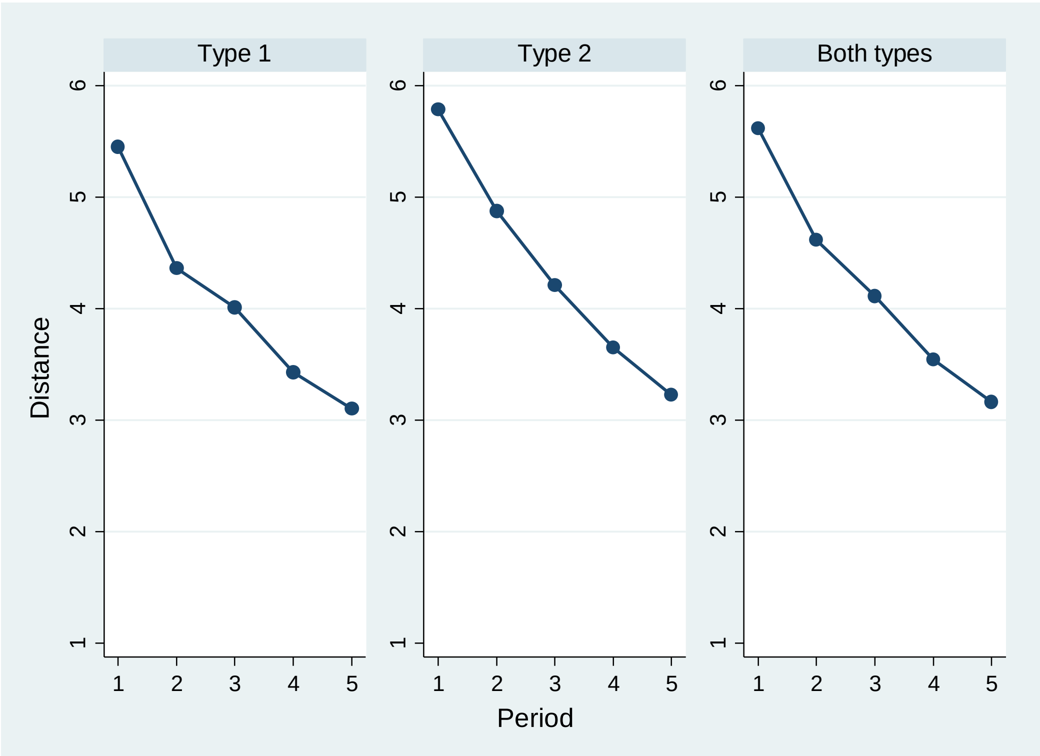

Figure 5. Average Distances to the Fair Equilibrium B1

Figure 6 shows the price movements of P_X / P_Y by periods. The three equilibria (i.e., the low, middle, and high equilibria) are also presented by the green, red, and orange lines, respectively. To draw these price movements, we first divided the subjects into 4 groups according to their prices in Period 1 and then trace their movements of the prices in Periods 2 – 5. The prices were calculated by subjects' end-of-period holdings of

[8] Here the distance of each subject at each period is defined as the Euclidean distance, which can be written as $\sqrt{(X_{it}-12)^2+(Y_{it}-15)^2}$ for type 1 subjects and $\sqrt{(X_{it}-18)^2+(Y_{it}-15)^2}$ for type 2 subjects, where *i* and *t* refer to subject and period indices, and *X* and *Y* stand for a subject's end-of-period holdings of commodities X and Y, respectively.

commodities X and Y, and the 4 groups were based on 4 price intervals: (i) price ≤ 0.44 (2.93% of subjects); (ii) 0.44 < price ≤ 1.08 (50.13% of subjects); (iii) 1.08 < price ≤ 2.22 (41.17% of subjects); and (iv) price > 2.22 (5.77% of subjects). As shown in the figure, a certain level of fluctuation in the price can be observed among the subjects whose prices in Period 1 were either not larger than the price at A2 (see Figure 6 – I) or larger than the price at C1 (see Figure 6 – IV). For the majority of subjects (91.3% of subjects), when their prices in Period 1 were between the prices at A2 and B1 (resp. between the prices at B1 and C1), an upward (resp. a downward) tendency towards the middle equilibrium can be observed. Although the panel data regression of the variable *Price* on the variable *Period* confirmed the significance of these two tendencies ($p < 0.05$ in both cases), the results obtained from a Wilcoxon signed-rank test indicates that it is only in the case of the initial price being between 1.08 and 2.22 that the price in Period 5 is equal to the middle equilibrium price ($p = 0.3842$).[9]

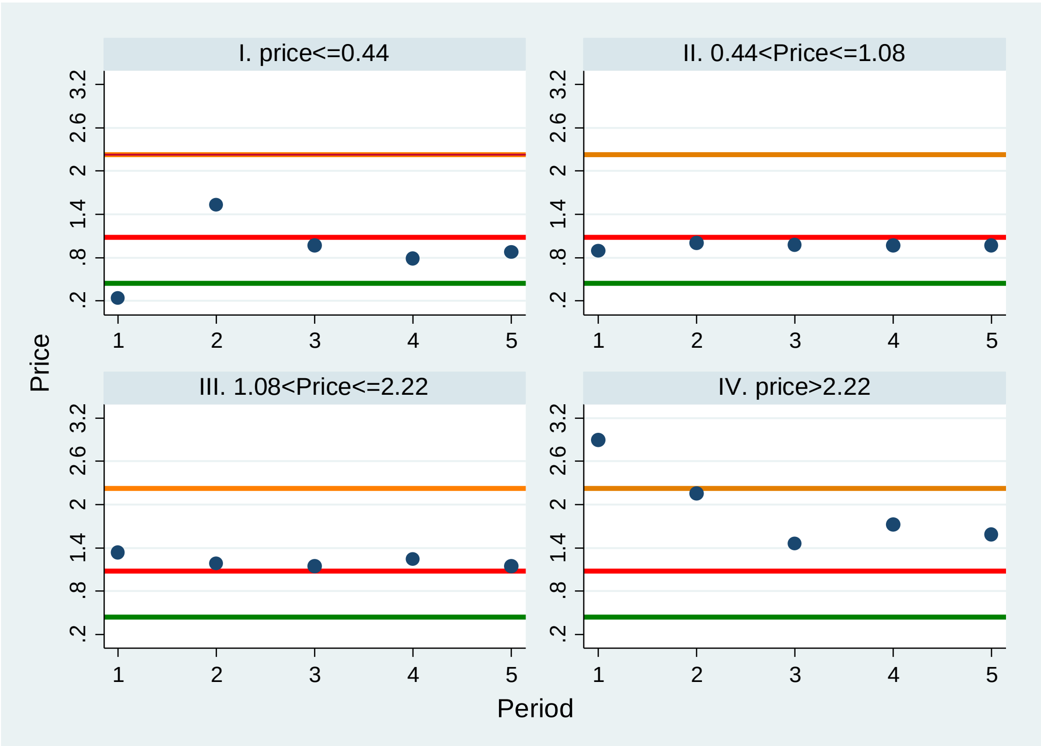

Figure 6. Price Movement by Periods

[9] For other two initial price intervals, the prices in Period 5 are also significantly not equal to the middle equilibrium price.

Figure 7 presents the movements of the type 1 subjects' final holdings of commodity X by periods.[10] The three equilibria (i.e., the low, middle, and high equilibria) are again presented by the green, red, and orange lines, respectively. Similar to the case of the price movements, to draw the movements of final holdings of X, we first divided the type 1 subjects into 4 groups according to their final holdings of X in Period 1 and then trace their movements of the amount of X in Periods 2 – 5. The final holdings of X in Period 1 were based on 4 intervals: (i) $X \leq 7$; (ii) $7 < X \leq 12$; (iii) $12 < X \leq 16$; and (iv) $X > 16$. As indicated from the figure, it seems that no matter where they started the final holdings of commodity X converged to the middle equilibrium with the passing of periods. By combining the results from the panel data regression and the Wilcoxon signed-rank test together, we confirmed that the end-of-period holdings of X converged to the middle equilibrium in Period 5 in three of four intervals that mentioned above.[11] The only exceptional interval was that the final holdings of X in Period 1 were larger than between the low equilibrium and the middle equilibrium (i.e., $7 < X \leq 12$). In this interval, we found that the variable *Period* did not have significant effect on the final holdings of X, and the amount of X was statistically equal to 11 in all the 5 periods (see the dark blue line in Figure 7).

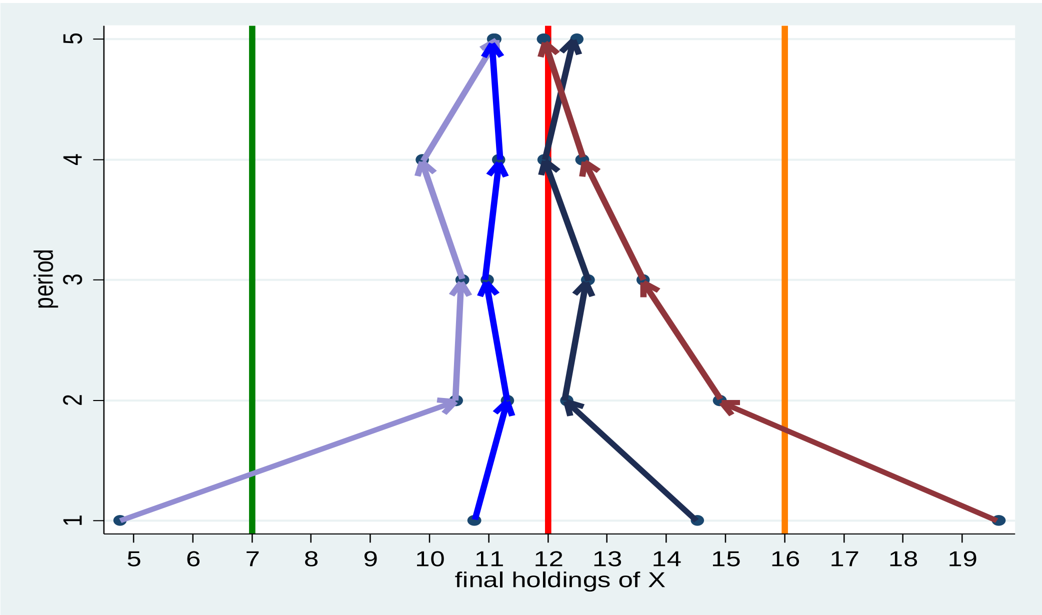

Figure 7. Final Holdings of X

[10] By Walras' law, we only need to focus on market of commodity X. In addition, by feasibility it is sufficient to consider the movements in final holdings of subjects of type 1 only.
[11] The panel data regression was run by regressing the variable *Final holdings of X* on the variable *Period*, and the Wilcoxon signed-rank test was conducted to test whether the end-of-period holdings of X was equal to 12. These results are available upon request.

Summing up the above descriptions, while existing experimental evidences supporting Marshallian dynamics are mostly provided in a double auction market (e.g., Plott and George, 1992; Plott and Smith, 1999; Plott et al., 2013), our results exhibit that Marshallian path is even supported in a pit market.

5. Discussions

Shimomura and Yamato (2012) studied how different compositions of ethnicities (i.e. Kikuyu, Luo, and Kalenjin) in Kenya trade in the similar market environment as in the current study. They found that ethnic diversity plays an important role in the evolution of markets. In sessions with Luo and/or Kikuyu subjects only, there was no convergence of allocations. However, in the sessions with Kalenjin subjects, allocations converged to the intermediate allocation, especially in later periods. Moreover, convergence to the intermediate equilibrium occurs considerably faster with Kalenjin subjects and the frequency of transactions with Kalenjin subjects is significantly lower than that with Luo and/or Kikuyu subjects only. They concluded that less frequent transactions resulted in the more efficient outcomes of the experimental market. In the current study, we also perform a robustness check to investigate whether our findings of Marshallian path in a pit market are similarly driven by the Kalenjin subjects. The comparison results for the data with and without Kalenjin subjects show that Marshallian dynamics is supported in both the sessions with and without Kalenjin subjects, and it is more obvious in the sessions where Kalenjin subjects participated than those with Luo and/or Kikuyu subjects only.[12]

In our view, the evidence that there is no convergence to the intermediate equilibrium in sessions with Luo and/or Kikuyu subjects only in Shimomura and Yamato (2012) might be due to the differences in experimental design between their study and ours. These differences are threefold. First, the parameterization of subjects' utility functions is different. In Shimomura and Yamato (2012), the parameterization led the payoff of the intermediate equilibrium for both types of subjects to be 2000 tokens, while in the current study we avoid this happening because the number of 2000 might be too conspicuous to attract subjects' notice. Second, different from that each trader in the current study is individual, each trading group in Shimomura and Yamato (2012) contained two subjects from the same ethnicity, which allows them being able to discuss with each other within each group. Third, each subject in Shimomura and Yamato (2012) participated in three experimental sessions, while that number in the current study is two.

[12] These results are not reported here, but are available upon request.

Given that the above-mentioned differences might lead to different experimental behavior, more research in future is needed to verify our findings.

6. Concluding remarks

Our laboratory experiment is designed to study dynamics in pit market trading. In our exchange economy model, three competitive equilibria exist. The two equilibria with the lowest, and the highest relative prices are beneficial for one type of the consumers, and the intermediate price gives an equitable allocation. Our result shows strong support for the convergence to the intermediate equilibrium, which is unstable in Walrasian tatonnement dynamics and is stable in Marshallian quantity adjustment process. In our experiments, Marshallian path predicts that consumers in the market finally reach at an "equitable" allocation where payoffs for both types of consumers are identically the same.[13] This naturally raises the question of whether our experimental results were due to subjects' fairness preferences on payoffs. However, our experimental design rules out this possibility, because each type of subjects can only know their own payoffs.

Plott (2000) reports that *in a double auction market* the Marshallian model works well when supply curves are forward-falling, in contrast, in the backward-bending case stability is captured by the Walrasian model and the Marshallian model of dynamics is rejected. Given that said, under what conditions Marshallian dynamics work *in a pit market* remains still unknown to us. In a recent study on investigating the change in the price in call market experiments, Plott and Pogorelskiy (2015) demonstrate that the Newton-Jaws model based on the Newton method provides a better description of how the markets operate than the Walrasian model. The Newton method (see details in Bossaert and Plott (2008)) might be a useful tool for examining this question. We leave this issue open and welcome any efforts to explore it.

[13] In our data, both two-tailed t test and Wilcoxon rank sum test cannot reject that mean and median payoffs are the same in Period 5, respectively (t test: p = 0.6294; Wilcoxon rank sum test: p = 0.7022).

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Appendix 1: Local Stability Conditions of Price and Quantity Adjustment Processes in Two-Consumer Two-Good Exchange Economies

First of all, we give formal definitions of "two-good exchange economy," and "competitive equilibrium":

DEFINITION A1. A *two-good exchange economy* is a list (I, U, ω) such that I is a nonempty finite set, $U = (U_i)_{i \in I}$ is a profile of real-valued functions from $\mathbb{R}^2_+$, and $\omega = (\omega_i)_{i \in I}$, where $\omega_i = (\overline{x_i}, \overline{y_i})$, is a profile of points of $\mathbb{R}^2_+$. Then an element of I is called a *consumer*. For each $i \in I$, U_i and ω_i are called the *utility function, and the individual endowment, of consumer* i, respectively. The profile of non-negative vectors $(x_i, y_i)_{i \in I}$ is called an *allocation of* (I, U, ω) if $\sum_{i \in I} x_i = \sum_{i \in I} \overline{x_i}$ and $\sum_{i \in I} y_i = \sum_{i \in I} \overline{y_i}$.

DEFINITION A2. Let (I, U, ω) be a two-good exchange economy. Then the vector $((x_i^*, y_i^*)_{i \in I}, (p_X^*, p_Y^*)) \in (\mathbb{R}^2_+)^I \times \mathbb{R}^2$ is a *competitive equilibrium*, or simply *equilibrium, for* (I, U, ω) if

(1) for each $i \in I$, $p_X^* x_i^* + p_Y^* y_i^* \leq p_X^* \overline{x_i} + p_Y^* \overline{y_i}$, and

$U_i(x_i^*, y_i^*) \geq U_i(x_i, y_i)$ for each $(x_i, y_i) \in \mathbb{R}^2_+$ such that $p_X^* x_i + p_Y^* y_i \leq p_X^* \overline{x_i} + p_Y^* \overline{y_i}$;

(2) $\sum_{i \in I} x_i^* = \sum_{i \in I} \overline{x_i}$ and $\sum_{i \in I} y_i^* = \sum_{i \in I} \overline{y_i}$.

The profile of non-negative vectors $(x_i^*, y_i^*)_{i \in I}$, and the vector (p_X^*, p_Y^*) are called an *equilibrium allocation,* and an *equilibrium price vector, for* (I, U, ω), respectively.

We next investigate local dynamics of price adjustment process, which work in neighborhoods of equilibria. Simply speaking, the price adjustment process, or "Walrasian" adjustment process, means that the relative price of X goes up when X is excessively demanded, and the relative price of X goes down when X is excessively supplied. We first give the definitions of market excess demand function, and the local stability and instability of Walrasian adjustment process.

DEFINITION A3. Let (I, U, ω) be a two-good exchange economy, and d_i^X be the demand function for X of consumer $i \in I$. Define the set of the demanders $ID(P)$ for X and the set of the suppliers $IS(P)$ of X by

$$ID(P) = \{ i \in I \mid d_i^X(P,1) - \bar{x}_i \geq 0 \}; \text{ and}$$

$$IS(P) = \{ i \in I \mid d_i^X(P,1) - \bar{x}_i < 0 \}.$$

for each $P > 0$. Then the *market demand function*, simply *demand function for* X is defined by

$$D^X(P) = \sum_{i \in ID(P)} \left(d_i^X(P,1) - \bar{x}_i \right),$$

the *market supply function*, simply *supply function of* X is defined by

$$S^X(P) = \sum_{i \in IS(P)} \left(\bar{x}_i - d_i^X(P,1) \right),$$

and the *market excess demand function*, simply *excess demand function for* X is defined by

$$E^X(P) = D^X(P) - S^X(P) = \sum_{i \in I} \left(d_i^X(P,1) - \bar{x}_i \right)$$

for each $P > 0$.

DEFINITION A4. Let (I, U, ω) be a two-good exchange economy. Suppose that $D^X(P^*) = S^X(P^*) = x^*$. Then *Walrasian adjustment process with the excess demand function* E^X is the ordinary differential equation: $\dot{P} = W(E^X(P))$, where W is a real-valued function from $\mathbb{R}$ such that $W(0) = 0$ and $W'(z) > 0$ for each $z \in \mathbb{R}$. We say that (x^*, P^*) is *locally Walras-stable* (resp. *locally Walras-unstable*) if $E^X{}'(P^*) < 0$ (resp. $E^X{}'(P^*) > 0$). The competitive equilibrium $((x_i^*, y_i^*)_{i \in I}, (p_X^*, p_Y^*))$ for (I, U, ω) is called a *locally Walras-stable equilibrium* (resp. *locally Walras-unstable equilibrium*) if $(D(p_X^*/p_Y^*), p_X^*/p_Y^*)$

is locally Walras-stable (resp. locally Walras-unstable) .

The local Walrasian stability and instability of a competitive equilibrium for a two-consumer economy is characterized in an Edgeworth box in the following way: Let $((x_1*, y_1*),\ (x_2*, y_2*),\ (P*,1))$ be a competitive equilibrium, then $E^X(P*) = 0$. Suppose that $((x_1*, y_1*),\ (x_2*, y_2*),\ (P*,1))$ is a locally Walras-stable equilibrium such that $\overline{x_1} - x_1* > 0$. Then $E^X{}'(P*) < 0$. Draw the budget line passing through the competitive allocation and the initial allocation. Note that $\left(\overline{x_1} - x_1*\right)/\left(x_2* - \overline{x_2}\right) = 1$ because $x_1* + x_2* - \overline{x_1} - \overline{x_2} = 0$. Consider a relative price slightly higher than $P*$, draw the new budget line, and find the intersections with the offer curves of the consumers. Denote by (x_1, y_1), and (x_2, y_2) the intersections of the budget line with the offer curves of consumers 1 and 2, respectively. Recall $E^X{}'(P*) < 0$, then the zero excess demand at $P*$ becomes negative when the relative price is marginally higher than $P*$. Thus, $x_1 + x_2 - \overline{x}_1 - \overline{x}_2 < 0$, namely $\left(\overline{x_1} - x_1\right)/\left(x_2 - \overline{x_2}\right) > 1$. Then X is excessively supplied, so that the relative price decreases and converges to $P*$. Similarly, by considering a relative price slightly lower than $P*$, we can have $x_1 + x_2 - \overline{x}_1 - \overline{x}_2 > 0$, namely $\left(\overline{x_1} - x_1\right)/\left(x_2 - \overline{x_2}\right) < 1$. Then X is excessively demanded, and thereby the relative price increases and converges to $P*$. The points A and C in Figure A1 therefore represent locally Walras-stable equilibria.

On the other hand, suppose that $((x_1*, y_1*),\ (x_2*, y_2*),\ (P*,1))$ is a locally Walras-unstable equilibrium such that $\overline{x_1} - x_1* > 0$. Then $E^X{}'(P*) > 0$, and $\left(\overline{x_1} - x_1\right)/\left(x_2 - \overline{x_2}\right) = 1$. Consider a relative price slightly higher than $P*$, and choose (x_1', y_1'), and (x_2', y_2') in the same way as a locally Walras-stable equilibrium is considered. Then we can see that the zero excess demand at $P*$ becomes positive when the relative price marginally goes up. Thus, $x_1' + x_2' - \overline{x}_1 - \overline{x}_2 > 0$. Hence, $\left(\overline{x_1} - x_1'\right)/\left(x_2' - \overline{x_2}\right) < 1$. Similarly, by considering a relative price slightly lower than $P*$, we can have $x_1' + x_2' - \overline{x}_1 - \overline{x}_2 < 0$, namely $\left(\overline{x_1} - x_1'\right)/\left(x_2' - \overline{x_2}\right) > 1$. The point B in Figure A1 therefore describes a locally Walras-unstable equilibrium.

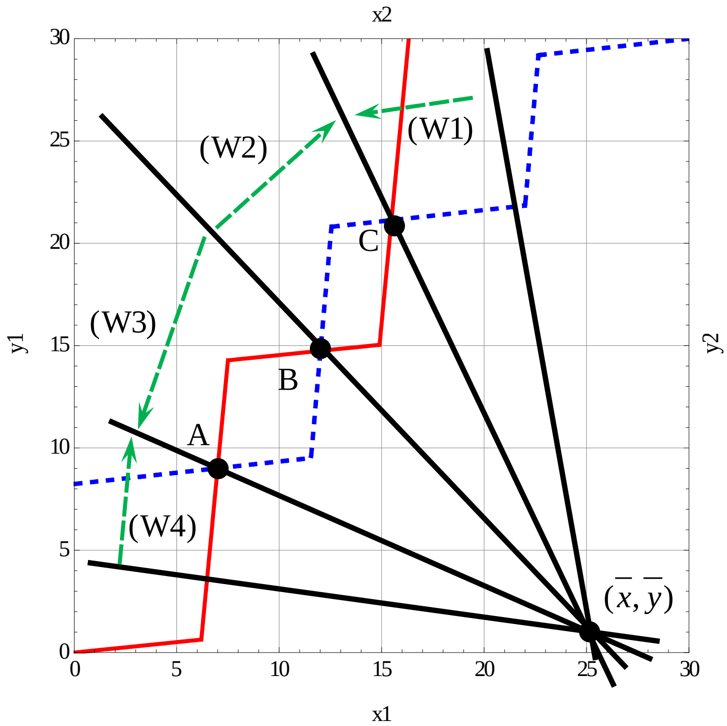

Figure A1. Local Walrasian Stability of Three Competitive Equilibria

We next discuss dynamics of quantity adjustment process. We give the definitions of local stability and instability of "Marshallian" adjustment process. To formulate them, we define the "demand price function" and the "supply price function" of an exchange economy, which are respectively "local inverse functions" of the demand and supply functions.

Let D^X and S^X be the demand function, and the supply function, for X, respectively. Let $D^X(P^*) = S^X(P^*) = x^*$, and assume $D^X{}'(P^*) \neq 0$. Then, by the inverse function theorem, there exists an open interval V in R_{++} such that $x^* \in V$ and a function Δ^X from V to R_{++} such that $P^* = \Delta^X(x^*)$, $x = D^X(\Delta^X(x))$ and $\Delta^X{}'(x) = 1/D^X{}'(\Delta^X(x))$ for each $x \in V$. The function Δ^X is a local inverse function of D^X. Similarly, by assuming $S^X{}'(P^*) \neq 0$, we can show that there exists an open interval W in R_{++} such that $x^* \in W$ and a differentiable function Σ^X from W to R_{++} such that $P^* = \Sigma^X(x^*)$, $x = S^X(\Sigma^X(x))$ and $\Sigma^X{}'(x) = 1/S^X{}'(\Sigma^X(x))$ for each $x \in W$. The function Σ^X is a local inverse function of S^X. Notice that $G = V \cap W$ is an open interval in $\mathbb{R}_{++}$ such that $x^* \in G$. Hence, suppose that $G = V = W$. By considering the neighborhood[14] G of x^*, we may define the following concepts:

DEFINITION A5. Suppose that $D^X(P^*) = S^X(P^*) = x^*$, $D^X{}'(P^*) \neq 0$ and $S^X{}'(P^*) \neq 0$. Let G be a neighborhood of x^*. The *demand price function for* X *on* G is defined by

$$\Delta^X(x) \;=\; \{P > 0 \mid x = D^X(P)\}$$

for each $x \in G$. The *supply price function of* X *on* G is defined by

$$\Sigma^X(x) \;=\; \{P > 0 \mid x = S^X(P)\},$$

for each $x \in G$. The *excess demand price function for* X *on* G is defined by

$$\Phi^X(x) \;=\; \Delta^X(x) - \Sigma^X(x)$$

for each $x \in G$.

Notice that $\Phi^X(x^*) \;=\; \Delta^X(x^*) - \Sigma^X(x^*) \;=\; P^* - P^* = 0.$

DEFINITION A6. Suppose that $D^X(P^*) = S^X(P^*) = x^*$, $D^X{}'(P^*) \neq 0$ and $S^X{}'(P^*) \neq 0$. Let G be a neighborhood of x^*, and Φ^X be the excess demand price function for X on G. Then *Marshallian adjustment process with the excess demand price function* Φ^X *on* G is the ordinary differential equation: $\dot{x}$ = $M(\Phi^X(x))$, where M is a real-valued function from $\mathbb{R}$ such that $M(0) = 0$ and $M'(z) > 0$ for each $z \in \mathbb{R}$. We say that (x^*, P^*) is *locally Marshall-stable* (resp. *locally Marshall-unstable*) if $\Phi^X{}'(x^*) < 0$ (resp. $\Phi^X{}'(x^*) > 0$). The competitive equilibrium $((x_i^*, y_i^*)_{i\in I}, (p_X^*, p_Y^*))$ for (I, U, ω) is called a *locally Marshall-stable equilibrium* (resp. *locally Marshall-unstable equilibrium*) if $(D^X(p_X^*/p_Y^*), p_X^*/p_Y^*)$ is locally Marshall-stable (resp. locally

[14] We call an open interval containing the real number x^* a *neighborhood of* x^*.

Marshall-unstable).

The local Marshallian stability and instability of a competitive equilibrium for a two-consumer economy is characterized in an Edgeworth box in the following way: Suppose that ((x_1*, y_1*) , (x_2*, y_2*) , $(P*,1)$) is a locally Marshall-stable competitive equilibrium such that $\overline{x_1} - x_1*$ > 0. Then, $S^X(P*)$ = $\overline{x_1} - x_1*$ = $x_2*-\overline{x_2}$ = $D^X(P*)$. This means that consumer 1 is the supplier, and consumer 2 is the demander, for X at the relative price $P*$. Define $x*$ = $S^X(P*)$ = $\overline{x_1} - x_1*$, then $\Phi^X{}'(x*)$ < 0. Draw the vertical line passing through the competitive allocation. Note that $\left(\overline{x_1} - x_1*\right)/\left(x_2*-\overline{x_2}\right)$ = $\left(y_1*-\overline{y_1}\right)/\left(\overline{y_2} - y_2*\right)$ = 1 because $x_1*+x_2* - \overline{x_1} - \overline{x_2}$ = $y_1*+y_2* - \overline{y_1} - \overline{y_2}$ = 0. Consider a supply of X by consumer 1 slightly more than $\overline{x_1} - x_1*$ under the feasibility constraint of X, $x_1*+x_2* - \overline{x_1} - \overline{x_2}$ = 0. Draw the vertical line at the new supply level of X, and find the intersections with the offer curves of the consumers. Denote by (x_1, y_1), and (x_2, y_2) the intersections of the vertical line with the offer curves of consumers 1 and 2, respectively. In addition, let P_1 and P_2 be the associated supply price of consumer 1 and demand price of consumer 2, respectively. Recall $\Phi^X{}'(x*)$ < 0, then the zero excess demand price at $x*$ becomes negative when the supply of X is marginally greater than $x*$. Thus, $P_2 - P_1$ < 0, namely $P_2 < P_1$. Then consumer 2, the demander, appreciates X less than consumer 1, the supplier, does at the level $x*$, so that the supply of X decreases and converges to $x*$. Similarly, by considering a supply level slightly less than $\overline{x_1} - x_1*$, we can show $P_2 > P_1$. Then the demander 2 appreciates X more than the supplier 1 does, so that the supply of X increases and converges to $x*$. The point B in Figure A2 therefore represents locally Marshall-stable equilibria.

On the other hand, suppose that ((x_1*, y_1*), (x_2*, y_2*), $(P*,1)$) is a locally Marshall-unstable equilibrium such that $\overline{x_1} - x_1*$ > 0. Then, $S^X(P*)$ = $\overline{x_1} - x_1*$ = $x_2*-\overline{x_2}$ = $D^X(P*)$. Define $x*$ = $S^X(P*)$ = $\overline{x_1} - x_1*$, then $\Phi^X{}'(x*)$ > 0. Draw the vertical line passing through the competitive allocation. Note that $\left(\overline{x_1} - x_1*\right)/\left(x_2*-\overline{x_2}\right)$ = $\left(y_1*-\overline{y_1}\right)/\left(\overline{y_2} - y_2*\right)$ = 1 because

$x_1{*}+x_2{*}-\overline{x_1}-\overline{x_2}$ = $y_1{*}+y_2{*}-\overline{y_1}-\overline{y_2}$ = 0. Consider a supply of X by consumer 1 slightly more than $\overline{x_1}-x_1{*}$ under the feasibility constraint of X, $x_1{*}+x_2{*}-\overline{x_1}-\overline{x_2}$ = 0. Draw the vertical line at the new supply level of X, and find the intersections with the offer curves of the consumers. Denote by (x_1, y_1), and (x_2, y_2) the intersections of the vertical line with the offer curves of consumers 1 and 2, respectively. In addition, let P_1 and P_2 be the associated supply price of consumer 1 and demand price of consumer 2, respectively. Recall $\Phi^X{}'(x^*)$ > 0, then the zero excess demand price at x^* becomes positive when the supply of X is marginally greater than x^*. Thus, P_2-P_1 > 0, namely $P_2 > P_1$. Then consumer 2, the demander, appreciates X more than consumer 1, the supplier, does at the level x^*, so that the supply of X increases and diverges from x^*. The points A and C in Figure A2 therefore describe locally Marshall-unstable equilibria.

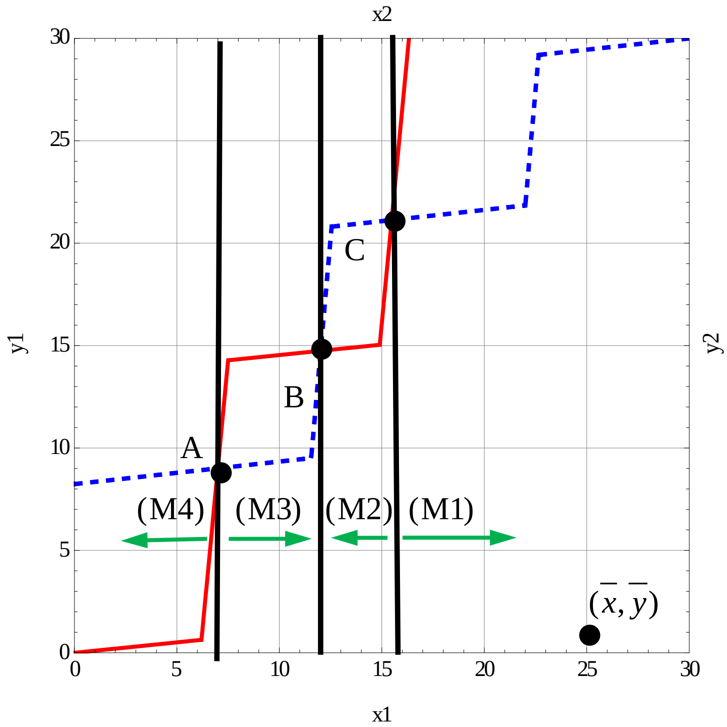

Figure A2. Local Marshallian Stability of Three Competitive Equilibria

Appendix 2: Experimental Instruction

This is an experiment about decision making and economics. The instructions are simple. If you follow them carefully and make good decisions, you might earn a considerable amount of money that will be paid to you. In this experiment, you will make decisions to trade or hold two kinds of commodities, called X and Y in a sequence of trading periods.

I. Introduction

1. There are (20) traders in total. Please make sure that you have the following items:
    a) “Payoff Table” (one)
    b) “Record Sheet” (three)
    c) Name tag (one)

2. Please check whether your trader name (A, B, C…) in your “Record Sheet” is the same as the <u>first</u> letter in your name tag.

3. Your “Payoff Table” is your own SECRET information. <u>You are NOT allowed to reveal the information regarding your “Payoff Table” to any other person.</u> We will show you how to read the “Payoff Table” later.

4. At the beginning of each period of the experiment, you will be given some amounts of Commodity X and/or Y. These amounts are shown in the first row of your “Record Sheet”. This endowment is also your own SECRET information, so <u>you are NOT allowed to reveal the information regarding your endowment to any other person.</u>

II. Trading Rules

The trading rules are as follows:

1. First of all, please put on your name tag so that the other traders can see your trader name.

2. Each trader will be given pink cards and/or white cards in an envelope. One pink card is one unit of commodity X, and one white card is one unit of commodity Y. The number of pink cards (resp., white cards) equals to the amount of Commodity X (resp., Commodity Y) in the first row of your “Record Sheet.” You can take pink and white cards (Commodities X and Y) out of the envelope only when you check the number of cards or

trade them.

3. Walk around this room and find a person to trade. Be careful NOT to reveal to any other person your "Payoff Table" and "Record Sheet". The same notice applies to the following steps 4, 5, and 6.

4. Start a negotiation when you find a person that wants to trade with you. You CANNOT give Commodity X or Y more than you hold. Moreover, the trading ratio of Y to X (= (Amount of Y)/(Amount of X)) should be greater than or equal to (1/4 = 0.25). Remember that the trading ratio of Y to X cannot be less than (1/4 = 0.25).

5. If you reach an agreement, then report the agreement to an experimenter. In front of the experimenter, trade Commodity X with Commodity Y according to the agreement. After that, write the trading result in your "Record Sheet." This is the end of one trade.

6. Repeat the above steps 3-5 after one trade is completed. You have (12) minutes for each period. You can trade as many times as you want within the time limit. For the next person to trade with, you can choose any person: she/he may be the same as or different from one of the persons you have already traded. We accept only agreements that have reached within the time limit.

7. Please go back to your seat after each period. Please make sure that all commodity cards you traded are in your envelope. This is the end of the first period.

8. At the beginning of the second period, you will receive the same materials as those of the first period. That is, the amounts of Commodities X and Y you initially have at Period 2 are the same as those at the beginning of Period 1. We will distribute pink cards and /or white cards in an envelope. Those amounts are shown in your "Record Sheet". We will also collect the commodity cards and the envelope used in Period 1. After a 2-minute break, Period 2 starts. This experiment has (5) periods. The above steps are repeated (5) times.

III. An Example

We will give you an example to explain how to read the "Payoff Table" and how to fill out the "Record Sheet" by way of an example. In the following explanations, we will use the “Pilot Payoff Table” which has nothing to do with the “Payoff Table,” but the “Pilot Payoff Table” should help you read the “Payoff Table” in the experiment.

1. Suppose that your trader name is “A”.

2. Take a look at Table 1-(a). Your endowment is shown in the second row of the “Record Sheet.” In this example, you are given endowment of 9 units of Commodity X and 8 units of Commodity Y.

Record Sheet

Date (day/month/year): Time: ~

Trader Name: **A**

Your Name Tag ID: xxxxx Your Name xxxxx xxxxx

Period 1

Trade Number	Amount of Change in X	Amount of Change in Y	Person You Trade with	Amount of X	Amount of Y	Payoff
0				**9**	**8**	**4905**
1						

Table 1-(a)

Next please see Table 2. This table represents a part of the “Pilot Payoff Table.” In this table, the horizontally aligned numbers denote the amounts of Commodity X and the vertically aligned numbers denotes the amounts of Commodity Y. You are endowed with 9 units of Commodity X and 8 units of Commodity Y, so your initial payoff is the number in the cell of column 9 - row 8, that is, 4905. This number is the value shown in the “Payoff” of “Trade Number 0” in the “Record Sheet”.

Pilot Payoff Table

Amount of Y

25	····	7209	7284	7359	7434	7509	7584	7659	7734	····
24	····	7145	7220	7295	7370	7445	7520	7595	7670	····
23	····	7073	7148	7223	7298	7373	7448	7523	7598	····
22	····	6994	7069	7144	7219	7294	7369	7444	7519	····
21	····	6907	6982	7057	7132	7207	7282	7357	7432	····
20	····	6810	6885	6960	7035	7110	7185	7260	7335	····
19	····	6703	6778	6853	6928	7003	7078	7153	7228	····
18	····	6585	6660	6735	6810	6885	6960	7035	7110	····
17	····	6455	6530	6605	6680	6755	6830	6905	6980	····
16	····	6311	6386	6461	6536	6611	6686	6761	6836	····
15	····	6152	6227	6302	6377	6452	6527	6602	6677	····
14	····	5976	6051	6126	6201	6276	6351	6426	6501	····
13	····	5781	5856	5931	6006	6081	6156	6231	6306	····
12	····	5566	5641	5716	5791	5866	5941	6016	6091	····
11	····	5328	5403	5478	5553	5628	5703	5778	5853	····
10	····	5066	5141	5216	5291	5366	5441	5516	5591	····
9	····	4776	4851	4926	5001	5076	5151	5226	5301	····
8	····	4455	4530	4605	4680	4755	4830	4905	4980	····
7	····	4101	4176	4251	4326	4401	4476	4551	4626	····
6	····	3709	3784	3859	3934	4009	4084	4159	4234	····
5	····	3276	3351	3426	3501	3576	3651	3726	3801	····
4	····	2798	2873	2948	3023	3098	3173	3248	3323	····
3	····	2269	2344	2419	2494	2569	2644	2719	2794	····
2	····	1685	1760	1835	1910	1985	2060	2135	2210	····
1	····	1039	1114	1189	1264	1339	1414	1489	1564	····
0	····	325	400	475	550	625	700	775	850	····
	····	3	4	5	6	7	8	9	10	····

Amount of X

Table 2

Let us begin the first trading.

3. Suppose that you negotiate with Trader B, and you and B reach the agreement that "4 units of Commodity X that you have are traded for 7 units of Commodity Y that Trader B has."

4. Report the agreement to the experimenter. The experimenter will fill out the following table on the blackboard for you.

Deal				
Trader that gave X	**Amount of X**	**Trader that gave Y**	**Amount of Y**	**Ratio(=Y/X)**
A	**4**	**B**	**7**	**1.75**

Table 3-(a)

In this case, as shown in Table 3-(a), the experimenter writes "A" in the blank of "Trader that gave X", "4" in "Amount of X", "B" in "Trader that gave Y" and "7" in "Amount of Y." Remember that the trading ratio of Y to X (=Y/X) should be greater than or equal to (1/4 = 0.25).

5. Following the experimenter's guidance, trade Commodity X for Y according to the agreement. You give 4 pink cards (Commodity X) to Trader B and instead receives 7 white cards (Commodity Y) from Trader B.

6. Next please fill out your "Record Sheet." See Table 1-(b). Write "-4" in the blank of "Amount of Change in X", "7" in "Amount of Change in Y", and "B" in "Person You Trade with" in the second row of "Trade Number 1" of the "Record Sheet".

As a result of this trade, you now hold 5 units of Commodity X and 15 units of Commodity Y. According to the "Pilot Payoff Table" (Table 2), you will find that your payoff is "6302."

Write "5" in the blank of "Amount of X," "15" in "Amount of Y," and "6302" in "Payoff".

Record Sheet

Date (day/month/year): Time: ~

Trader Name: **A**

Your Name Tag ID: xxxxx Your Name xxxxx xxxxx

Period 1

Trade Number	Amount of Change in X	Amount of Change in Y	Person You Trade with	Amount of X	Amount of Y	Payoff
0				**9**	**8**	**4905**
1	**-4**	**7**	**B**	**5**	**15**	**6302**
2						

Table 1-(b)

Then, the first trading is completed. Now, let us move on to the second trading.

7. Suppose that you negotiate with Trader K and agree "to trade your 2 units of commodity Y for Trader K's 3 units of commodity X."

8. Report the agreement to the experimenter. The experimenter will fill out the following table on the blackboard for you.

Deal				
Trader that gave X	**Amount of X**	**Trader that gave Y**	**Amount of Y**	**Ratio(=Y/X)**
A	**4**	**B**	**7**	**1.75**
G	**5**	**H**	**4**	**0.8**
L	**12**	**F**	**14**	**1.17**
K	**3**	**A**	**2**	**0.67**

Table 3-(b)

As shown in Table 3-(b), the experimenter writes "K" in the blank of "Trader that gave X", "3" in "Amount of X," "A" in "Trader that gave Y" and "2" in "Amount of Y."

9. Following the experimenter's guidance, trade commodities according to the agreement. You will give 2 white cards (commodity Y) to Trader K, and in turn take 3 pink cards (commodity X).

10. Then, fill out your "Record Sheet" as follows. Look at the row of Trade 2 of Table 1-(c). Write "3" in the blank of "Amount of Change in X," "-2" in "Amount of Change in Y" and "K" in "Person You Trade with."

As a result of this trading, you own 8 units of X and 13 units of Y. According to the "Pilot Payoff Table," your payoff is found to be 6156. So write "8" in the blank of "Amount of X," "13" in "Amount of Y" and "6156" in "Payoff."

Record Sheet

Date (day/month/year): Time: ~

Trader Name: **A**

Your Name Tag ID: xxxxx Your Name xxxxx xxxxx

Period 1

Trade Number	Amount of Change in X	Amount of Change in Y	Person You Trade with	Amount of X	Amount of Y	Payoff
0				**9**	**8**	**4905**
1	**-4**	**7**	**B**	**5**	**15**	**6302**
2	**3**	**-2**	**K**	**8**	**13**	**6156**

Table 1-(c)

Then, the second trading is completed.

Arrows in the "Pilot Payoff Table" indicate the changes in your payoff. In our experiment, you can make as many trades as you want within (12) minutes.

Now we will explain about your earnings. Your earnings depend on the <u>final payoff</u> that you earn in one randomly selected period from the experiment. This period is chosen by a random device after the experiment, so nobody can tell during the experiment. Your earnings are computed in the following way:

Your earnings =
(your final payoff at one period randomly chosen) × (1.14) Ksh

For example, suppose that (i) Period 1 is randomly selected after the experiment, and (ii) your final payoff at the end of Period 1 is (6156) as in Table 1-(c). Then your earnings are (7018) Ksh because (6156) × (1.14) = (7018). We round off the decimal places.

That's all. If you have any questions, please raise your hand.

Now, let us start the experiment. First, look at your "Payoff Table." We will give you 5 minutes so that you can look over the table and understand it very well. During this period, please make sure that you completely understand all the rules.

If you have any questions, please let us know quietly. Our staff will come to help you. Please remember that you are NOT allowed to communicate with any other person until the experiment starts.

Meantime, our staff will distribute pink and/or white cards in an envelope. Notice that the trading period number is printed in each card. You can only use cards with the same number as the numbers of the period going on. For example, in Period 3, you can only use cards with "3".

Remember that you are NOT allowed to reveal the information regarding your "Payoff Table" or the information regarding your "Record Sheet" to any other person. If this happens, the experiment will be stopped at that point.

Appendix 3: Payoff Tables

A. Payoff table for the type 1 subjects

Amount of Y

30	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	2068	2247	2247	2247	2247	2247	2247	2247	2247	2247	2247	2247	2247	2247
29	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	2068	2195	2195	2195	2195	2195	2195	2195	2195	2195	2195	2195	2195	2195
28	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	2068	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142	2142
27	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	2068	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090
26	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	2037	2037	2037	2037	2037	2037	2037	2037	2037	2037	2037	2037	2037	2037
25	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984
24	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1932	1932	1932	1932	1932	1932	1932	1932	1932	1932	1932	1932	1932	1932
23	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1879	1879	1879	1879	1879	1879	1879	1879	1879	1879	1879	1879	1879	1879
22	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827	1827
21	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1774	1774	1774	1774	1774	1774	1774	1774	1774	1774	1774	1774	1774	1774
20	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722
19	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1669	1669	1669	1669	1669	1669	1669	1669	1669	1669	1669	1669	1669	1669
18	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1616	1616	1616	1616	1616	1616	1616	1616	1616	1616	1616	1616	1616	1616
17	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1516	1564	1564	1564	1564	1564	1564	1564	1564	1564	1564	1564	1564	1564	1564
16	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511	1511
15	670	675	681	686	691	697	702	1145	1424	1429	1434	1440	1445	1450	1456	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459	1459
14	670	675	681	686	691	697	702	1145	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406	1406
13	670	675	681	686	691	697	702	1145	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354	1354
12	670	675	681	686	691	697	702	1145	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301	1301
11	670	675	681	686	691	697	702	1145	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248	1248
10	670	675	681	686	691	697	702	1145	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196
9	670	675	681	686	691	697	702	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143	1143
8	670	675	681	686	691	697	702	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091	1091
7	670	675	681	686	691	697	702	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038	1038
6	670	675	681	686	691	697	702	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985	985
5	670	675	681	686	691	697	702	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933
4	670	675	681	686	691	697	702	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880	880
3	670	675	681	686	691	697	702	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828	828
2	670	675	681	686	691	697	702	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775	775
1	670	675	681	686	691	697	702	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723	723
0	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

Amount of X

B. Payoff table for the type 2 subjects

Amount of Y

30	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
29	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
28	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
27	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
26	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
25	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
24	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
23	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
22	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1750	1756	1761	1767	1772	1778	1783
21	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1723	1728	1734	1739	1745	1745	1745	1745	1745	1745	1745	1745
20	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695
19	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1645	1645	1645	1645	1645	1645	1645	1645	1645	1645	1645	1645
18	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595
17	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545
16	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1465	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495	1495
15	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1445	1445	1445	1445	1445	1445	1445	1445	1445	1445	1445	1445	1445
14	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395	1395
13	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1345	1345	1345	1345	1345	1345	1345	1345	1345	1345	1345	1345	1345
12	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1295	1295	1295	1295	1295	1295	1295	1295	1295	1295	1295	1295	1295
11	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1245	1245	1245	1245	1245	1245	1245	1245	1245	1245	1245	1245	1245
10	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1147	1152	1195	1195	1195	1195	1195	1195	1195	1195	1195	1195	1195	1195	1195
9	695	701	706	712	717	723	728	734	1103	1108	1114	1119	1125	1130	1136	1141	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145	1145
8	695	701	706	712	717	723	728	734	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095	1095
7	695	701	706	712	717	723	728	734	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045
6	695	701	706	712	717	723	728	734	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995	995
5	695	701	706	712	717	723	728	734	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945
4	695	701	706	712	717	723	728	734	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895	895
3	695	701	706	712	717	723	728	734	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845	845
2	695	701	706	712	717	723	728	734	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795	795
1	695	701	706	712	717	723	728	734	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745	745
0	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695	695
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Amount of X