Keynes's Beauty Contest in Stock Markets: An Experimental Study *

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Abstract

We experimentally examine the validity of Keynes's 'beauty contest' analogy in stock markets: professional investors trade based not on their own fundamental valuations of stocks but on others' valuations. To this end, we designed a laboratory stock market with informed and less-informed traders and explored whether the behaviour of the former is affected by the valuations of the latter. We found informed traders participate in the beauty contest: their trades and market prices are affected by less-informed traders' valuations. Our experimental evidence suggests real-world stock prices are likely to fluctuate due to the mass psychology of the market.

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> [I]t is not sensible to pay 25 for an investment of which you believe the prospective yield to justify a value of 30, if you also believe that the market will value it at 20 three months hence. – John Maynard Keynes (1936, p. 155).

More than 80 years ago, Keynes (1936) likened professional investors' speculation on stock markets to a 'beauty contest'. He argued that professionals trade stock, not based on their own long-term forecast of companies' assets but on the anticipation of market valuation after a few months. Consequently, he suggested stock prices are subject to waves of optimistic or pessimistic sentiments caused by the mass psychology of ignorant individuals, even on a market with professional investors.

In academia, there are two conflicting views regarding the validity of the beauty contest analogy. The proponents of the efficient market hypothesis would argue against this concept because professionals with knowledge of stocks (informed traders) should conduct arbitrage transactions based on their own valuations, rather than speculate on the vagaries of individuals (less-informed traders).[1] By contrast, recent theoretical research is consistent with the beauty contest phenomenon. The theoretical models on limits to arbitrage claim that informed traders with short horizons, who have to close their positions in the short term, are only concerned with the valuations of the less-informed traders that affect near future prices (DeLong *et al.*, 1990a, 1990b; Froot *et al.*, 1992; Allen *et al.*, 2006). Other models argue informed traders, even with long horizons, seek capital gains by riding on others' valuations on a market with short-sales constraints (Allen *et al.*, 1993; Abreu and Brunnermeier, 2003; Scheinkman and Xiong, 2003).

Therefore, it is an empirical question whether informed traders participate in the beauty contest (i.e. they trade by riding on the valuation of less-informed

[1] This argument traces back to Friedman (1953) and Fama (1965).

traders) or not (i.e. they conduct arbitrage based on their own valuation). Answering the question empirically is important for our understanding of the formation of stock prices. If data reject the analogy of a beauty contest, we predict professionals' trade (arbitrage) brings stock prices close to fundamental values, meaning prices do not fluctuate dramatically due to the vagaries of individuals. By contrast, if the beauty contest story finds support, we argue professional trades do not correct the potential price impact of less-informed individual investors and stock prices can be susceptible to excess volatility and bubbles.[2]

However, to the best of our knowledge, no empirical study has examined the validity of the beauty contest phenomenon directly. We conjecture that this is attributable to the difficulty in collecting data on each trader valuation of a stock on real stock markets. That is, we cannot easily access the valuation data of professional investors (hedge funds, mutual funds, pension funds), as it is normally private. Even if we do, we would experience more difficulties in obtaining the valuation data of the less-informed individual investors.

Further, to the best of our knowledge, no experimental work has hitherto investigated Keynes's concept of beauty contest on stock markets. While there have been numerous asset market experiments over the past few decades (for review articles, see Duxbury, 1995; Sunder, 1995; Noussair and Tucker, 2013; Palan, 2013; Powell and Shestakova, 2016), they have not examined if the behaviour of informed traders is subject to the valuations of less-informed traders. Some asset market experiments such as Cheung *et al.'s* (2014) and Akiyama *et al.'s* (2017) explore whether traders' behaviour is affected by *others' rationality*, but do not examine whether traders' behaviour is affected by *others' valuation*. While there are a series of experiments on the 'beauty-contest game', sometimes called the 'guessing game' or 'average game' (e.g. Nagel, 1995; Duffy and Nagel, 1997; Ho *et al.,* 1998; Güth *et al.,* 2002; Camerer *et al.,* 2004),

[2] LeRoy and Porter (1981) and Shiller (1981) report excess volatility of stock prices cannot be justified by fluctuations in dividends.

these experiments focus on the cognitive ability and depth of reasoning of human beings and not professional investors' behaviour and price formation on stock markets, as earlier described by Keynes (1936).

This study examines the validity of the 'beauty contest' concept on stock markets by conducting an asset market experiment with a unique design. In our laboratory, we create both informed and less-informed traders, as in Plott and Sunder (1982), Plott and Sunder (1988), and Friedman *et al.* (1984). In our experiment, we control informed traders' own valuations of the stock by setting the dividend of the stock at a fixed level. Furthermore, we manipulate less-informed traders' valuations of the stock (without deceiving subjects[3]) by using a unique experimental device. When we observe informed traders' behaviour (bids and asks) is subject to the valuations of less-informed traders, we conclude that informed traders participated in Keynes's beauty contest in our laboratory.

Specifically, we design the following laboratory stock market. The stock traded has a maturity of three periods (Periods 1, 2, and 3) and pays a single terminal (non-stochastic) dividend $d = 200$ at the end of Period 3. The subjects who play the role of informed traders know this value ($d = 200$) and buy and sell stocks among themselves during Period 1. The subjects who play the role of less-informed traders enter the market in Period 2 and the informed and less informed trade during Period 2. The less informed do not know the true value of d but have their own valuation of the stock based on their beliefs of terminal dividend $\tilde{d}$. Under the experimental device shown below, the experimenter set $\tilde{d}$ as optimistic, pessimistic, or unbiased compared to the true value of d ($= 200$) depending on treatment, without deceiving the less-informed traders. The informed traders in Period 1 know not only the entries of the less-informed traders in Period 2 but also their beliefs $\tilde{d}$. We examine if the behaviour (bids

[3] Subjects who are deceived by an experimenter lose trust in experimenters, so experimental economists avoid using deception in their experiment. For this argument, see Friedman and Sunder (1994).

and asks) of an informed trader in Period 1 is affected by the beliefs of less-informed traders who enter the market in the following period (Period 2).

According to the body of theoretical literature mentioned above, whether informed traders ride on the valuations of the less-informed traders may depend on their trading horizon. Thus, we also explore the impact of informed traders' time horizon on their participation in the beauty contest. We design both short- and long-horizon environments for the informed traders. In the short-horizon environment, informed traders exit the market at the end of Period 2, while in the long-horizon environment, they stay in the market until the end of Period 3 and can receive the final dividend.

Our experimental results show informed traders participate in the beauty contest. Informed traders' behaviour (bids and asks) in Period 1 is significantly affected by less-informed traders' beliefs on the dividend. This indicates informed investors trade by riding on the stock valuations of the less-informed traders. Consequently, stock prices in Period 1 are also affected by the valuations of less-informed traders. Furthermore, we observe these phenomena regardless whether informed traders have short- or long-term horizons, indicating informed traders participate in the beauty contest, regardless of the length of their trading horizons.

The remainder of the paper is structured as follows. In Section 1, we describe the elements of our experimental design and the procedures and methods used for analysing the data. Section 2 presents the experimental results. Section 3 discusses the results and implications. Section 4 concludes the paper.

1. Experimental Design and Procedures

1.1. Experimental Design

Each session has 10 subjects with five playing the role of 'informed traders' and the other five representing the 'less-informed traders'.[4] Each informed trader is initially endowed with either six or two units of stock, as well as 1,800 points of experimental currency as cash. Every less-informed trader is endowed with only 1,800 points of cash.[5]

Each session has three periods (Periods 1, 2, and 3) during which the subjects trade stocks. A stock pays a single terminal dividend (d), 200, at the end of Period 3, and is thereafter liquidated with zero value. That is, the stock in our experiment is traded for only three periods and pays a single non-stochastic terminal dividend – a different design from the one introduced by Smith *et al.* (1988), where the stock is traded for 10–15 periods for multiple stochastic dividends. We choose this rather simple design to minimise confusion for subjects and determine if informed traders' behaviour is affected by the stock valuation made by less-informed traders.[6]

The trading horizon of informed traders comprises short- and long-horizon environments, as seen in Figure 1. In the short-horizon environment, informed traders are present on the market only during Periods 1 and 2 and have to close their positions by the end of Period 2 (see the upper part of Figure 1). That is, they cannot receive terminal dividend d. The less-informed traders enter the market at Period 2, trade stocks during Periods 2 and 3, and receive dividends from the stocks they hold at the end of Period 3. In the long-horizon environment, informed traders are present in all three periods (see the lower part of Figure 1). They can receive dividends from their stocks at the end of Period

[4] In the experiment, we referred to informed traders as Type A traders and less-informed traders as Type B traders to avoid framing effects. See Appendices A and B for experimental instructions.

[5] We endowed 1,800 points of cash to each less-informed trader such that, even when the market price is 300 (i.e. the highest number in three boards that are subsequently explained) and the endowment of stock to each informed trader is six, the less-informed traders have enough cash to buy all six (= 1,800/300) units of stock.

[6] In the experimental design introduced by Smith *et al.* (1988), mispricing is caused by subjects' confusion about the declining fundamental value of the asset (Huber and Kirchler, 2012; Kirchler *et al.*, 2012).

3. The trading horizon of the less-informed traders is the same as that in the short-horizon session: they trade during Periods 2 and 3 and receive terminal dividends at the end of Period 3.

[Insert Figure 1 Here]

We design a market on which informed traders know the true dividend value, d (200), but less-informed traders do not know d with certainty and may have a biased belief about dividend $\tilde{d}$, which may be biased upward or downward compared to d (200). In general, it seems difficult to induce the less-informed traders to have biased beliefs without deceiving them in a laboratory setting. To overcome this challenge, we developed the following unique experimental device.

Before Period 1 starts, only informed traders were told that the value of d is 200. Although less-informed traders know that informed traders are aware of the exact value of d, less-informed traders are not informed of its exact value. Instead, both informed and less-informed traders are instructed they will get to see one of the three different boards, Board X, Board Y, or Board Z, each with a $1/3$ probability. The three boards convey the following information (see the upper part of Figure 2).

- Board X: The number given at the top is the true dividend and the middle and bottom numbers are fake dividends (board on the upper left of Figure 2).
- Board Y: The middle number is the true dividend and the top and bottom numbers are fake dividends (board in the upper middle of Figure 2).
- Board Z: The bottom number is the true dividend and the top and middle numbers are fake dividends (board on the upper right of Figure 2).

[Insert Figure 2 Here]

Although both informed and less-informed traders know that the composition of the three boards is as described in the upper part of Figure 2, they are not informed of the exact numbers on the boards.

The actual numbers on each board are as follows (see the lower part of Figure 2). Board X contains numbers, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 200 \\ 150 \\ 100 \end{pmatrix}$; Board Y, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 250 \\ 200 \\ 150 \end{pmatrix}$; and Board Z, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 300 \\ 250 \\ 200 \end{pmatrix}$.

The experimenter chooses one of three boards (*X, Y*, or *Z*) for each session. Before Period 1 starts (just after informed traders are told the true dividend is 200), the experimenter shows the board to both informed and less-informed traders. Assume the experimenter shows Board X, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 200 \\ 150 \\ 100 \end{pmatrix}$. Informed traders should be aware the presented board is Board X because they know the true dividend is 200 and see 200 at the top of this board. Less-informed traders, on the other hand, are not sure whether the board $\begin{pmatrix} 200 \\ 150 \\ 100 \end{pmatrix}$ is Board X, Y, or Z, because they do not know the true dividend. They would consider that, if the board shown is Board X, 200 is the true dividend; if it is Board Y, 150 is the true dividend, and if it is Board Z, 100 is the true dividend. Since they are told each board has a $1/3$ probability of being selected, their belief, $\tilde{d}$, has a $1/3$ probability of being 200, 150, or 100. This means that the expected dividend value (their valuation of the stock), $E[\tilde{d}]$, is 150 $(= 200 \times \left(\frac{1}{3}\right) + 150 \times \left(\frac{1}{3}\right) + 100 \times \left(\frac{1}{3}\right))$, which is lower than the true dividend (d) of 200. In this case, less-informed traders would have a pessimistic valuation compared to the true dividend. We call sessions adopting this setting 'pessimistic treatment'.

Similarly, if the experimenter shows Board Y, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 250 \\ 200 \\ 150 \end{pmatrix}$, less-informed traders' belief, $\tilde{d}$, has a 1/3 probability of being 250, 200, or 150. Therefore, $E[\tilde{d}] = 200$, which is equal to the true dividend. In this case, less-

informed traders would have an unbiased valuation and we refer to sessions adopting this setting 'unbiased treatment'.

Finally, if Board Z, $\begin{pmatrix} Top \\ Middle \\ Bottom \end{pmatrix} = \begin{pmatrix} 300 \\ 250 \\ 200 \end{pmatrix}$ is shown, less-informed traders' belief, $\tilde{d}$, has a $1/3$ probability of being 300, 250, or 200; $E[\tilde{d}] = 250$, which is higher than the true dividend of 200. In this case, less-informed traders would have an optimistic valuation compared to the true dividend. We call sessions adopting this setting 'optimistic treatment'.

Therefore, by changing a board, we manipulate whether less-informed traders' beliefs regarding the dividend are pessimistic, unbiased, or optimistic. The experimenter uses this new experimental device to manipulate the beliefs of less-informed traders, $\tilde{d}$, without deceiving the subjects. We compare the behaviour of informed traders in Period 1 among the three (pessimistic, unbiased, and optimistic) treatments and examine whether their trades are affected by the valuations of the less-informed traders.

Note that informed traders could rationally predict the valuations of less-informed traders. The information structure adopted during each session is common knowledge to both informed and less-informed traders. Therefore, informed traders know that the less-informed ones have a valuation based on the three numbers shown on the board.

Finally, to verify whether the experimental results are robust to the cash-to-asset value ratio, one of the two levels of initial stocks, six or two units, is adopted for each session.

In summary, we conduct 12 different sessions using three treatment variables: three types of information given to less-informed traders (pessimistic, unbiased, or optimistic) × two levels of investment horizons (short or long) to informed traders × two levels of initial endowment of stock given to informed traders (six or two units).

Table 1 summarises our experimental sessions. The name of each session consists of three parts separated by two hyphens, as seen in the leftmost column.

The prefixes ‘Opt’, ‘Mid’, and ‘Pess’ indicate the type of information given to less-informed traders, that is, ‘Opt’ for optimistic, ‘Mid’ for unbiased, and ‘Pess’ for pessimistic. The terms placed between two hyphens, ‘short’ or ‘long’, represents the trading horizons of informed traders. The digit in the suffix, 6 or 2, corresponds to the initial amount of stock allocated to each informed trader.

[Insert Table 1 Here]

During each period, the market employs call market rules (e.g. Friedman, 1993; Van Boening *et al.,* 1993; Cason and Friedman, 2003; Haruvy *et al.,* 2007), not a continuous double auction as in Plott and Sunder (1982), Plott and Sunder (1988), and Smith *et al.* (1988). Call market rules are adopted to focus on the pure effects of less-informed traders’ beliefs on the behaviour of informed traders, rather than the strategic interactions and information transmission through the market.[7]

In this call market, we accept bids (buy orders) and asks (sell orders) for 10 minutes during each period. Subjects have the opportunity to submit as many different bids and asks as they can afford. One order consists of only one price and the maximum quantity the sender of the order is willing to trade at that price. To submit a bid, the subjects must have cash on hand (i.e. there is no borrowing). To submit an ask, the subjects must have stocks on hand (i.e. there are no short sales). When submitting their orders, the subjects do not observe the orders of other subjects. Once 10 minutes have passed, the computer sorts asks (bids) from the lowest (highest) to the highest (lowest) to aggregate them into a market-supply (demand) curve. The market is cleared at the uniform price at the intersection of the supply and demand curves for all the transactions during that period.[8] All asks (bids) that are lower (higher) than the market-clearing price

[7] We understand that these are interesting issues on asset markets, but they are not the focus of this study.

[8] In a figure where the vertical axis represents the price and the horizontal axis represents quantity, if vertical overlap occurs at the intersection, the market-clearing price is the midpoint of the overlap. When a horizontal overlap occurs at the intersection, as many transactions as possible take place during the overlap (rightmost point of the overlap).

are executed. When multiple orders equal to the market-clearing price are sent, some of them may not be executed. In such cases, priority is given to orders made earlier during the 10-minute period.

The market-clearing price is disclosed once at the end of each period and only to subjects who took part at that period. In addition, each trader's bids, asks, and trading volume is private information. Therefore, less-informed traders cannot observe the price, orders, and transactions in Period 1 or update their beliefs, $\tilde{d}$, before they trade in Period 2.[9] Moreover, they cannot update $\tilde{d}$ even during Period 2 because they cannot observe others' orders. These settings prevent less-informed traders' belief $\tilde{d}$ from being updated and place $\tilde{d}$ under the experimenter's manipulation.

Once participants in the period are informed of the market-clearing price and their own trading volume, they write them on a record-sheet within 10 minutes. Then, they proceed to the next period or to receive the terminal dividend.

1.2. Experimental Procedures

We conducted all 12 sessions at Osaka University and implemented them using programs written in Java on a network of computers. The participants were undergraduate and graduate students. To recruit participants, we posted flyers on the campus and sent emails to students who had applied to other previous experiments. We invited at least 10 subjects to each session and none participated in more than one session. Totally, 162 subjects reached the laboratories on time. During each session, we played pre-recorded instructions and trading manuals, while each participant read printed copies (Appendices A and B), which took about one hour. We then trained them in the use of the market software for 15 minutes. Next, we conducted an examination to check their understanding of the rules and used the results to select 10 subjects able to

[9] Under this setting, the informed traders in Period 1 do not have an incentive to buy (sell) at a price higher (lower) than their valuation to manipulate the beliefs of the less-informed traders by showing that price.

participate in the remainder of the session. The examination took about half an hour. Subjects who did not qualify for examination (42 subjects) were paid 3,000 JPY (25.63 USD) and left the session. In total, 120 (= 10 subjects × 12 sessions) subjects cleared the examination and the experimenter corrected their wrong answers. Next, they were randomly assigned to one of the two roles – informed or less-informed trader. True dividend (200) was informed of the informed traders, one of the three boards was shown to both informed and less-informed traders, and they were given 10 minutes to strategize. Next, the participants proceeded to the market, which took 50 minutes (10 minutes to submit orders for Periods 1, 2, and 3, and 10 minutes for recording for Periods 1 and 2). After Period 3, dividends were paid and each point of the experimental currency held by the subjects was converted to yens. The conversion rate for less-informed traders was 2.5 JPY per point of experimental currency, which makes the value of each less-informed trader's initial allocation 4,500 JPY (38.44 USD). The conversion rate for informed traders depended on the amount of initial allocation of stocks to make the value of each subject's initial allocation 4,500 JPY. When it was two (six) units, the conversion rate was 1.5 $(45/22)$ JPY.[10] Subjects who proceeded to the market after the examination earned an average of 4,488 JPY (39.03 USD). Each session took approximately three hours, from giving instructions to the dividend payment.

1.3. Data Analysis

To check for evidence of Keynes's beauty contest phenomenon on our experimental market, we focus on the behaviour of informed traders in Period 1. Informed traders who know the true dividend value (200) trade among themselves in Period 1, expecting the less informed, with their beliefs on the dividend ($\tilde{d}$), will enter the market and trade in Period 2. We examine whether

[10] These conversion rates were private information so that less-informed traders could not back-calculate the true value of the dividend from the conversion rates of informed traders.

the bids and asks submitted by informed traders during Period 1 are affected by the beliefs ($\widetilde{d}$) of less-informed traders. If we observe the bids and asks are higher (lower) when less-informed traders have optimistic (pessimistic) beliefs, we argue the behaviour of informed traders is affected by the stock valuation of less-informed traders and conclude that informed traders participated in the beauty contest. In addition, we examine the market-clearing price in Period 1 and explore how stock prices are affected by the beauty contest phenomenon. Further, we also see observational changes between the short- and long-horizon environments. In the former case, informed traders exit the market after Period 2 and have no chance to receive the terminal dividend; in the latter, they exit the market at Period 3 and can receive the terminal dividend.

To test statistically whether the behaviour of informed traders and market prices in Period 1 are affected by less-informed traders' valuations of the stock, we estimate the following equations for both short- and long-horizon environments:

$$BID = \alpha_1 + \beta_1 \times E[\widetilde{d}] + \gamma_1 \times INITIAL\ STOCKS + u_1, \quad (B)$$
$$ASK = \alpha_2 + \beta_2 \times E[\widetilde{d}] + \gamma_2 \times INITIAL\ STOCKS + u_2, \quad (A)$$
$$PRICE = \alpha_3 + \beta_3 \times E[\widetilde{d}] + \gamma_3 \times INITIAL\ STOCKS + u_3. \quad (P)$$

In equation (B), BID includes either all the bids of informed traders in Period 1 (equation B-1) or the highest bid for each informed trader in Period 1 (equation B-2). In equation (A), ASK represents either all asks of informed traders in Period 1 (equation A-1) or the lowest ask for each informed trader in Period 1 (equation A-2). In equation (P), $PRICE$ is the market-clearing price in Period 1.[11]

In all equations, $E[\widetilde{d}]$ is the expected dividend value of less-informed traders; $E[\widetilde{d}]$ is 250 for the optimistic treatment, 200 for the unbiased treatment, and 150

[11] When the lowest ask price (best offer) is higher than the highest bid price (best bid), no trades occur. In such a case, their midpoint is considered as the market-clearing price during that period.

for the pessimistic treatment. $INITIAL\ STOCKS$ is the initial endowment of stocks for informed traders (i.e. six or two), and u_1, u_2, and u_3 are error terms.

If each coefficient on $E[\tilde{d}]$ $(\beta_1, \beta_2, \beta_3)$ is significantly positive, we claim that informed traders' bid, ask, or the market price in Period 1 are affected by the valuation of less-informed traders.

Since the BID in equation (B-1) and ASK in equation (A-1) submitted by the same subject are correlated, robust standard errors clustered for subjects are reported for equations (B-1) and (A-1). For equations (B-2), (A-2), and (P), Eicker-Huber-White standard errors are reported.

2. Experimental Results

Figure 3 depicts informed traders' bids, asks, and market-clearing prices for Period 1. In each panel, the downward- and upward-pointing triangles represent the median of all informed traders' bids and the median of all informed traders' asks in Period 1, respectively.[12] Further, × designates the market-clearing price in Period 1. [13] The two upper (lower) panels exhibit those for the short-horizon (long-horizon) environments and the two panels on the left (right) show those for the sessions in which six (two) units of stock are initially allocated to informed traders.

[Insert Figure 3 Here]

First, we examine the bids, asks, and prices for the short-horizon environments depicted in the two upper panels. In each of the two panels, the median bid is the highest in the optimistic treatment, showing the higher the

[12] Assume the following three bids are submitted: a bid of five shares at price 200, a bid of one share at price 210, and a bid of one share at price 220. Then, in calculating the median bid price, we consider the first bid of five shares at price 200 as five bids of 'one share at price 200'. Therefore, the median bid price in this example is not 220, but 200 (the fourth highest bid price of the seven bids). The median ask prices are calculated similarly.

[13] In Opt-long-6 and Opt-long-2, no trades occurred during Period 1, because the lowest ask price was higher than the highest bid price, so we used their midpoint as the market-clearing price.

valuation less-informed traders have, the higher the bid informed traders make in Period 1. Similarly, asks seem to be positively related to the valuation of less-informed traders. In each of the two upper panels, the median ask is the highest in the optimistic session. These results indicate that informed traders' behaviour (bid and ask) is positively related to less-informed traders' valuations of the stock.

We also find stock prices depend on the valuation made by less-informed traders. Each of the two upper panels shows the market-clearing prices are highest for optimistic treatment, second highest for the unbiased treatment, and lowest for the pessimistic treatment. This result indicates that Period 1 prices, which are determined by trading only between informed traders, fluctuate due to the valuations made by less-informed traders entering the market in Period 2.

We observe the same tendencies for long-horizon environments. Each of the two lower panels shows that the informed traders' bids, asks, and market-clearing prices in Period 1 are positively related to the valuation of less-informed traders, although to a less extent, compared to the short-horizon environment. The median bids and asks are the highest in optimistic treatments as are prices.[14]

The regressions results confirm these observations. Table 2 shows the regressions results for short-horizon environments. We find $E[\widetilde{d}]$ has significantly positive effects on BID (all-bid in B-1, highest bid in B-2), ASK (all-ask in A-1), and $PRICE$ (market-clearing price in P), which shows the behaviour of informed traders (except for the lowest ask) and market prices in Period 1 are positively related to the stock valuation of less-informed traders.[15]

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[14] Some may note that bids, asks, and prices in the short-horizon environment (upper two panels) are lower than those in the long-horizon environment (lower two panels). This reflects the risk that informed traders in the short-horizon environment may not be able to sell all stocks held by the end of Period 2 when they exit the market.

[15] Note the coefficient on $E[\widetilde{d}]$ is positive but insignificant in the regression of the lowest ask (A-2). This is due to one outlier which corresponded to one trader making an extraordinary high ask (500, which is the lowest ask for the trader) in the Pess-short-2 session. When regression (A-2) is conducted without this outlier, the coefficient on $E[\widetilde{d}]$ becomes 0.785 ± 0.162 (SE) and is statistically significant (p-value < 0.0001).

Table 3 shows the regressions results for the long-horizon environments. It is observed that $E[\widetilde{d}]$ has significantly positive effects in all regressions. These results suggest that the behaviour of informed traders and market prices are subject to the valuations of less-informed traders, not only for short-horizon environments but also for long-horizon ones.

[Insert Table 2 Here]

[Insert Table 3 Here]

3. Discussion

Our experimental results show that informed traders participate in Keynes's beauty contest—they trade stocks, not on their own but on others' valuations of the stock. The bids, asks, and resulting market-clearing price of informed traders in Period 1 increase when less-informed traders have higher valuations of the stock. This result is observed regardless whether the trading horizon of informed traders is short (i.e. they exit the market without receiving the dividends) or long (i.e. they stay in the market and receive the dividends).

Our results in the short-horizon environment suggest that, when informed traders have short trading horizons, they engage in speculative trades based on others' valuation. Since they have to leave the market after Period 2, before the dividend (d) is realized, they are only concerned with the sales price of Period 2, which is largely determined by the valuation of less-informed traders. Therefore, informed traders' behaviour and the market price in Period 1 are affected by the valuations of less-informed traders. This experimental result supports the theoretical studies of DeLong *et al.* (1990a, 1990b) and Froot *et al.* (1992), who claim that informed traders with short-trading horizons speculate on noise traders' (or market) valuations that affect near future prices. Our result also aligns with the agency model of professional arbitrage (Shleifer and Vishny, 1997), in arguing that professional managers may not take opportunities to

conduct arbitrage because these managers are subject to short-term periodical evaluations.

Our results for the long-horizon environment indicate that, even when informed traders have long trading horizons and could conduct arbitrage based on their own valuations, they seek for capital gains by riding on others' valuations. This finding supports recent theoretical works claiming that stock prices form bubbles even on a market with long-term informed traders under short-sales constraints (Allen *et al.,* 1993; Abreu and Brunnermeier, 2003; Scheinkman and Xiong, 2003).

In addition, our laboratory results are also consistent with recent empirical evidence showing professional investors ride on market sentiments and trends. Brunnermeier and Nagel (2004) show that hedge funds were riding the technology bubble from 1998 to 2000 by predicting the high investor sentiment prevailing on the market. Griffin et al. (2011) find that institutional investors actively purchased technology stocks during the run-up and rapidly reversed course in March 2000. Zheng *et al.* (2018) examine the trading behaviour of hedge funds from 1995 to 2014 and show that some hedge funds increase their portfolios' market exposure during periods of high sentiment. These empirical results suggest professional investors ride on the optimistic or pessimistic sentiments of less-informed individual investors, which is consistent with our experimental evidence that informed traders ride on the valuations of less-informed traders.

Based on our laboratory results, as well as related theoretical and empirical results, we conjecture that the phenomenon of Keynes's beauty contest often occurs on real stock markets. Professionals tend to ride on market valuations rather than trade on their own valuation, irrespective of trading horizon. This suggests that, even in a market with professionals, stock prices are vulnerable to the vagaries of (less-informed) individuals and the mass psychology of the market, not only in specific circumstances such as bubble periods or financial crises but also during normal times. This implies excess stock price volatility,

which cannot be solely justified by variations in fundamentals (LeRoy and Porter, 1981; Shiller, 1981), can be attributable to the vagaries of ignorant individuals or noise traders.

Finally, our laboratory experiment relates to those of Cheung *et al.* (2014) and Akiyama *et al.* (2017), who conduct asset market experiments in which the experimenter manipulates subjects' information regarding the rationality of others. They show that speculative trading (and price bubbles) is more likely to occur and subjects' price forecasts deviate from the fundamental values more significantly when the subjects doubt the rationality of other traders. Their experiments suggest traders speculate on the belief of *others' irrationality*. By contrast, our experiment shows traders speculate on the belief of *others' valuation*, which has long been argued as Keynes's beauty contest on financial markets.

4. Concluding Remarks

Keynes's beauty contest is well known on financial markets. Since Keynes (1936) developed it more than 80 years ago, the story is frequently mentioned in both academic and non-academic worlds to explain investors' behaviour and price fluctuations on stock, real estate, and exchange markets.[16] However, there has been no empirical research to test the empirical validity of this story directly. In this paper, we experimentally examined Keynes's beauty contest on an experimental stock market. To this end, we designed a laboratory, in which we created both informed and less-informed traders and manipulated less-informed traders' valuations of the stock. We then explored if informed traders' behaviour is subject to the valuations of less-informed traders. Our laboratory results supported Keynes's analogy. We found informed traders' behaviour and market prices are affected by the valuations of less-informed traders. These phenomena

[16] See, for example, Shiller (2011) and Thaler (2015).

are observed regardless whether informed traders have short- or long-term horizons.

Our experimental results supports the recent theoretical models arguing that informed traders speculate on others' valuations and that asset prices deviate from the fundamentals (DeLong *et al.,* 1990a, 1990b; Froot *et al.*, 1992; Allen *et al.*, 1993; Scheinkman and Xiong, 2003; Abreu and Brunnermeier, 2003; Allen *et al.*, 2006). Our results are also consistent with recent empirical evidence showing that professional investors ride on the market sentiment and trends and destabilise stock prices (Brunnermeier and Nagel, 2004; Griffin et al., 2011; Zheng *et al.*, 2018).

To the best of our knowledge, our experiment is the first to study Keynes's beauty-contest analogy to describe a stock market. Our laboratory evidence suggests the possibility that Keynes's beauty contest occurs on real stock markets, not only during bubble periods and financial crises but also during normal times. We assume that, even with professional investors on a market, stock prices are likely to fluctuate due to the mass psychology of the market. We also consider excess stock price volatility that cannot be solely justified by variations in fundamentals (LeRoy and Porter, 1981; Shiller, 1981) can be attributed to the vagaries of ignorant individuals or noise traders.

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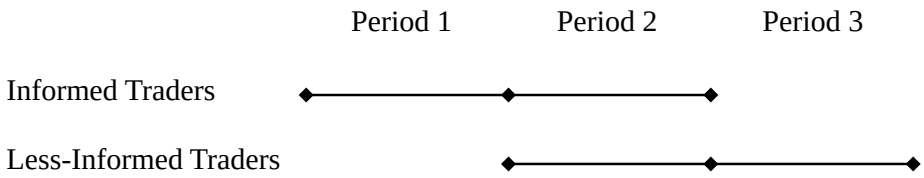
[Short-horizon environment]



[Long-horizon environment]

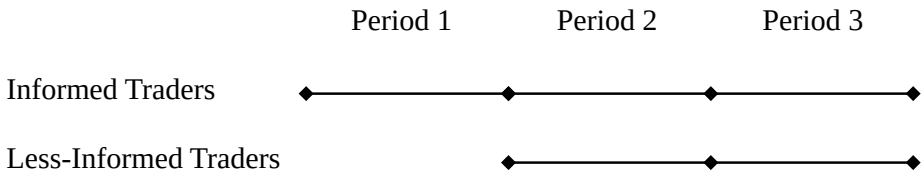


Figure 1. Trading-Horizon Structures

Note: The figure depicts the periods in which each trader type can participate (i.e. trading horizon for each type of trader).

[Three boards explained in the instructions]

	Board X	Board Y	Board Z
	True Dividend	Fake Dividend	Fake Dividend
	Fake Dividend	True Dividend	Fake Dividend
	Fake Dividend	Fake Dividend	True Dividend
Probability of being chosen:	1/3	1/3	1/3

[Three boards that can be shown in the experiment]

Board X	Board Y	Board Z
200	250	300
150	200	250
100	150	200

Figure 2. Board Information Provided to Traders

Note: During all sessions, composition of the upper three boards is explained in the instructions. Before Period 1 starts, the true value of the dividend, 200, is shared only with five informed traders. Then, one of the three boards at the bottom (left one for a pessimistic environment, middle for an unbiased environment, and right for an optimistic environment) is shown to both informed and less-informed traders.

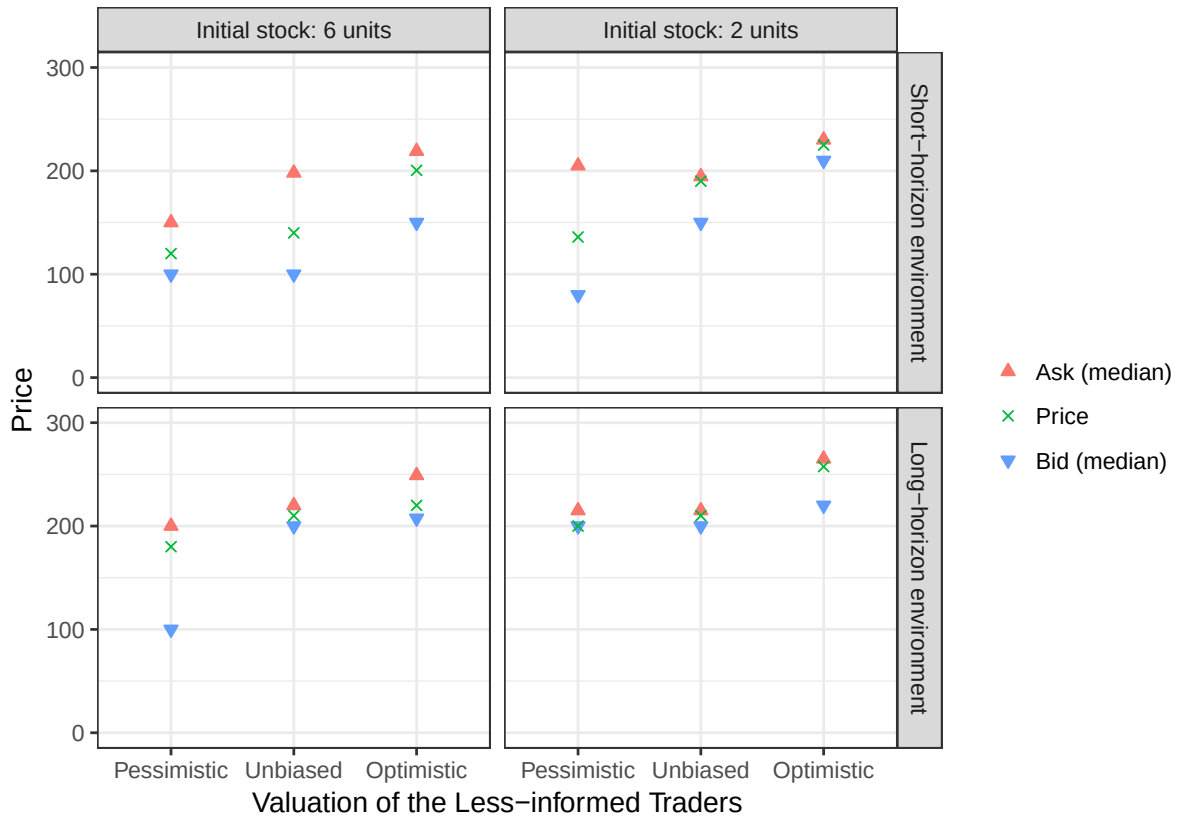


Figure 3. Bids, Asks, and Prices in Period 1 in Pessimistic, Unbiased, and Optimistic Treatments

Note: This figure depicts informed traders' median ask (upward-pointing triangle), median bid (downward-pointing triangle), and the market clearing price (×) in Period 1 for each session. The two upper (lower) panels exhibit those for the short-horizon (long-horizon) environments, and the two panels on the left (right) exhibit those for sessions in which six units (two units) of stocks were allocated to informed traders initially. In Opt-long-6 and Opt-long-2, no trades occurred in Period 1, so we used the midpoint between the lowest ask price (best offer) and the highest bid price (best bid) as the market-clearing price. In each panel, the horizontal axis represents less-informed traders' belief, or $E[\tilde{d}]$, and the vertical axis price.

Table 1. Summary of Experimental Sessions

Session name	Information on dividend (d)		Trading periods		Initial stocks for each		Initial cash for each		Number of traders	
	Informed	Less-Inf [a]	Informed	Less-Inf	Informed	Less-Inf	Informed	Less-Inf	Informed	Less-Inf
Short trading horizon sessions										
Opt-short-6	200	300, 250, 200	1, 2	2, 3	6	0	1,800	1,800	5	5
Mid-short-6	200	250, 200, 150	1, 2	2, 3	6	0	1,800	1,800	5	5
Pess-short-6	200	200, 150, 100	1, 2	2, 3	6	0	1,800	1,800	5	5
Opt-short-2	200	300, 250, 200	1, 2	2, 3	2	0	1,800	1,800	5	5
Mid-short-2	200	250, 200, 150	1, 2	2, 3	2	0	1,800	1,800	5	5
Pess-short-2	200	200, 150, 100	1, 2	2, 3	2	0	1,800	1,800	5	5
Long trading horizon sessions										
Opt-long-6	200	300, 250, 200	1, 2, 3	2, 3	6	0	1,800	1,800	5	5
Mid-long-6	200	250, 200, 150	1, 2, 3	2, 3	6	0	1,800	1,800	5	5
Pess-long-6	200	200, 150, 100	1, 2, 3	2, 3	6	0	1,800	1,800	5	5
Opt-long-2	200	300, 250, 200	1, 2, 3	2, 3	2	0	1,800	1,800	5	5
Mid-long-2	200	250, 200, 150	1, 2, 3	2, 3	2	0	1,800	1,800	5	5
Pess-long-2	200	200, 150, 100	1, 2, 3	2, 3	2	0	1,800	1,800	5	5

[a] Informed traders knew less-informed traders' information on the dividend.

Table 2. OLS Estimation Results on Informed Traders' Bids and Asks and Market Prices in a Short-Horizon Environment

	Dependent variable:				
	all bid	highest bid	all ask	lowest ask	market price
	(B-1)	(B-2)	(A-1)	(A-2)	(P)
E[d]	0.966***	0.922***	0.581**	0.401	0.847***
	(0.173)	(0.138)	(0.263)	(0.396)	(0.080)
INITIAL STOCKS	−4.409	−10.951**	−12.293	−10.896	−7.542**
	(5.204)	(4.308)	(7.318)	(7.557)	(2.210)
Constant	−49.740	10.560	142.314	164.153	29.250
	(35.707)	(33.549)	(88.140)	(119.602)	(18.010)
Observations	210	26	98	27	6
R^2	0.380	0.509	0.251	0.139	0.960
Adjusted R^2	0.374	0.466	0.236	0.067	0.934

Note: The dependent variable represents either all bids of all informed traders (B-1), highest bids for each informed trader (B-2), all asks of all informed traders (A-1), lowest asks for each informed trader (A-2), and market clearing price (P), all of which are regarding Period 1 in a short-horizon environment. E[d] in the independent variables is the expected value of the less-informed traders' belief of terminal dividend: that is, +50 in Opt, 0 in Mid, and −50 in Pess. INITIAL STOCKS represents the initial endowment of the stocks given to each informed trader: that is, six or two units. Between the parentheses, the robust standard errors clustered by subject are reported in (B-1) and (A-1), and Eicker-Huber-White standard errors in (B-2), (A-2), and (P).

***, **, * Significant at the 1, 5, and 10 percent levels, respectively.

Table 3. OLS Estimation Results on Informed Traders' Bids and Asks and Market Prices in a Long-Horizon Environment

	Dependent variable:				
	all bid	highest bid	all ask	lowest ask	market price
	(B-1)	(B-2)	(A-1)	(A-2)	(P)
E[d]	0.740***	0.427***	0.581***	0.536***	0.488**
	(0.145)	(0.103)	(0.149)	(0.093)	(0.094)
INITIAL STOCKS	−6.690*	−4.301*	−3.140	−4.346*	−4.792
	(3.710)	(2.347)	(2.602)	(2.502)	(2.290)
Constant	53.097	127.223***	127.430***	135.894***	134.583***
	(34.854)	(20.229)	(30.626)	(16.859)	(17.780)
Observations	176	27	68	24	6
R^2	0.471	0.435	0.429	0.526	0.886
Adjusted R^2	0.465	0.388	0.412	0.481	0.810

Note: The dependent variable represents either all bids of all informed traders (B-1), highest bids for each informed trader (B-2), all asks of all informed traders (A-1), lowest asks for each informed trader (A-2), and market clearing price (P), all of which are regarding Period 1 in a long-horizon environment. In Opt-long-6 and Opt-long-2, no trades occurred during Period 1 because the highest bid price (best bid) was lower than the lowest ask price (best offer), and hence we used their midpoint as the market clearing price. E[d] in the independent variables is the expected value of the less-informed traders' belief of terminal dividend, that is, +50 in Opt, 0 in Mid, and −50 in Pess. INITIAL STOCKS represents the initial endowment of the stocks given to each informed trader, that is, six or two units. Between the parentheses, the robust standard errors clustered for subjects are reported in (B-1) and (A-1), and Eicker-Huber-White standard errors in (B-2), (A-2), and (P).

***, **, * Significant at the 1, 5, and 10 percent levels, respectively.

Appendix A. Instructions for Sessions Opt-short-2, Mid-short-2 and Pess-short-2 (Originally written in Japanese)

This instruction sheet explains the rules to be applied for the overall experiment. Upon completing the experiments, each subject will receive a reward proportionate to the amount of "gross profit" he/she makes during the experiments. As such, it is critical that subjects understand the rules associated with these experiments so as to maximize the reward they can receive. The details of the experiments are visually depicted in the diagram entitled "Experiment Flowchart," which is attached to this instruction sheet. Please listen to the explanation of these instructions carefully while referring to the flowchart for clarification.

The experiments consist of three trading periods, respectively called the "first trading period," the "second trading period," and the "third trading period." The purpose of each trading period is to trade a piece of paper called a "Share." Subjects that possess "shares" can receive cash points in exchange for the shares they turn in at the end of the third trading period. From this point forward, we refer to the cash received in exchange for shares turned in at the end of the third trading period as "dividends." Over the course of the three trading periods, all "Cash" received during trades is measured in units called "Points." Dividends and gross profits are also measured in "points."

Before the experiments begin, participants are randomly divided into two groups (i.e., Type A and Type B). Each of these groups will be comprised of five participants, each of which will be assigned a number; Type A participants will be numbered from 1 to 5 and Type B participants will be numbered from 6 to 10. These numbers are used exclusively to identify participants.

Type A subjects will be allotted two[1] share units and 1,800 cash points prior to the beginning of the first trading period. These subjects will be allowed to participate in the first and second trading periods, and must submit their shares to

[1] In sessions in which six units of stocks are initially allocated, replace "two" with "six" in this sentence.

the experimenter at the completion of the second trading period. No Type A subjects are permitted to participate in the third trading period. [2]

Type B subjects are allotted 1,800 cash points prior to the start of the first trading period. Type B subjects cannot participate in, or observe, the first trading period, but can participate in the second and third trading periods.

Participants in both groups can increase the number of shares they own (which decreases the cash they own by "Shares purchased × Transaction Price") through the purchase of shares. Conversely, subjects can decrease the number of shares they own (which increases the cash they own by "Shares sold × Transaction Price") through the selling of shares. In the pages following this instruction sheet, we explain how transaction prices, sell quantities, and buy quantities are determined using the trading system operation manual.

Upon completion of the third trading period, Type B subjects submit all the shares they own to the experiment conductor in return for dividends.[3] The amount of dividend received will be equal to "Shares held upon the completion of the Third Trading × Dividend amount per unit of Shares." Although the value of dividends per share is the same for all participants, some participants are unaware of this value. Because Type A subjects always have zero share units at the conclusion of the second trading period, they will not receive dividends in exchange for shares.[4]

[2] In the long-horizon sessions, replace this paragraph with the following: "Type A subjects are provided with two share units and 1,800 cash points before the first trading period. Moreover, Type A subjects can participate in all three trading periods."

[3] In the long-horizon sessions, replace this sentence with the following: "Subjects of either type are to submit all remaining shares to the experiment conductor upon completing the third trading period. They will receive dividends in return."

[4] In the long-horizon sessions, omit this sentence.

Information related to dividends allotted to subjects per unit of shares is detailed below. Type A subjects are informed of the amount of dividends they will receive per share submitted prior to the start of the first trading period. In contrast, Type B subjects will be shown one of three following boards.

- Board X: Board with the true value of dividends per share at the top line of the board and false dividends per share in the middle and lower lines.
- Board Y: Board with true value of dividends per share in the middle line of the board and false dividends per share in the top and lower lines.
- Board Z: Board with true value of dividends per share on the bottom line of the board with false dividends per share in the middle and top lines.

Board X	Board Y	Board Z
True Dividend	Fake Dividend	Fake Dividend
Fake Dividend	True Dividend	Fake Dividend
Fake Dividend	Fake Dividend	True Dividend

Please note that for all three boards, the values of the numbers will be in descending order from top-to-bottom such that:

"Top Number" > "Middle Number" > "Bottom Number."

The conductor of the experiment selects a board to show to Type B subjects prior to the start of experiments. Type B participants all have a 1-in-3 chance of seeing any of the boards and will be made aware that one of the three values on the board they see is the true dividend amount. However, the participants will not be informed of which board (X, Y, or Z) is chosen, will therefore be unaware of which value (top, middle, or bottom) is the true one. Participants will only be made aware of this value when they receive dividends at the conclusion of the experiment. Type A subjects will be notified of which board has been shown to Type B subjects before the beginning of the first trading period.

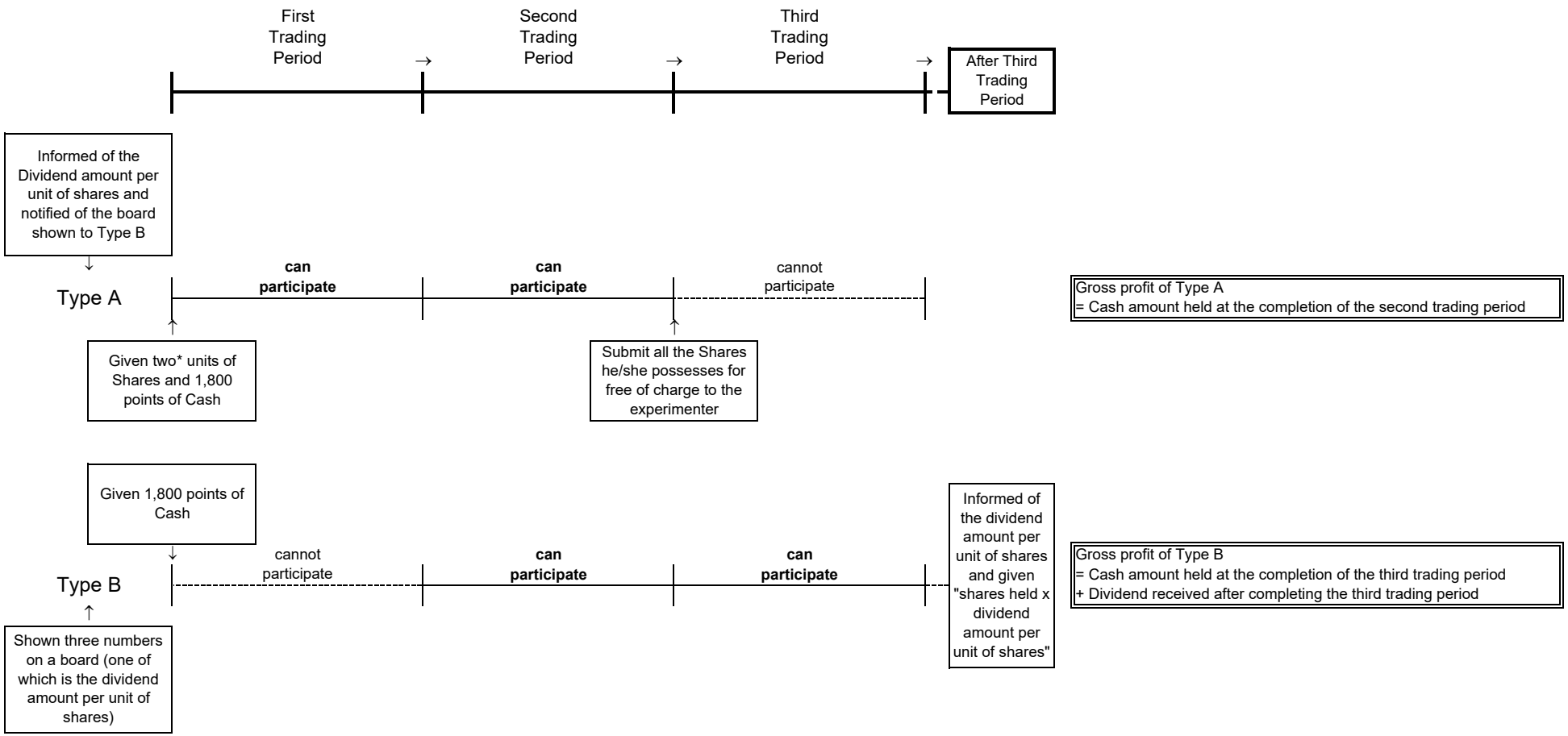
For Type A subjects, the number of cash points they hold at the end of the second trading period is treated as their gross profit. In contrast, the number of cash points held by Type B subjects after receiving their dividends is treated as their gross profit. In other words, Type B subjects' gross profits are equal to the amount of cash held upon the completion of the third trading period plus the dividends they receive after completing the third trading period.[5]

The amount of reward subjects receive is based on their gross profit. The formula used to calculate each participant's reward will be provided to him or her prior to the start of the first trading period. This formula differs between Type A and Type B subjects, but the formulae are similar in that gross profit is positively related to reward.

The procedures outlined above explain the details of today's experiments. Please do not talk to other subjects during the experiments, and pay close attention to the instructions provided by the experiment conductor.

[5] In the long-horizon sessions, replace this paragraph with the following: "Regardless of the subject type, the amount of cash held after receiving dividends at the conclusion of the third trading period represents the gross profit of that individual. In other words, gross profit is calculated as the number of cash points held at the conclusion of the third trading period plus the dividends received following the third trading period."

Experiment Flowchart for Sessions Opt-short-2, Mid-short-2 and Pess-short-2 (Originally written in Japanese)



* In sessions in which six units of stocks are initially allocated, replace “two” in this phrase with “six.”

Appendix B. Trading System Operation Manual for Sessions
Opt-short-2, Mid-short-2, Pess-short-2, Opt-long-2, Mid-long-2 and Pess-long-2
(Originally written in Japanese)

In this experiment, shares are traded through a trading system operated on a personal computer. This pamphlet describes how to operate the system as well as how and under what rules the transaction prices and quantities are determined.

1. Experiment processes

After selecting the subjects that are to participate in the experiment, the experiment shall proceed as per the following flowchart:

> Numbering of Subjects → Display the Dividend Amount per Share on a Board → Start the First Trading Period → … → Complete the Third Trading Period → Receive Dividend and Calculate Gross Profit

The trading system is used from the start of the first trading period until the completion of the third trading period. The following paragraphs in this section describe the procedures to be followed from the commencement of the first trading period until the completion of the third trading period.

Please refer to Table 1. The left most column of Table 1 describes the name of the trading period. The second column shows the "work description." Note that the first trading period is divided into three periods. The first of these periods is referred to as "Order Receiving (10 min.)." During this period, the system receives transaction orders from subjects through the personal computers with which they input their responses. The second part of the first trading period is referred to as "Order summation – Calculation to select successful trading – Notification to subjects." This period lasts several seconds during which the system enumerates the orders received through the trading

system in the previous period. This (a) determines which transaction order wins and the price at which it was made (the rules are described later), and (b) notifies each subject whether his/her order was the winning transaction. In Table 1, the third period is called “Recording the transaction on individual record sheet (10 minutes).” During this period, each subject writes in the result of his/her order on his/her own record sheet.

The steps that comprise the second trading period are identical to those that comprise the first trading period. This is also true for the third trading period, but with one small difference—in the third trading period, the final step (i.e., recording the result of the transaction on a record sheet) does not occur.

The right-hand column of Table 1 (i.e., “Time”) will be explained in the next section as part of the description as to how to operate the trading system.

2. How to read and use each panel

Each subject will be provided with a personal computer on which he/she will operate the trading system. On each of these computers, an experimenter will log into a trading system on behalf of each subject prior to the commencement of the first trading period.

● Main panel

Upon the experimenter’s logging into the trading system, participants will be directed to the first display screen, entitled the “Main Panel” (see Fig. 2-1).

The upper line of the Main Panel, which is labeled with the heading “Name of the Subject,” displays the participant’s identification number. As illustrated by Fig. 2-1, subject number 1 will identified as “M01,” subject number 2 will be identified as “M02,” and so on. This identification scheme will continue until subject number 10, who will be identified as “M10.”

The column below the “Name of the Subject” field indicates the stage of the experiment in which the participant is currently engaged. Before the experiment begins, this field contains text that reads “Before starting

experiment" (see Fig. 2-1). Immediately following the start of the experiment (i.e., during the first trading period), this field displays "Market 1" (see Fig. 2-2). During the second trading period, this field reads "Market 2." During the third trading period, this field reads "Market 3."

Below the field that indicates the phase of the experiment, there is another field labeled "Share sell/buy" when orders to sell or buy are received. The number of seconds remaining in the order receiving period appears below this column. Because the order receiving period lasts ten minutes, this column initially reads "600 seconds remaining." Once the time allotted for this period expires, the column reads "0 second remaining." Examples of that which is displayed on the PCs are shown in the "Main Panel Display" section of the "Time" column in the Table 1.

All panels other than the Main Panel depict time as dates (i.e., year, month, and day) rather than in seconds.[1] Please refer to the "Other Panels" column under the "Time" column of Table 1. During the first, second, and third trading periods, the years are respectively listed as "2001," "2002," and "2003." At the beginning of the order receiving period, the transaction date is listed as "January 1st." At the end of this ten-minute period, the transaction date is listed as "June 23rd." These dates are simulated, and are not related to actual dates or events.

Now, we return to the Main Panel. There are five buttons below the column displaying the time remaining in seconds. Clicking any of these five buttons reveals a new panel with different functions to the subject. For example, by clicking the topmost button titled "Transaction Result," the "Transaction Result Panel" opens, and by clicking the "Order" button below this, the subject can enter the "Order Panel." Similarly, clicking three other buttons called "Cancel Order," "Order History," or "Transaction History" respectively open "Order Cancellation Panel," "Order History Panel," or "Transaction

[1] This program was originally written for another type of an experiment in which time was represented by date. Due to technical limitations, we were unable to fully replace the representation of the date with minutes in our attempt to adapt to the program for this experiment.

History Panel." The following sections describe how to use each panel, based on the actions of a fictitious subject.

● Transaction History Panel (1)

For example, if the participant is currently operating in the order receiving period of the first trading period, he/she must confirm how much cash and how many units of shares he/she has. He/she can check them on the Transaction History Panel.

Fig. 2-3 provides an illustration of the "Transaction History Panel." By clicking the "Update" button, the subject can display the most current information concerning his/her monetary and unit holdings. If the subject has yet to engage in any transactions, the panel displays only one line (see Fig. 2-3).

The column labeled "Date" indicates the date on which the featured Transaction was made. This date is presented as year-month-day. If the subject has yet to engage in any transactions, cash points and share holdings remain unchanged, and the date is listed as 2001/1/1 (i.e., date when the experiment starts).

In Fig. 2-3, the "Action" field reads "Default," indicating that the numbers on this panel have remained unchanged since their pre-experiment state. Columns "No." to "Amount" are irrelevant, and can therefore be ignored at this point. The column labeled "Cash" indicates the number of cash points the subject has on hand. Similarly, the column labeled "Shares" shows the number of shares that the subject holds. In Fig. 2-3, the subject has 1,800 cash points and 2 units of shares.[2]

● Order Panel

To place an order, the subject must activate the Order Panel.

[2] In sessions in which six units of stocks are initially allocated, replace "2" in this sentence and Fig. 2-3 with "6."

For the purposes of this experiment, to place an order, subjects must attend to the following three elements in this panel:

(i) the subject must indicate whether he/she intends to buy or sell;

(ii) the user must indicate the number of cash points to be exchanged per share in the order;

(iii) the user must indicate how many share units are to be traded.

Fig. 2-4 provides an illustration of the Order panel. As indicated in the figure, the Order panel consists of interactive fields in which the user can toggle all three of these elements. That is, "Sell/Buy" field is for element (i) above, "Order Price" field for (ii), and "Order Quantity" field for (iii). Then, the user should select the appropriate "Market" (see below). After entering this information, the subject should click "Send" to direct the order specifications to the trading system. Upon doing so, the order will be referred to as an "Order Set."

Subjects that are permitted to participate in a particular trading period are able to place multiple orders until no time remains in the order receiving period, provided that the conditions described later are met. The following example illustrates how to place the first order during the first trading period. To place an order, the user must first select and enter the necessary information in the following four fields:

- The "Market" field indicates the trading period in which the subject is currently engaged. To select the appropriate trading period, the user should click the "▼" button in the "Market" field to activate the dropdown menu. Below are listed the three options available in this dropdown menu and their corresponding trading periods.
    - Select "Security Market 1" during the order receiving period of the first trading period.
    - Select "Security Market 2" during the order receiving period of the second trading period.

- Select “Security Market 3” during the order receiving period of the third trading period.

- The “Sell/Buy” field is intuitively designed to indicate whether an order is a buy or sell command (element (i) above). If the user wishes to place an order to sell, he/she should click ○ to the left of “Sell.” To indicate an order to buy, the user clicks the ○ to the left of “Buy.”

- The “Trading Partner” field can be ignored.[3]

- In the “Order Price” field, the user is to indicate how many cash points are to be exchanged per share (element (ii) above). If the user wishes to place an order to sell, he/she enters the ask price. In contrast, if the user wishes to place an order to buy, he/she enters the bid price. All entries in the “Order Price” field must be in whole numbers; decimals and fractions are not accepted.

  The letters “pt” to the right of this field serve as an abbreviation for “points,” which serve as the units of cash that are used in this experiment.

  When the user places an order to buy and the transaction is completed, the actual purchase price of the transaction is lower than or equal to the bid price. Similarly, when the user places an order to sell and the transaction is completed, the actual selling price is greater than or equal to the ask price.

- To indicate the number of share units the user wishes to trade, he/she must indicate this number in the “Order Quantity” field (element (iii) above). Specifically, when placing an order to sell, the user enters the ask quantity in this field. When placing an order to buy, the user enters the bid quantity

[3] This program was originally written for another type of experiment in which bilateral trading was supported. In adapting the program to this experiment, we were unable to delete all unnecessary fields. Here and throughout these instructions, we asked subjects to ignore some fields that we were not able to delete from the program.

in this field. As in the “Order Price” field, the user must use only whole numbers in this field.

Once the user has entered the necessary information in the appropriate fields, he/she clicks the “Send” button in the lower left region of the Order Panel. If the order is the first, the trading system automatically checks whether a number of specific conditions are met. If either of these conditions is not met, the system will return an error message to the user once it receives the faulty order. If, however, the above conditions are met, the order is accepted.

When the user places an order to sell, it is first necessary for the ask quantity to be lower than the number of shares the user has on hand. If the user asks to sell a greater number of shares than he/she has on hand, then he/she will be unable to deliver the required number of shares to the transaction partner. This scenario is illustrated in the Fig. 2-5. The width of the line labeled “Shares held” represents the number of shares the subject has on hand at the time of the transaction. The subject can select “Sell Order Qty A” as the ask quantity during the first order, but not “Sell Order Qty B.” If the order to sell quantity B is accepted, the subject is unable to deliver the number shares promised. The difference between the number of shares promised and the number of shares held is labeled as “Deficiency” in Fig. 2-5.

When the user places an order to buy, the product of the bid price multiplied by the bid quantity should be lower than the amount of cash points that a subject has on hand. If the product of the bid price multiplied by the bid quantity exceeds cash points on hand, then the subject has insufficient cash to pay to the trading partner when the transaction takes place.

If the above conditions are met and the order is accepted, the user can again open the Order panel to place a second order. A subject who has placed the first order as order to sell can place the second order as an order to buy. In turn, a subject who has placed the first order as order to buy can place the second order as an order to sell. Alternatively, a subject can place both the first and

second orders as either an order to sell or an order to buy. The subject must ensure that the second order adheres to multiple conditions.

First, if the second order is an order to sell, the conditions that must be met are contingent on the order type of the first order. If the first order was an order to buy, then the ask quantity must be smaller than the number of shares held when placing the order. If the first order was an order to sell, then the sum of "ask quantities" for both the first and second orders must be less than or equal to the number of shares the user has on hand. If this condition is not met, then the subject has an insufficient number of shares to deliver to his/her trading partner(s) if both orders are completed. Fig. 2-6 illustrates this scenario. Specifically, Fig. 2-6 shows how many shares a subject can offer in the second order to sell when he/she has selected "Sell Order Qty A" as the ask quantity in the first order. This subject can select "Sell Order Qty C" as the ask quantity for the second order, but not "Sell Order Qty D," since he/she cannot deliver the amount of shares shown as "Deficiency" to trading partner(s) if both orders to sell with sales quantities A and D are traded.

This condition applies to the third and all subsequent orders as well. The sum of all past ask quantities as well as the order about to be placed must be less than or equal to the number of shares held. However, if the subject cancels any previous order(s) to sell, the ask quantity or quantities of the canceled order(s) will be added to the amount he/she can place in a new order to sell.

If the second and later orders are orders to buy, then the sum of the products of the respective bid quantities and bid prices for all respective previous orders to buy, as well as the product of the bid quantity and bid price of the current order to buy must be less than or equal to the amount of cash the user has on hand. If this condition is not met, the subject has insufficient cash points to pay to the trading partner(s). That said, if this condition is not met, the subject can place a new order to buy by canceling previous order(s). If he/she does so, the amount of cash points in the canceled order(s) is added to the amount available for the new order to buy.

● Order Cancellation Panel

After clicking the order “Send” button, the user can check the “Order Cancellation Panel” to confirm whether the order has been received.

Fig. 2-7 provides an illustration of the Order Cancellation panel. The user is to open this panel during the order receiving period and select the current trading period by pressing ▼ next to the “Market” column, selecting the appropriate trading period, and clicking the “Update” button. This panel depicts the current status of all orders that have been sent and were not canceled in the current trading period. Information related to each order is depicted its own respective row. If multiple orders have been placed, then multiple rows appear in this panel. Each row contains the specifics related to each order. Orders are listed sequentially, with the newest order appearing in the top row.

To the extreme left of each row, there is a check box field (□) that is to be checked if the user wishes to cancel the order. Specifically, the user is to check this box, then click the “Cancel” button at the top of the panel to cancel the order. When canceled, the checked order will be deleted from the panel. By checking multiple orders and pressing the “Cancel” button, it is possible for the user to cancel multiple orders simultaneously.

The column labeled “Organization No.,” as well as the column immediately to its right can be ignored. The column labeled “Order Time” displays the date on which the order was sent. This date is formatted as year-month-day.

The “Sell/Buy” column displays “Want to Sell” when the user makes an order to sell and “Want to Buy” when the user makes an order to buy. The columns labeled “Sent/Receipt” and “Partner” can be ignored. The “Market” column shows the current trading period; the “Price” column shows the price of the ordered units; and the “Qty” column shows the number of units bought or sold.

An illustrative example of this panel in Fig. 2-7 shows that the first order during the first trading period is an order to buy Y units of shares at the bid price of XXX points. The second order during the same trading period is an order to sell W units of shares at the ask price of VVV points. During the actual experiments, these figures will be numerical rather than alphabetical.

● Order History Panel

To see all the orders that have been placed, the user can opt to display the "Order History Panel" (see Fig. 2-8). As with previous panels, the subject can display the latest information on all past orders (including cancelled orders) by pressing the "Update" button.

All information on the Order History panel is depicted in a manner similar to the Order Cancellation panel. The "Order ID" column can be ignored. The far-right column, which is labeled "Cancellation Time," indicates the date on which an order was canceled in year-month-day format. Only orders that have been canceled will have entries here.

● Transaction Result Notification Panel

After ten minutes have passed in the order receiving period, the trading system tabulates all orders received and determines which orders are to be traded at given prices. The rules that govern this process are explained later. For subjects that successfully engage in a transaction, a "Transaction Result Notification Panel" automatically appears and displays how many units of shares have been sold/bought at a given price. If this screen appears more than once, each display shows the results of each respective successful transaction.

Figs. 2-9 and 2-10 provide illustrative examples of this panel. Fig. 2-9 shows that a subject bought Y units of shares at the price of XXX points. Fig. 2-10 illustrates an example in which a subject sold W units of shares at the price of VVV points. In the actual experiment, these values will be numerical rather than alphabetical.

● Transaction Result Panel

To determine the prices at which shares were sold/bought during a given trading period, the user can open the “Transaction Result Panel” (see Fig. 2-11).

Upon opening this panel, the user can click the ▼ button to activate a dropdown menu and select the appropriate trading period. When the appropriate trading period has been selected, the subject will click the “Update” button. The resulting screen illustrates the price of the transactions that was made during that trading period. Note that the user is unable to select a trading period in which he/she was unable to participate.

For example, if the trades made during the first trading period were collectively valued at XXX points, the screen depicted in Fig. 2-11 is displayed. In the real version of the experiment, XXX will be displayed numerically rather than alphabetically.

● Transaction History Panel (2)

To see the results of the transactions and the number of cash points and shares that have been accumulated or lost, the user can open the “Transaction History Panel” (see Fig. 2-12). Fig. 2-12 provides an illustration of the “Transaction History” panel following the sale of W units of shares at the price of VVV points during the first trading period. On this panel, the bottom row summarizes values in the pre-experiment phase. The second row from the bottom summarizes information related to the transaction made during the first trading period, as well as how the cash points and shares balances changed following the first transaction.

The column labeled “Action” reads “Sell,” as the order was to sell shares rather than buy them. Moreover, the columns labeled “Quantity,” “Price,” and “Amount,” which are highlighted in yellow, summarize the details of successful transactions. The “Quantity” column indicates the number of shares

bought. When a user makes orders to sell, this figure is negative. The "Price" column depicts price of the shares in the transaction. Finally, the column labeled "Amount" indicates the sales revenue that results from a transaction (i.e., price × quantity sold). If the user made an order to buy (i.e., price × quantity bought), this figure is negative.

The column labeled "Cash" shows the number of cash points the subject has on hand after increases or decreases that result from transactions. Fig. 2-12 shows that the subject's total cash points is equal to his/her initial sum of 1800 points plus the revenue generated from the sale of share units (i.e., VVV × W).

The "Shares" column indicates the number of shares a user holds after increases or decreases that result from transactions. Beginning with 2 shares, a sale of W units of shares results in a balance of "2 – W" share units.[4] Fig. 2-13 illustrates a scenario in which a subject purchased Y units of shares at the price of XXX cash points during the first trading period.

All figures that are represented alphabetically here will be depicted numerically in the actual experiment.

3. Determining the success of the transaction

This final section describes the protocol for determining whether a transaction is successfully processed by the system, as well as the prices and quantities that characterize the transaction. The experiment consists of three trading periods, the rules of which are all identical with respect to the determination of prices and quantities. It is most useful to first describe the rules associated with the first trading period.

● Determinant Conditions of Successful Orders to Sell/Buy

For the purposes of this experiment, the trading system is primarily meant to (a) summarize orders to sell and buy that are received during the ten-minute

[4] In sessions in which six units of stocks are initially allocated, replace "2" in this sentence, Fig. 2-12, and Fig. 2-13 with "6."

order receiving period, and (b) determine which orders (of those received during that period) are successfully traded. Before explaining how to determine which orders were made successfully, let us first consider the conditions that must be met with regard to the relationship between orders to sell and orders to buy. In this scenario, for the sake of simplicity, we assume each order to sell/buy to use one share unit as the ask/bid quantity.

We also assume that all sellers wish to sell their shares at the highest price possible and all buyers wish to buy shares at the lowest price possible. Given this, let us consider a scenario in which the order to sell and order to buy can be characterized as such:

$$\text{Ask Price} \leq \text{Bid Price}$$

If the ask price is less than or equal to the bid price, then both the seller and buyer can agree to this transaction without reservation.

$$\text{Ask Price} \leq \text{Transaction Price} \leq \text{Bid Price}$$

This is possible because the seller can sell at the ask price or higher and the buyer can buy at the bid price or lower.

Because the nature of this transaction is amenable to both the selling and buying parties, the trading system can effectively process a transaction of this type. That said, because there are a number of combinations of sell and buy orders, there must be mechanisms to optimally match such orders.

● Determining transaction order priority

In this experiment, it is necessarily to apply the following rules to determine which sell order is of the highest priority to match to specific buy orders. First, the sell order with the lowest ask price shall be given the highest priority to trade. Similarly, the buy order with the highest bid price shall be given the

highest priority. This protocol prioritizes orders that can be sold at the lowest price and bought at the highest. If multiple orders are priced similarly, priority will be given to the order that was made earliest.

● Matching orders to sell and orders to buy

Using these principles of prioritization, the trading system optimally matches orders to sell and orders to buy. More specifically, the order to sell with the highest priority (i.e., lowest ask price) is matched with the order to buy with the highest priority (i.e., highest bid price). After matching the most optimal pair of orders, the system then matches the order with the second-lowest ask price and the second-highest bid price. This matching process continues until the formula can no longer be applied.

$$\text{Ask Price} \leq \text{Bid Price}$$

However, because orders to sell are prioritized in order of lowest ask price, and orders to buy are prioritized in order of highest bid price the relationship between orders to sell and orders to buy will eventually be as follows:

$$\text{Ask Price} > \text{Bid Price}$$

When this occurs, the matching process between orders to sell and orders to buy will be unsuccessful, and the matching process will end.

● Determining Transaction Price

This section explains the process for determining the price of a transaction made by the matching orders to sell and orders to buy. First, it is important to note that the shares traded through this system are of the exact same type, regardless of whether they are bought or sold. Given this, it is logical to apply a rule whereby the same transaction price is applied to the matching of any

orders. Therefore, the trading system applies the same transaction price to all shares traded in a given trading period.

The process by which the transaction price is determined is as follows. First, orders are matched as per the process described above (i.e., as long as the ask price is less than or equal to the bid price). Given this, the transaction price is greater than or equal to the ask price of the last tradable order to sell and less than or equal to the bid price of the last tradable order to buy.

$$\begin{array}{c}\text{Ask Price of}\\ \text{the last tradable}\\ \text{Order to Sell}\end{array} \leq \text{Transaction Price} \leq \begin{array}{c}\text{Bid Price of}\\ \text{the last tradable}\\ \text{Order to Buy}\end{array}$$

This transaction price is to be applied to all transactions made during a given trading period.

It is possible to determine the exact price of a transaction. However, this may be too difficult to comprehend. Nevertheless, its complexity will not pose a problem to the successful implementation of the program. Determination of a transaction's price can be performed as follows:

Transaction price of shares = Midpoint of the Values A and B

where

A. Smaller of
"Bid price of the last tradable order to buy" and
"Ask price of the first non-tradable order to sell"

B. Larger of
"Ask price of the last tradable order to sell " or
"Bid price of the first non-tradable order to buy"

● Characteristics of Transaction Price

Given the transaction price determined through the above process, all orders to sell are sold at a price higher than the ask price and all orders to buy are purchased at a price lower than the bid price. In this way, all transactions are completed at a price equal to or better than the original bid/ask prices. However, all orders that fail to become part of successful transactions are characterized by conditions that dissuade a seller or buyer from trading. The transaction prices of these orders are defined by the following relationship:

$$\text{Bid Price} \leq \text{Transaction Price} \leq \text{Ask Price}$$

Under this condition, subjects who send non-tradable orders to sell would feel satisfied that they did not need to sell the shares at a price lower than the ask prices. Similarly, subjects who send non-tradable orders to buy would be satisfied that they did not need to buy shares at a price higher than the bid prices.

● If the Bid/Ask Quantity is Greater than 1

The above scenarios all related to cases in which the bid/ask quantities were one share unit. If the bid/ask quantity is greater than or equal to two, such as “Q” units of shares with Bid/Ask Price of “P” cash points, assume that the Orders with 1 unit of share as Bid/Ask Quantity at Bid/Ask Price of “P” are made “Q” number of times. By assuming as such, this method for determining transaction price can be applied to orders of any quantity.

● Post-transaction Procedures

Once the transactions are completed as per the steps outlined above, the trading system notifies subjects of their successful orders and adjusts their cash points and share totals accordingly. Following this tabulation, all orders (successful and unsuccessful) are automatically deleted from order records.

All subjects must record the results of their transactions on their own record sheets, and proceed to the next trading period.

This system uses the same transaction price for all transactions made during the same period. Nevertheless, transaction prices may differ across trading periods.

● Determining Bid/Ask Prices for Trading

Finally, let us consider the bid/ask prices that would be most advantageous to the subjects. In reality, there is no one-size-fits-all formula for determining the optimal method for placing orders. Still, there are two characteristics of ask prices that are best to keep in mind:

- Shares will never be sold at a price lower than the ask price.
- Lower ask prices are given higher priority in transactions.

Given this, there are some guidelines to follow when buying or selling:

- If the user wishes to avoid selling unless the price is higher, he/she should place an order to sell with a higher ask price.
- If the user wishes to sell shares at any price, he/she should place an order to sell with a lower ask price.

Similarly, the bid price has the following two characteristics:

- Shares will never be bought at a price higher than the bid price.
- A higher bid price is provided a higher priority in being part of a successful transaction.

So that:

- If a user wishes to avoid buying shares unless they are priced low, he/she should place an order to buy at a lower bid price.
- If a user wishes to buy shares, even at higher prices, he/she should place an order to buy at a higher bid price.

Please attempt to develop your own formulae for placing orders optimally during the experiments.

This concludes the explanation of a trading system.

Table 1. Trading schedule

Trading period	Work description	Time			
		Main Panel Display		Other Panels	
First Trading	Order Receiving (10 min.)	Market 1	100 sec left ↓ 0 sec. left	Security Market 1	2001/1/1 ↓ 2001/6/23
	Order summation ↓ Calculation to select successful trading ↓ Notification to subjects				
	Recording the transaction on individual record sheet (10 min.)				
Second Trading	Order Receiving (10 min.)	Market 2	100 sec. left ↓ 0 sec. left	Security Market 2	2002/1/1 ↓ 2002/6/23
	Order summation ↓ Calculation to select successful trading ↓ Notification to subjects				
	Recording the transaction on individual record sheet (10 min.)				
Third Trading	Order Receiving (10 min.)	Market 3	100 sec. left ↓ 0 sec. left	Security Market 3	2003/1/1 ↓ 2003/6/23
	Order summation ↓ Calculation to select successful trading ↓ Notification to subjects				

Fig. 2-1 Pre-experiment Main Panel

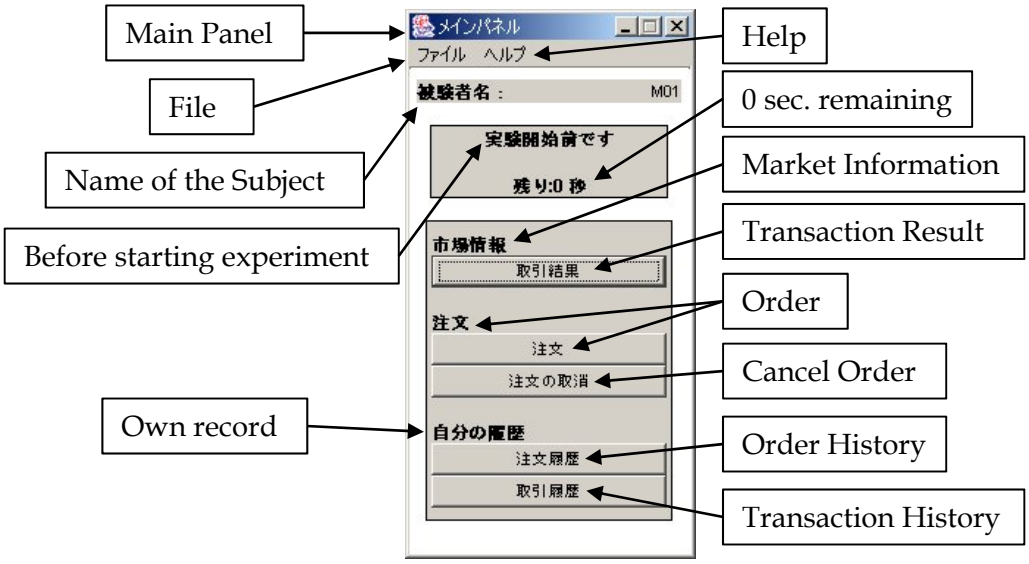


Fig. 2-2 Main Panel Display Immediately Following the Start of the Experiment

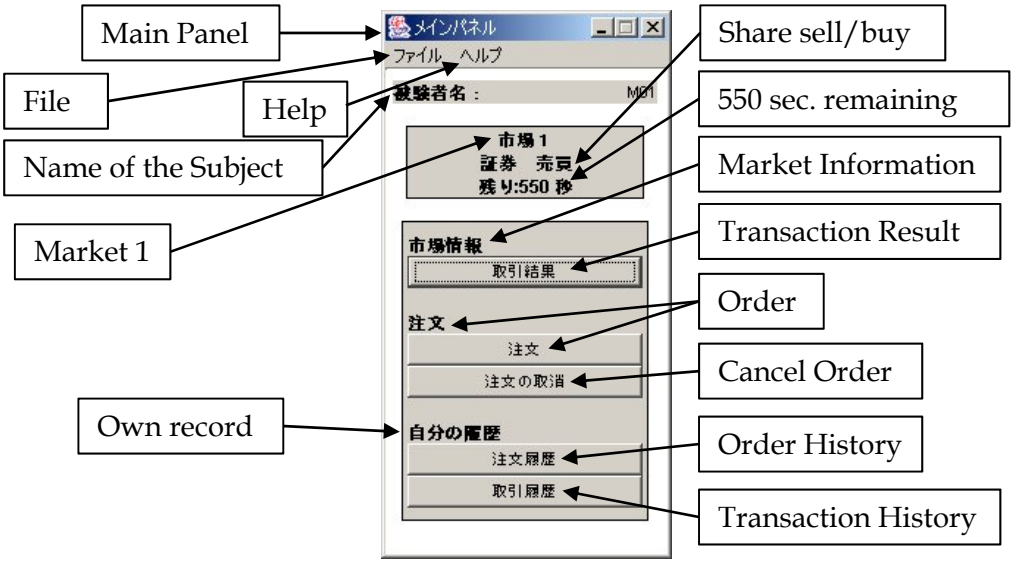


Fig. 2-3 Transaction History Panel (When Starting the Experiment)

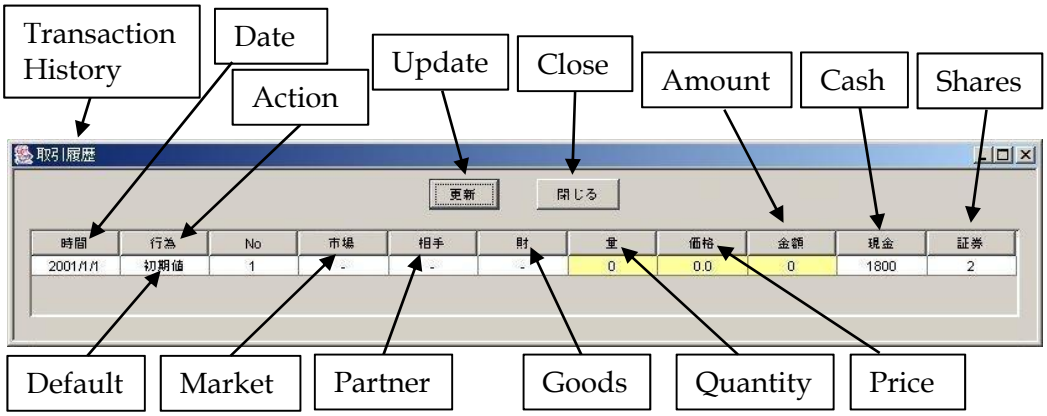


Fig. 2-4 Order Panel

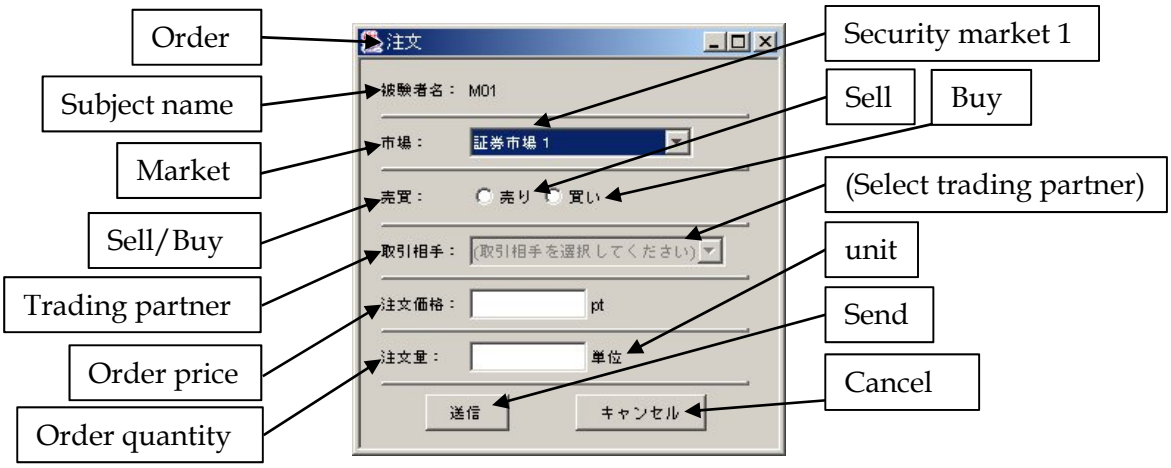


Fig. 2-5 Condition 1 of the Order to Sell

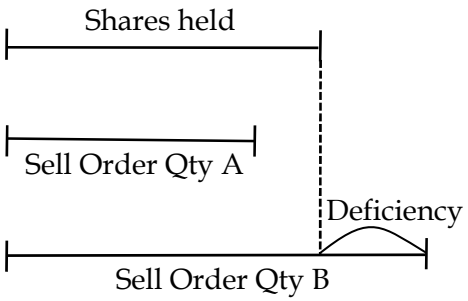


Fig. 2-6 Condition 2 of the Order to Sell

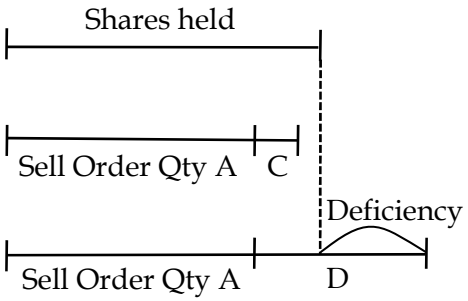


Fig. 2-7 Order Cancellation Panel

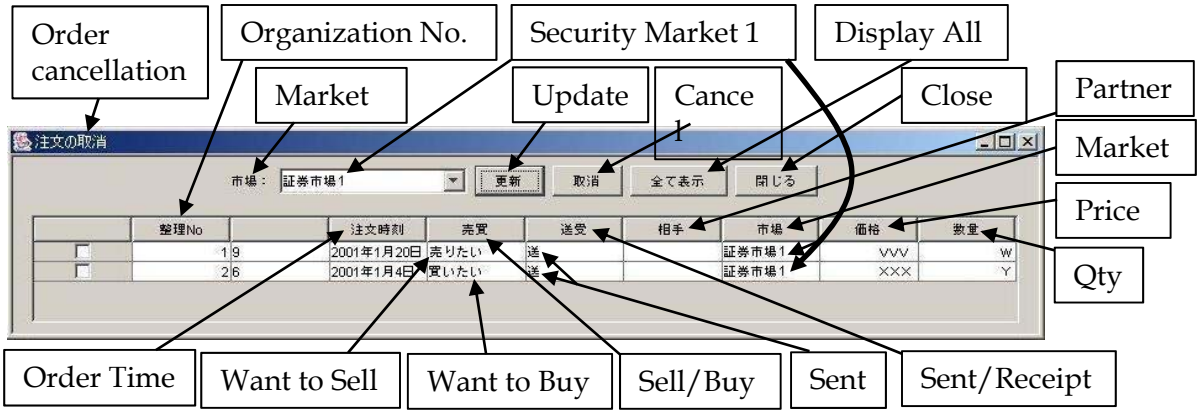


Fig. 2-8 Order History Panel

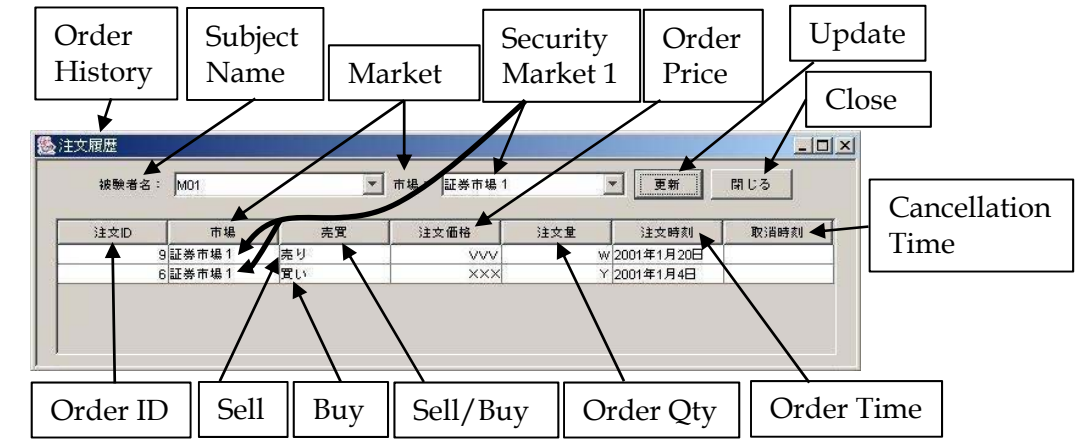


Fig. 2-9 Notification of Buy

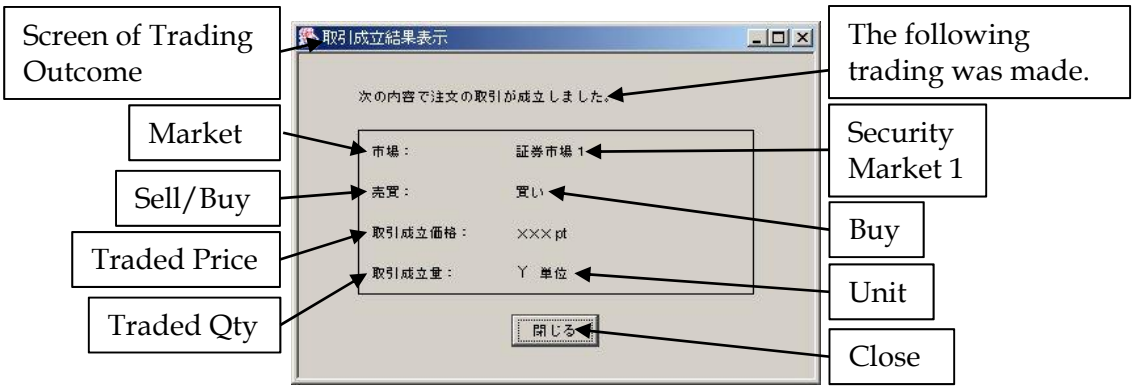


Fig. 2-10 Notification of Sell

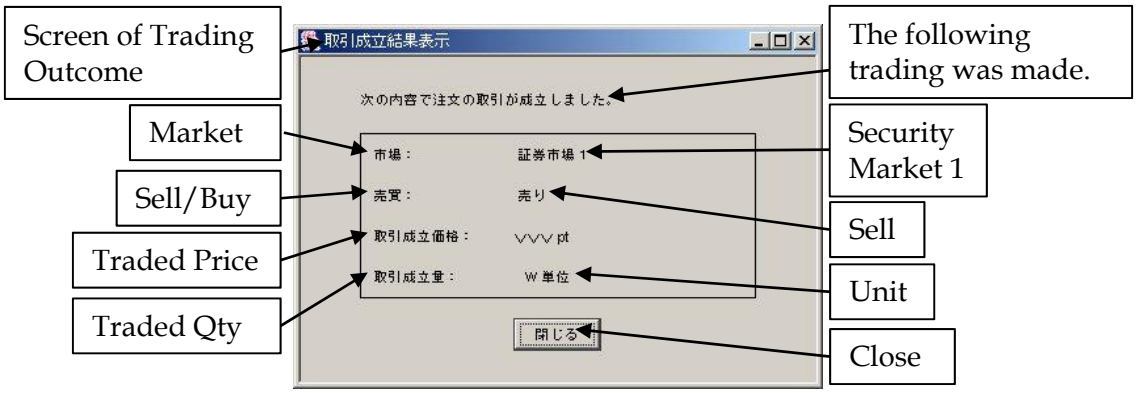


Fig. 2-11 Transaction Result Panel

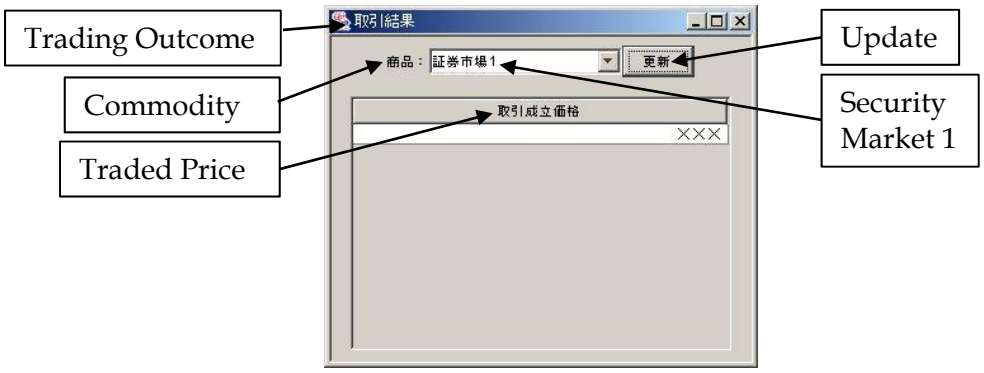


Fig. 2-12 Transaction History Panel (When a Sell Order was made)

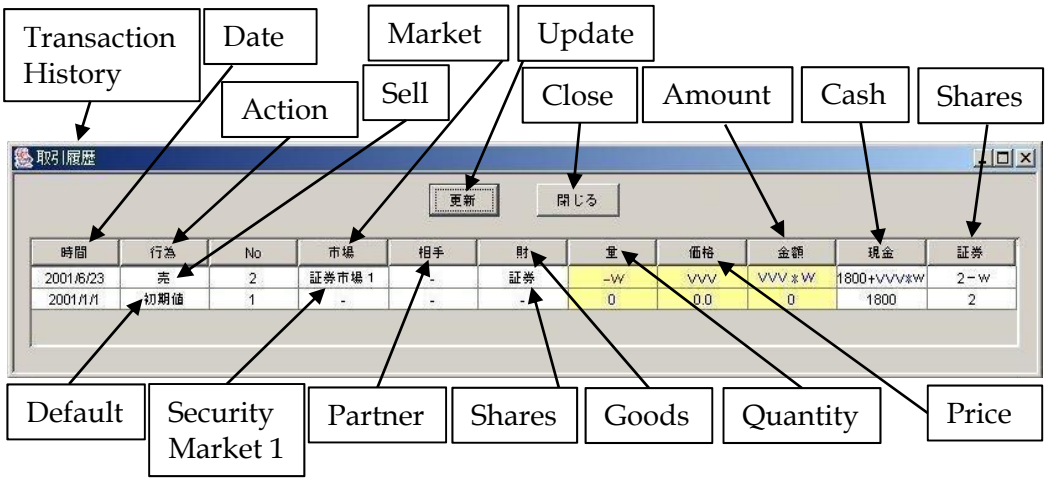


Fig. 2-13 Transaction History Panel (When Purchased)