Rational Investor Sentiment *

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November 2002

*We are grateful for comments by Michel Habib and Shyam Sunder. Moreover, the paper benefited from presentations at Vienna, Zurich, Bergen, Bielefeld and at the Council for Social Sciences in Münchenwiler. Financial support by the national center of competence in research "Financial Valuation and Risk Management" is gratefully acknowledged. The national centers in research are managed by the Swiss National Science Foundation on behalf of the federal authorities.
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Abstract

We explain excess volatility, short-term momentum and long-term reversal of asset prices by a repeated game version of Keynes' beauty contest. In every period the players can either place a buy or sell order on the asset market. The actual price movement is determined by average market orders and noise. It is common knowledge that the noise process is an exogenous random walk. Our model explains short-term momentum and long-term reversal of stock prices by unpredictable switches in the coordination of the players. When the players are coordinated on buying (selling), we say the market is in the up (down) mood. In this model changing investor sentiment is a rational strategy as it leads to a Nash equilibrium of the coordination game. We give experimental evidence in support of our claims.

Keywords: Experimental asset markets, investor sentiment, behavioral finance.
JEL-Classification: G12, C91.

1 Introduction

Ninety percent of what we do is based on perception. It doesn't matter if that perception is right or wrong or real. It only matters that other people in the market believe it. I may know it's crazy, I may think it's wrong. But I lose my shirt by ignoring it.

"Making Book on the Buck"
Wall Street Journal, Sept. 23, 1988, p. 17

Traditional finance argues that stock prices follow their fundamental values. According to this view, expressed for example in the form of the discounted dividends model, stock prices are equal to the present value of expected future dividends. Moreover, on this assumption any short-term fluctuations in prices result from unforeseen changes in expected future dividends. Consequently, all period-to-period price changes of a stock are unpredictable random movements (see Cootner (1964) for an early treatment of this view which was most prominently put forward by Fama (1970)). These cornerstones of traditional finance can be derived from asset pricing models where investors maximize expected utility over an infinite horizon and have rational expectations with respect to the price process (Lucas (1978)). In addition, they are certainly sound guidelines for investors who hold an asset indefinitely.

However, recent empirical evidence has cast substantial doubt on the discounted dividends model and the unpredictability of stock market prices. Whereas dividend growth is a good indicator for stock market prices in the long run, on shorter horizons stock prices often deviate substantially from their fundamental values and are more volatile than the dividends (Shiller (1981)). Moreover, short-term momentum and long-term reversal of stock market prices are empirically robust stock price anomalies (see, for example, Jegadeesh (1990), De Bondt and Thaler (1985), Lo and MacKinlay (1999), Campbell (2000) and Hirshleifer (2001)).

Various explanations of these phenomena are currently discussed. Conrad and Kaul (1998) and Johnson (2002), for example, try to embed these phenomena into the traditional view of finance. Models of behavioral finance, by contrast, explain excess volatility and predictability of stock market prices by breaking with the complete rationality hypothesis underlying traditional finance. See Jegadeesh (2001), for example, for an evaluation of alternative explanations of stock price momentum. The most prominent explanations (e.g. Daniel, Hirshleifer, and Subrahmanyam (1998), Hong and Stein (1999), Barberis, Shleifer, and Vishny (1998)) are based on "investor sentiment". Barberis, Shleifer, and Vishny (1998), for example, use a Lucas (1978) asset pricing model with a fundamental value following a random walk. The representative investor, however, believes that the market switches between two regimes, a "momentum" and a "mean-reversion" state, in accordance with some exogenous Markov process. If investors carry out a Bayesian updating in every period, their behavior will exhibit two behavioral anomalies, namely "representativeness bias" and "underreaction".

In explaining these deviations from the fundamental values, we follow Keynes'

(1936) classical description of stock markets. Starting from the observation that very few investors hold stocks for ever, Keynes points out that for most investors the selling value of their stock will be more important than the dividends. Hence beliefs about the fundamental value of a stock may be less important than higher order beliefs, i.e. beliefs about the other investors' beliefs about the asset price. As an analogy he also compares stock markets to newspaper beauty contests in which the reader whose choice coincides with the average pick receives a prize. Thus, in the short run, guessing the average opinion on the stock market price is much more important than guessing the correct fundamental value. As a result, stock market prices may deviate from their fundamental values. According to Keynes they may even become an almost arbitrary social convention. While Keynes' analogy of the beauty contest does not contain a prediction about the degree of the deviation from the fundamental value, it has nevertheless made clear that in the short run stock markets exhibit the structure of coordination games, as the initial quote from a trader cited above also documents. The coordination game structure of stock markets has recently also been emphasized in the behavioral finance literature. Shleifer (2000), for example, points out the importance of "noise trader risk", which is also called "market risk": All investment strategies based on fundamental values run the risk that the average investor does not follow the fundamental view. Even though the fundamental investor will eventually benefit from his strategy, in the short run he will lose and may even be deprived of his wealth before the long-term development of the asset prices turns to his favor. Or as Keynes has put it: "Markets can remain irrational longer than you can remain solvent." A prominent case for the importance of market risk are the losses incurred by LTCM's strategy based on the expectation that the share prices of Royal Dutch Petroleum and Shell Transport and Trading should be in line with a 3:2 parity. This fundamental view was based on the fact that these two firms had agreed to share profits in this ratio. However, as Froot and Dabora (1999) have documented from 1980 to 1995 the 3:2 parity was more and more violated.

The idea of our paper is to argue that excess volatility, short-term momentum and long-term reversal can be explained as the outcome of a repeated beauty contest with noise. We have in mind a set of investors interacting repeatedly on a market for a long-lived asset on which noise traders will also participate. To separate the importance of second-order beliefs from the importance of having correct beliefs about the underlying exogenous random process in the market, we assume that it is common knowledge that noise trading follows a simple random walk. Hence, in contrast to Barberis, Shleifer, and Vishny (1998), the traders have no misperceptions about the statistical distribution of the exogenous random process. Moreover, as already argued by Keynes, we assume that in each period the investors are assessed in terms of the gains/losses resulting from actions they have taken in that period. To keep things simple, in each period every investor can only decide to buy or to sell one unit of the asset. Consequently, if she decides to buy (sell) and prices go up (down) in this period, the investor will get a fixed positive reward. Otherwise she will get a lower reward. In the first case this is justified because the investor has bought an asset that appreciated in that period. In the second case she has sold an asset that depreciated. One may think, for example, of the investor as being the manager of a pension fund, an insurance fund or a hedge fund. It is now a common business practice that the principals of the funds evaluate the managers according to the per period performance of the managers' actions taken in that period. Moreover, one may also think of private investors managing the family's fortune. Again, the investor will then be monitored by some of the other family members, most likely also in every period. Stock market prices are determined endogenously by the demand and supply in the asset market. In analogy to many market-maker models we assume that prices go up if demand exceeds supply and vice versa. As in many asset pricing models, the price movements in our model reflect the average opinion of the market disturbed by some noise. Every player observes the price movement, yet without knowing the individual players' actions. That is to say the game we are considering is a repeated coordination game with imperfect monitoring. The first paper to study imperfect monitoring games was Green and Porter (1984) in the context of an oligopoly model with stochastic demand. Their paper initiated a whole line of research analyzing the set of equilibria and the learning dynamics for this interesting class of games. See, for example, Abreu, Pearce, and Stacchetti (1990), Lehrer (1990), Lehrer (1992a), Lehrer (1992b), Kalai and Lehrer (1995) and Gilli (1999).

The specific model we are considering has numerous Nash equilibria. For example, any pattern of coordinated play in which all strategic players choose identical actions in every period, constitutes a perfect Bayesian Nash equilibrium of the repeated game. Hence, as in Keynes' original beauty contest, the rational outcome of the game is arbitrary. However, actual play of this game in the computer laboratory gives a clear prediction: After an initial learning phase, all strategic players decide to buy, i.e. they play "up" until the noise traders break this "up" regime. Thereupon the strategic players switch to a coordinated play of "down", i.e. they decide to sell until the "down" regime is eventually broken by noise so that the strategic players will switch back to playing "up". We call this outcome "switching behavior". Note that this switching behavior produces price trajectories that give rise to familiar stock price anomalies: Prices show excess volatility in the sense that the variance of stock market prices is much higher than the variance of the exogenous noise. Moreover, the prices show short-term momentum because whenever the strategic players are coordinated in one of the regimes the likelihood of price movements in the same direction is higher than a reversal. Eventually price movements will revert because any "up" or "down" regime will almost surely be broken by noise.

A natural interpretation of the outcome of this game is that the strategic players change their sentiment from bullish, ("up") to bearish ("down") regimes. Note that in our model both investor sentiment and its switches are *endogenous* as well as *rational*. Investor sentiment is rational within and therefore also across periods because in every period it is the best response to the investor sentiment shown by other investors. In particular, switching is also the best response to switching. It is endogenous because the rational players could, for example, also play stolid and remain in a particular mood.

In our model, given the per period evaluation of the performance of the investors, investor sentiment is the result of an equilibrium selection from the rational outcomes of a repeated coordination game with imperfect monitoring and noise. As we will discuss in detail, the equilibrium selection can be explained by well-known behavioral principles. The observed switching behavior is the only rational equilibrium that is consistent with probability matching and focal point analysis. It is consistent with probability matching because the relative frequency of the actions chosen by the strategic players matches the relative frequency of the outcome if it were determined by the dice only. Moreover, given a number of equilibria focal points play a major role. In this game the strategic players could use the outcome of the last period, the last two periods, the last three periods, etc. as a coordination device. The simplest such coordination device is to choose the outcome of the last period, and this is also what we observe.

To conclude the introduction, recall that Keynes (1936, p. 154) has already put forward the following observation: If stock market prices are not based on fundamentals but on second-order beliefs, then they can change "...violently as the result of a sudden fluctuation in opinion due to factors which do not really make much difference to the prospective yield... ." This is exactly what we observe as the result of our asset market game. In our market, prices are determined only by second-order beliefs and the current period outcome of the dice does not make a difference to the prospective future yield of the asset. Consequently, as Keynes summarizes on the same page of his book "...the market will be subject to waves of optimistic and pessimistic sentiment... ."

In the next section we give a formal representation of the game considered in this paper. Thereafter, in section 3, we describe the experimental set-up. Section 4 presents our results and section 5 concludes with a discussion.

2 The Model

We model the stock market by a stochastic coordination game. The game is played repeatedly in a finite number of periods. First we explain the stage game and then we define the repeated game as a sequence of such stage games.

2.1 The stage game

There is an odd number of strategic agents $i \in I = \{1, \ldots, n\}$, who in every period can buy or sell one unit of an asset. Since buying (selling) is rational only if the agent predicts that the asset price goes up (down) we sometime identify their actions with their predictions. Hence, the strategy set of agent i is given by $S_i = S = \{u, d\}$, where u(p) means that the agent buys because he predicts an increasing and d(own) means that she sells because she predicts a decreasing stock price. Her payoff is a fixed amount G(ain) if she predicted the correct movement and it is L(oss) otherwise. One may think of the investors as being agents for some principals of a fund. In every period the principals reward the agents by the success of their action taken at the beginning of that period. Hence, if the agent predicted that the asset price goes up and has thus bought an extra unit of the asset then this action was optimal if and only if prices increase. Analogously, selling one unit of the asset is the best action of that period if prices decrease. We assume that $G > 0 \geq L$. The actual stock price movement is determined by the actions of all agents and of $n+1$ noise traders who are modelled as follows.

Noise traders can be in an “up” or “down” mood. There is a correlated shock to the population of noise traders which determines the number of noise traders in “up” and “down” mood. Let $\omega \in \Omega = \{0, 1, \ldots, n+1\}$ denote the number of noise traders who are in an “up” mood and let $P(\omega)$ be the probability that $\omega \in \Omega$ is realized. We assume that $P(\omega) = 1/(n+2)$ for all $\omega \in \Omega$.

The noise traders’ sentiment is given by the difference in the number of traders in “up”, respectively “down” mood, i.e. by the random variable

$$\begin{aligned} X : \Omega &\rightarrow \mathbb{Z} \\ \omega &\mapsto X(\omega) = 2\omega - n - 1. \end{aligned}$$

Hence, the probability that the noise traders’ sentiment is positive or negative, respectively, is $0.5(n+1)/(n+2)$ and the probability that it is constant is $1/(n+2)$.

The actions of strategic agents and the noise traders’ sentiment are combined in a linear way to determine change in the stock price. Let $s \in \times_{i=1}^{n} S_i$ be the strategy profile of the agents and let $\omega \in \Omega$. Then the stock price change $r = r(s, \omega)$ is given by

$$r(s,\omega) = \begin{cases} u \text{ , if } |\{i \,|\, s_i = u\}| - |\{i \,|\, s_i = d\}| + X(\omega) > 0 \\ d \text{ , else} \end{cases} .^{1}$$

Thus, the stock price will increase if total investors' sentiment about the price change is positive, otherwise it will decrease. As we have argued in the introduction this feature, that stock price changes are the result coordination among the traders, seems to be conform with what we observe on real markets, at least in the short run: if the majority of traders believes that stock prices will go up (and hence act accordingly), prices will indeed go up.

Given $s \in \times_{i=1}^{n} S_i$ and $\omega \in \Omega$ the payoff of player i is

$$\pi^i(s,\omega) = \begin{cases} G \text{ , if } s_i = r(s,\omega) \\ L \text{ , else} \end{cases} .$$

The players have their actions simultaneously knowing neither the actions chosen by the other players nor the result of the chance move that determines the noise traders' sentiment. All strategic players have complete information about the structure of the game. We denote by $\Gamma = (I, (S_i)_i, (\pi^i)_i)$ the game thus defined.

[1] By $|A|$ we denote the cardinality of a set A.

The stage game Γ is a symmetric coordination game in expected payoffs. Hence, it is immediate to see that it has two Nash equlibria in pure strategies, namely s^U with $s_i^U = u$ for all $i = 1, \ldots, n$, and s^D with $s_i^D = d$ for all $i = 1, \ldots, n$. The expected payoff of agent i at these equilibria is

$$\mathbb{E}\pi^i(s^U, \omega) = \mathbb{E}\pi^i(s^D, \omega) = \frac{n+1}{n+2}G + \frac{1}{n+2}L.$$

A mixed strategy α_i of player i is a probability distribution over S_i, i.e. $\alpha_i \in \Delta(S_i)$.[2] The following theorem shows that the stage game has a unique equilibrium $\alpha = (\alpha_1, \ldots, \alpha_n)$ in strictly mixed strategies where $\alpha_i(u) = \alpha_i(d) = 0.5$ for all i. The proof is in Appendix A.

Theorem 2.1 *Let $\alpha = (\alpha_1, \ldots, \alpha_n)$ be a mixed strategy profile with $\alpha_i(u) \in (0,1)$ for at least one i. Then α is a mixed strategy Nash equilibrium of Γ if and only if $\alpha_i(u) = \alpha_i(d) = 0.5$ for all i.*

Observe that the expected payoff of an agent in the mixed Nash equilibrium is lower than her expected payoff in a pure strategy Nash equilibrium.

2.2 The repeated game

Consider now the game that results from a finite repetition of the game Γ. There is a finite number of periods $t = 1, 2, \ldots, T$, and in each period t the stage game Γ is being played. Contrary to the stage game we now have to distinguish between

[2]By $\Delta(S)$ we denote the set of all probability distributions over the finite set S.

an action taken by player i in period t and her strategy in t. Let

$$A_t^i = A^i = \{u, d\}$$

be the set of possible actions of player i in period t and denote by $a_t^i \in A_t^i$ the action chosen by i in period t. By ω_t we denote the realization of $\omega \in \Omega$ in period t. At the end of period t, each agent is informed about the price change r_t in that period but neither about ω_t nor about the actions taken by the other agents. Hence,

$$h_t^i = ((a_1^i, r_1), \ldots, (a_t^i, r_t))$$

is the history known by agent i at the beginning of period $t+1$ if she has taken actions a_τ^i and the price change was r_τ in periods $\tau = 1, \ldots, t$. By H_t^i we denote the set of all histories of agent i up to period t and we let

$$H^i = \bigcup_{t=0}^{T-1} H_t^i \text{ for } i = 1, \ldots, n,$$

where $H_0^i = \{h_0\}$ and h_0 is the null history. A *behavior strategy* of agent i is a mapping $\mathbf{s}_i : H^i \to \Delta(A^i)$ such that $\mathbf{s}_i(h_t^i) \in \Delta(A^i)$ is the probability distribution over i's actions in period $t+1$ if the history is h_t^i.[3] By $\mathbf{S}_i$ we denote the set of all behavior strategies of player i. The total expected payoff of player i at a strategy profile $\mathbf{s} \in \times_{i=1}^n \mathbf{S}_i$ is given by

$$u^i(\mathbf{s}) = \mathbb{E} \sum_{t=0}^{T-1} \pi^i \left[\left(\mathbf{s}_1(h_t^1), \ldots, \mathbf{s}_n(h_t^n) \right), \omega_t \right],$$

[3]Observe that by Kuhn's (1953) theorem we can restrict to behavior strategies since the repeated game we study is a game with perfect recall.

where the expectation is taken with respect to the probability distribution induced on individual histories and on paths $(\omega_t)_t$ by the strategies of the players and the noise. By $\Gamma^T = (I, (\mathbf{S}_i)_i, (u^i)_i)$ we denote the T times repeated coordination game with imperfect monitoring thus defined.

In the following we will study the Nash equilibria of Γ^T. It is immediate to see that $\mathbf{s}$ is a pure strategy Nash equilibrium if and only if it leads to coordination in all periods. Hence, any sequence of pure Nash equilibria of the stage game is a pure Nash equilibrium of Γ^T. Among these there are two stationary pure Nash equilibria $\mathbf{s}^U$ and $\mathbf{s}^D$ with $\mathbf{s}_i^U(h_t^i)(u) = 1$, respectively $\mathbf{s}_i^D(h_t^i)(u) = 0$ for all $h_t^i \in H^i$ and all i. We call this *stolid (up or down) behavior*. Under stolid behavior the price process is i.i.d. with

$$\text{Prob}(r_t = u) = \frac{n+1}{n+2}, \quad \text{Prob}(r_t = d) = \frac{1}{n+2}$$

for stolid up and with

$$\text{Prob}(r_t = d) = \frac{n+1}{n+2}, \quad \text{Prob}(r_t = u) = \frac{1}{n+2}$$

for all $t = 1, \ldots, T$, for stolid down.

But these are not the only possible equilibria in pure strategies. Obviously any pure strategy Nash equilibrium is payoff equivalent to a Nash equilibrium in pure strategies that depend on public information only, i.e. only on past price changes r_τ and not on past actions a_τ^i. One particularly simple Nash equilibrium in nontrivial public strategies is $\mathbf{s}^{SW}$ with

$$\mathbf{s}_i^{SW}(h_t^i)(u) = \begin{cases} 1 \text{ , if } r_t = u \\ 0 \text{ , else} \end{cases} ,$$

for all $h_t^i \in H_t^i$, all i and all $t \geq 1$, and $\mathbf{s}_i^{SW}(h_0)(u) = \mathbf{s}_j^{SW}(h_0)(u) \in \{0, 1\}$ for all $i \neq j$. Here, the price change of the last period is taken as a signal on which traders coordinate their action: players choose the last price movement as their action in any period $t \geq 2$. We call this *switch behavior* since the strategic traders' sentiment changes from an extreme "up" to an extreme "down" mood if and only if the noise traders have overruled them in the last period. Under switch behavior the price process is a stationary Markov process with

$$\begin{aligned} \text{Prob}(r_{t+1} = u \,|\, r_t = u) &= \frac{n+1}{n+2} \\ \text{Prob}(r_{t+1} = u \,|\, r_t = d) &= \frac{1}{n+2} \end{aligned}$$

for all $t = 1, \ldots, T$.

The repeated game also has many (perfect Bayesian) Nash equilibria in mixed strategies. For example, any sequence of pure and mixed Nash equilibria of the stage game gives rise to a mixed strategy Nash equilibrium of the repeated game. In particular, there is the stationary and symmetric mixed strategy Nash equilibrium $\mathbf{s}^R$ with $\mathbf{s}^R(h_t^i)(u) = 0.5$ for all $h_t^i \in H^i$ and all i. We call this *random behavior*. In this case the price process is a random walk with

$$\text{Prob}(r_t = u) = 0.5$$

for all $t = 1, \ldots, T$. Moreover, it is easy to see that any Nash equilibrium in strategies that depend on public information only must be given by a sequence of Nash equilibria (pure or mixed) of the stage game. In addition there is a plethora of perfect Bayesian Nash equilibria that depend on private information.

Summarizing we see that the repeated game has a large number of Nash equilibria and that the stochastic properties of the price process depend on the equilibrium that is being played. The only equilibrium selection theory that gives a unique prediction and is not based on behavioral principles is due to Harsanyi and Selten (1988). Their procedure selects the equilibrium with random behavior (in each period all players mix between u(p) and d(own) with probability 0.5). This is due to symmetry reasons and the fact that the Harsanyi-Selten procedure always selects a unique equilibrium. Since our game is symmetric with respect to the actions u(p) and d(own) and since the selection must not depend on the labelling of these actions, there is only one equilibrium for which there does not exist a different equilibrium with the role of the actions u(p) and d(own) just exchanged: the equilibrium with random behavior. This gives a testable hypothesis since we have seen that with random behavior the price process is a random walk, i.e. the exogenous randomness caused by noise traders is transformed one-to-one into endogenous randomness of the price process and phenomena like momentum, mean reversion of excess volatility should not be observed.

In the next section we will present the results of an experiment where the game was played in a computer laboratory. Surprisingly, the robust finding is that from the large set of equilibria the participants in this experiment select the switch equilibrium.

3 The Experiment

3.1 Hypotheses

From the equilibrium analysis we deduce the following testable hypotheses. The first question is whether we observe a random walk of the price or a different price distribution caused by a changing investors' sentiment connected with excess volatility. Hypothesis 1 consists of two parts and tests for a random walk and excess volatility.

Hypothesis 1a: The price movement is not a random walk.

Hypothesis 1b: The price volatility is higher than the volatility of the noise traders' sentiment (the chance move). We take the noise traders' sentiment as reference volatility to determine excess volatility, because in our model the price movement would follow the noise traders' sentiment if no other agents were present.

The next question concerns individual behavior in more detail. First we test for coordination.

Hypothesis 2: The agents are coordinated and use the same action in all periods.

As discussed above the game has several pure-strategy equilibria. One main point of discussion is which equilibrium is selected. We consider three main candidates (which are intuitive) as possible equilibrium outcomes: all agents play stolid u(p) every period, all agents play stolid d(own) every period, or all agents play the switch equilibrium. The third hypothesis correspondingly has three parts.

Hypothesis 3a: All agents play u(p) every period.

Hypothesis 3b: All agents play d(own) every period.

Hypothesis 3c: All agents play a switch strategy corresponding to the switch equilibrium.

In the last hypothesis we connect the behavior in the beginning of the game to the finally selected strategies. We focus on the expected three main types which are: play u(p) every period, play d(own) every period or switch (which need not be coordinated in the beginning as it is in the equilibrium strategy). We want to test whether the initial behavior correlates with the final behavior.

Hypothesis 4: If the majority of agents in a group plays either only u(p), only d(own) or switch (uncoordinated) in the beginning, then the resulting equilibrium will be that either all agents play u(p) or d(own) or switch, respectively.

3.2 Method

3.2.1 The Participants

50 students from the University of Zurich participated in the experiment. They were recruited by announcements in the university promising a monetary reward contingent on performance in a group decision making experiment. The participants' payoffs were given in ECU (experimental currency units). 100 ECU corresponded to 1 CHF (approximately \$0.6). The average payoff of a participant was 40 CHF (approximately \$25).

3.2.2 Experimental Procedure

The experiment lasted approximately 90 minutes with the first 20 minutes consisting of orientation and instructions and they were conducted in the computer laboratories of the University of Zurich. After the instructions on the structure of the game the participants played single games with 5 participants per game ($n = 5$). The noise traders' sentiment was determined by a 10-sided dice. The numbers 0 to 6 were identified with ω. For higher numbers the throw was repeated. We chose $L = 0$ to avoid the influence of loss aversion in our results. The gain was $G = 20$ ECU. The game was played in 5 sessions with 2 groups each (i.e. 10 participants per session). Participants were assigned randomly to a group. Each group played twice a sequence of 100 periods via computer terminals. The computer terminals were well separated from one another preventing communication between the participants. The price change and the gain of a person in a period were displayed on a computer terminal in the following period. The changes of the last seven periods were also visible. The subjects could see the total history by scrolling down in the field in which the last seven periods were displayed. Because their decision might depend on the whole history we made this information available.

After the single plays of the game a strategy game was played . All participants selected their strategies for this game. The strategies could depend on the whole information they had, especially on the whole history of play of the game and on their gains and on the period (a detailed description of the strategy game is given in Appendix B). The participants were asked to indicate when they change their strategy from u(p) to d(own) and when they change from d(own) to u(p) . They were free to give a response as they wanted, e.g. they could also choose a free text as an answer. One play of the strategy game was paid per person.[4] For this play the participants were randomly matched to each other. They were informed about this procedure.

[4] The payoff in the strategy game was 20 times as much as that in the single plays.

After the experiment was completed the participants were paid separately in cash contingent on their performance.

4 Results

Figures 1a, 1b, 1c show a typical outcome of the second 100 period round of the experiment. The full data set can be found in Appendix C. Figure 1a displays the cumulated change in the noise traders' sentiment and in the price, Figure 1b shows the choices of all participants and the price movement and Figure 1c presents the observed frequency of U(p) among the participants and the noise traders.

From Figures 1b and 1c we see that except for one period the participants are always coordinated. The price movement shows several periods of increasing prices followed by several periods of decreasing prices which are again followed by increasing prices and so on. If we compare Figure 1a with Figure 1c we find that the price movement changes direction exactly in those periods where the noise traders overrule the coordinated participants. Except for one period all participants are throughout coordinated on the price change of the previous period. Apparently the price movement is not a random walk, but shows the investors' sentiment phenomenon.

Figures 1a, 1b, 1c: Prices, noise traders' sentiment and coordination.

Figure 1a: Cumulated change in the noise traders' sentiment (diamonds) and in the price (triangles).

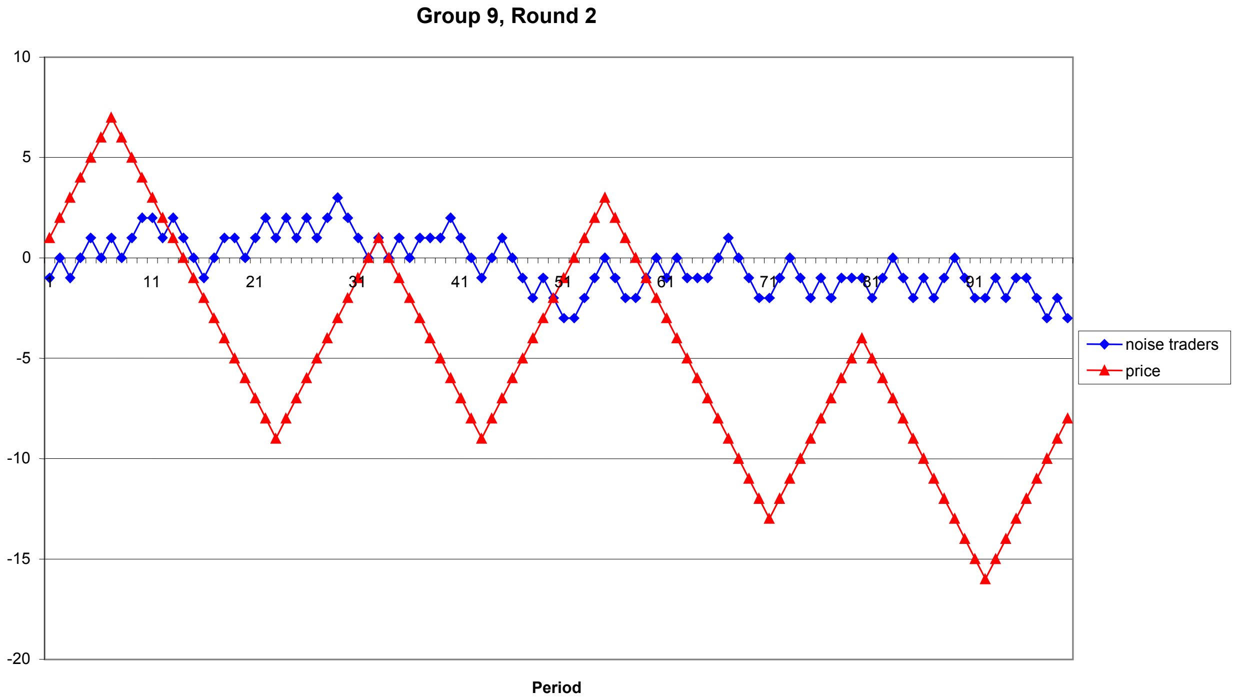


Figure 1b: Price change (triangles) and choices of the participants (circles and other shapes). Only the line with circles is visible, since all 5 lines overlap, except in period 12 where one person deviates. "Up" is denoted as +1 and "down" as -1.

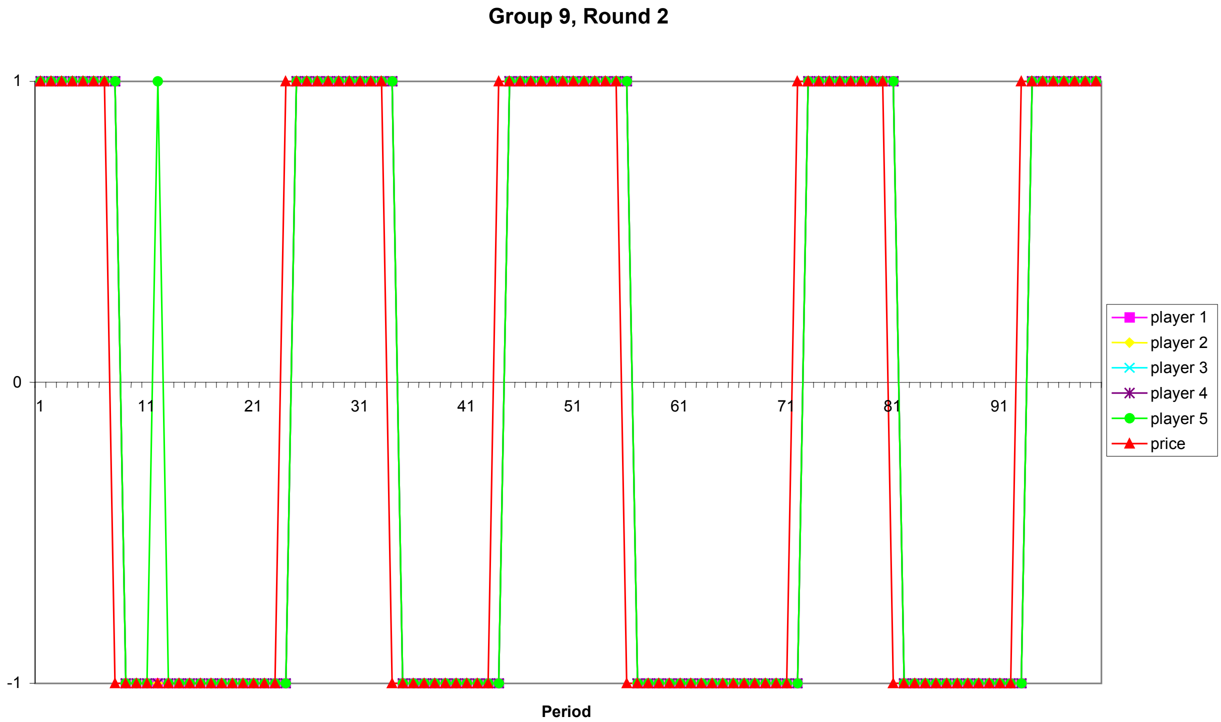
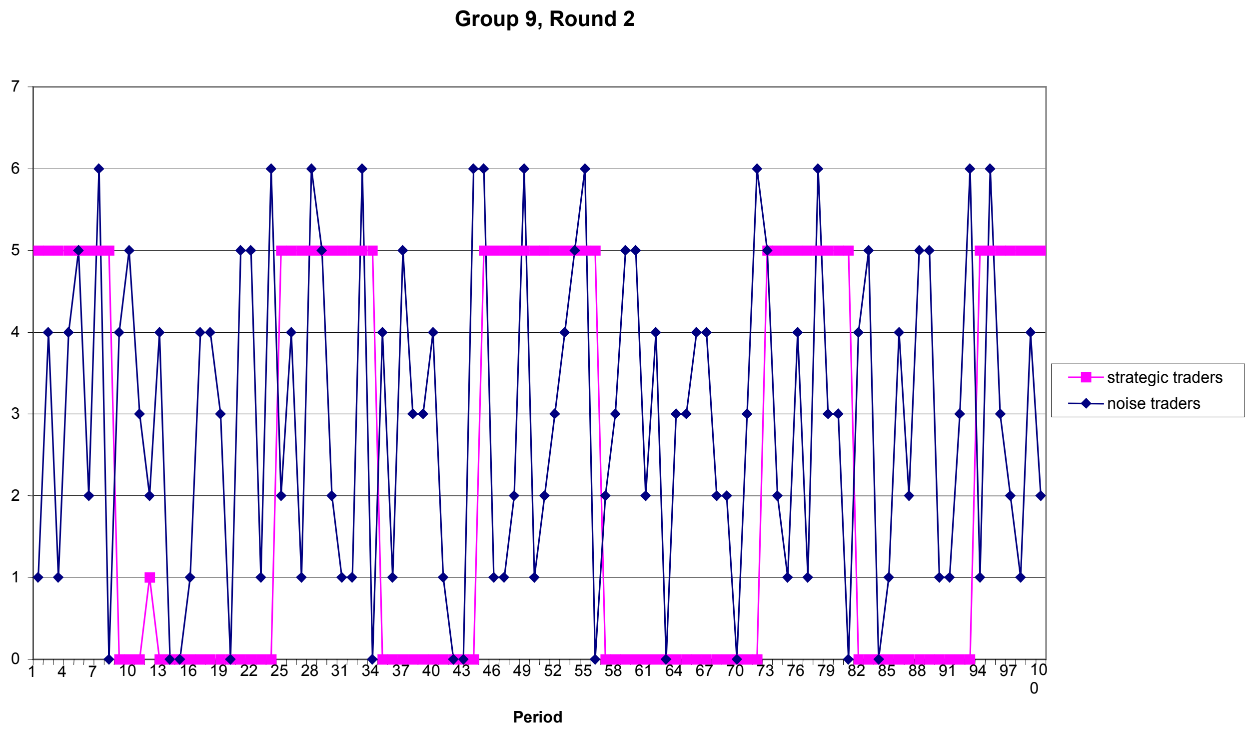


Figure 1c: Frequency of "up" choice among participants (rectangles) and noise traders (diamonds).



Tables 1a and 1b: The result of the strategy game.

Table 1a:

Choices in period 1	
u(p)[1]	d(own)
50	0

Table 1b:

Types of strategies				
Switch[2] after being wrong once	Switch after being wrong twice	Switch after being wrong three times	Switch after being wrong twice and being right seven/eight times[3]	Switch after being wrong twice and being right three times
41	3	1[4]	3	2

[1] All participants played u(p) until their strategies to switch given in Table 1b could be applied for the first time.
[2] Switching does for no participant depend on whether to switch from u(p) to d(own) or from d(own) to u(p).
[3] The numbers seven or eight differed between the 3 persons who chose this rule.
[4] This person added a complicate estimation about the future development of the price to this rule.

For a more detailed analysis we include the strategies obtained in the strategy game from experienced participants. Tables 1a and 1b show the frequencies of the different strategies. In the first period all participants choose u(p). In later periods they indicate under which conditions they switch their action from u(p) to d(own) and vice versa. For no person the decision to switch does depend on the direction (u(p) to d(own) or d(own) to u(p)). We observe five types of strategies which can be reduced to two main types. The first three types are of the form "switch after one's choice was wrong", i.e. after receiving the payoff zero. The switching only depends on the number of times someone has been wrong. 41 persons switch after they have been wrong once. This behavior corresponds to the switch equilibrium. Three participants switch after being wrong twice and one participant switches after being wrong three times. These strategies are of the same principal type as the first one. Although the participants were free to choose their strategy (they could even write a free text), most of them chose the same strategy or one similar to this. Three persons switch also after being right seven or eight times and two persons switch also after being right three times. These strategies reveal a preference for switching in contrast to the coordination observed in the 45 strategies of the first three types. One interpretation of these strategies might be that these persons want to match the movement of the noise traders' sentiment.

We use the data of the single plays of the game to test our hypotheses. The first hypothesis is that we do not observe a random walk in the price movement but a changing investors' sentiment. The null hypothesis that we observe a random walk can be rejected on a 5%-level for all groups (and on a 1%-level for nine groups). In nine groups we observe sequences of only u(p) and only d(own) with a length of at least seven. Assuming any Markovian distribution which generates these transitions these sequences have a probability of less than 1%. In all groups the cumulative price differs from the cumulated noise traders' sentiment in at least 90% of the periods. We also do not observe agents always playing u(p) or always playing d(own), but switching behavior in at least nine groups which we will characterize further by an analysis of the individual data. The one group that did not clearly show the behavior corresponding to the switch equilibrium consisted mainly of players who selected strategies in the strategy game which were of the last two types (cf. Table 1b).

The volatility of the price movement is in nine groups higher than the volatility of the movement of the noise traders' sentiment. The null hypothesis that we do not observe excess volatility is therefore rejected on the 1%-level in a binomial-test. This result supports our Hypothesis 1b that we observe excess volatility.

The next question we analyze concerns the coordination of the players. For a test of the hypothesis whether they are coordinated or not we compare the number of periods in which all agents use the same action with the number of periods in which they do not. First we classify one group as coordinated or not and than we use these data for a test. If one tests the null hypothesis that agents randomly choose their actions (assuming independence of the periods) in a two-sided binomial test the actual frequency of correlation is much too high. For every group the null hypothesis is rejected on a 5%-level (for nine groups it is rejected on the 1%-level). Since we can only treat every single group as an independent observation we classify a group as coordinated or not by the above test. We therefore have ten coordinated groups which allows us to reject the null hypothesis that the agents are not coordinated on the 1%-level on basis of the independent observations.

The third hypothesis is about the selection between possible equilibria. In no group stolid u(p) is observed. The same is true for the strategy stolid d(own). We thus have ten observations contradicting such a prediction. The corresponding Hypotheses 3a and 3b are rejected in a one-sided binomial test on the 1%-level.

Next we test Hypotheses 3c, i.e. whether the observed switching behavior is coordinated in the switch equilibrium. To this end we analyze whether the price switches at the points at which the chance move (the noise traders' sentiment) determines the price by overruling the strategic traders as it should in the switch equilibrium. We therefore count for every group separately the cases in which only the chance move determined the price ($\omega = 0$ or $\omega = 6$) and the participants followed this price change in the period afterwards and compare these cases with the ones in which the chance move determined the price and the participants did not follow it. We thus test the switch equilibrium against the random walk and the stolid up, respectively, stolid down equilibrium. We say that a groups plays the switch equilibrium, if the null hypothesis that a price change occurs after the chance move determined the price has probability 0.5 (random move) and the null hypothesis that it has probability 6/7 (u(p), respectively, d(own) play) are both rejected. We can reject these hypotheses on the 5%-level for nine groups. Again we have nine groups showing the switch equilibrium which is significant on the 1%-level in a one-sided binomial test. Hence, if we analyze the critical points of the price movement, which are those periods where only the noise traders' sentiment determined the price, the behavior in the following periods supports the switch equilibrium.

A second supporting argument for the observation of the switch equilibrium is obtained from the strategies given in the strategy game: 80% of the subjects play the switch strategy (if we allow for slight modifications around 90% play it). It is not possible to test the result against all other strategies. We test it against the other observed strategies in a chi-square-test. The null hypothesis that any observed strategy is equally likely as the switch strategy is rejected on the 1%-level assuming independence of all strategies.

The last hypothesis concerns the behavior at the beginning and at the end of the game. We do not only consider the first period of the game, where all subjects are coordinated on u(p) (see Table 1a) but the first ten periods. We take ten because we want to observe whether subjects play always u(p) or tend to switch (for whatever reasons). Ten is chosen arbitrarily, but for smaller numbers it is too likely that a switching on the signal of the noise traders' sentiment determining the price will not be observed. The hypothesis that subjects do not switch at least once in the first ten periods is rejected in a one-sided binomial test on the 1%-level assuming that all choices are independent.

Now we use the following criterion: A group shows switching behavior if we observe switching behavior for the majority of group members. Assuming that only the 10 groups are independent this gives the same test result as above.

According to the strategies in the strategy game which are already coordinated more than 80% of the subjects switch after $\omega = 0$ occurs for the the first time. Switching depends on the probability that $\omega = 0$ occurs. Nevertheless all participants will switch with probability one in a game of infinite length.

Thus we observe switching behavior in the beginning which is coordinated in a switch equilibrium at the end of the game.

5 Discussion

The experimental results clearly show that the switch equilibrium is selected in our stock market game. This is different from the prediction of the Harsanyi and Selten (1988) theory according to which the random behavior equilibrium should be selected. Hence, we will look for a refinement criterion relying on behavioral principles that solves the selection problem.

There are two main arguments for the selection of the switch equilibrium that we would like to put forward here, prominence (or focal points) and probability matching. If there are multiple equilibria and agents do not have any information about the strategy choices of the other players they do not know on which equilibrium they should coordinate. This situation was already illustrated by Schelling (1960) with his well known example about two strangers having to decide about a meeting point in New York without being able to communicate with each other. Schelling introduced the idea that persons coordinate on "focal points" (like the Grand Central Station in New York) if they have to solve such a problem. Focal or prominent points are the ones that easily come into the mind of a person if she thinks about the problem. However, choosing a focal point equilibrium in a symmetric coordination game requires the actions to be labelled in the same way for all players, i.e. it requires the existence of a common "frame". Otherwise, the players are in a state of complete ignorance about how their opponents perceive the game so that mixing uniformly between all actions seems to be the only reasonable thing to do. Hence, if there were no common frame in our game we would expect to observe the mixed equilibrium we named "random behavior". As we have seen, this is also the equilibrium that is selected according to the theory of Harsanyi and Selten (1988).

In our case actions are labelled "up" and "down" so that there is a common frame and the notion of a focal point can, in principle, be applied. Both actions, u(p) and d(own), could be focal leading to the stolid u(p), respectively stolid d(own) equilibria. One may suspect that the action u(p) is the focal one, which is also confirmed by the participants' choice in the first period of the strategy game. Nevertheless, in our experiments we neither observe the stolid u(p) nor the stolid d(own) equilibrium. This indicates that the players are uncertain about their opponents' attitude towards u(p) and d(own). In other words, there is a common frame but there is uncertainty about the interpretation of this frame.

This uncertainty can be resolved by using a public signal in order to label an action as "focal". In the repeated coordination game we are studying the price movement is an endogenous and publicly observable signal. Any history of past prices can be used as a signal but we will argue that the last period's price is the prominent one. Firstly, using the price movement in more than one period requires a sophisticated rule about how to translate these signals into actions. Hence, one coordination problem is replaced by another making the use of more than one signal very unreasonable.[5] A different argument in favor of using only one signal, i.e. one past price, relies on costs (cf. Binmore and Samuelson (2002)). If the observation and processing of a signal is costly, because it causes disutility,

[5]Of course, there is also not a unique way to translate the price in one period into an action but choosing u(p) and not d(own) when the signal was "up" clearly is the focal point here.

then the players' payoffs are maximized if they use one signal only.[6] Assuming that the cost of observing and processing a signal is not too high the players' payoff with the signal is higher than without, since in the latter case they are unable to identify focal points and will end up playing the mixed equilibrium with random behavior as we have argued above. Secondly, using the last period's price as a signal seems to be more prominent than using the price in any other previous period. The time scale induces a common framing which makes the last period's price a focal signal. Summarizing, in the switch equilibrium players overcome the coordination problem by choosing in each period the action that is focal according to the publicly observed signal, namely last period's price movement.

The second argument supporting the switch equilibrium considers the finding of Hypothesis 4. Even in the beginning of play participants switch (not coordinated, but they switch). In order to explain this preference for switching we consider this game for $n = 1$, i.e. a single person decision making problem for which the coordination problem disappears. It is known from many psychological studies (for a review see Fiorina (1971) or Brackbill and Bravos (1962)) that animals and human beings tend to perform probability matching in similar situations. This kind of behavior was also regarded as important for decision making by Arrow (1958). In our game probability matching means that persons select their strategy such that the frequency of u(p) choices is equal to the probabil-

[6]Provided, of course, they use the signal in the most efficient way, so that they achieve perfect coordination of their actions.

ity that the noise traders' sentiment is positive. Since there is no coordination problem the payoff of this strategy is equal to the payoff for playing u(p) every period or mixing with any probability. The secondary criterion here is that persons "like" to perform probability matching. In our experiment we observe switching behavior in the beginning analogous to probability matching. One simple argument for the switch equilibrium to be selected then is that it is the only prominent equilibrium (like always playing u(p) or always playing d(own)) in which switching behavior is coordinated.

Contrary to stolid up, stolid down or random behavior play of the switch equilibrium induces price trajectories that share many properties with real stock market prices. The price process shows short-term momentum, i.e. the probability of a price increase (decrease) is higher than that of a decrease (increase) whenever the price increased (decreased) in the last period. It shows long-term reversal since eventually any "up" or "down" regime is broken by noise and it shows excess volatility, i.e. the variance of prices is higher than the variance of the exogenous noise. Interestingly, in order to generate these properties our model does not appeal to notions of boundedly rational behavior.[7] Instead, the observed price process is driven by equilibrium play where the players' sentiment constantly changes between an "up" and a "down" mood and the turning points are determined by exogenous noise. Hence, seemingly irrational stock market phenomena can in fact be explained by rational investor sentiment.

[7] This is true even if the observed equilibrium selection may be the result of boundedly rational behavior.

A Appendix

Proof of Theorem 2.1: Let $\alpha = (\alpha_1, \ldots, \alpha_n)$ be a mixed strategy Nash equilibrium of Γ. With a slight abuse of notation we let $\alpha_i = \alpha_i(u)$ for all $i \in I$. Then $\alpha_i = 1$ implies

$$\begin{aligned}
&\text{Prob}(r = u \,|\, \alpha_{-i}, s_i = u) \geq \text{Prob}(r = d \,|\, \alpha_{-i}, s_i = d) \\
\iff & \sum_{l=0}^{n-1} \frac{l+2}{n+2} \sum_{\substack{K \subset I \setminus \{i\} \\ |K| = l}} \prod_{k \in K} \alpha_k \prod_{\substack{k \notin K \\ k \neq i}} (1 - \alpha_k) > \sum_{l=0}^{n-1} \frac{l+2}{n+2} \sum_{\substack{K \subset I \setminus \{i\} \\ |K| = l}} \prod_{k \in K} (1 - \alpha_k) \prod_{\substack{k \notin K \\ k \neq i}} \alpha_k \\
\iff & \sum_{l=0}^{n-1} \frac{2l - n + 1}{n+2} \sum_{\substack{K \subset I \setminus \{i\} \\ |K| = l}} \prod_{k \in K} \alpha_k \prod_{\substack{k \notin K \\ k \neq i}} (1 - \alpha_k) \geq 0.
\end{aligned} \tag{1}$$

Similarly, $\alpha_i = 0$ implies that the inequality holds with "$\leq$", and $\alpha_i \in (0, 1)$ implies that the inequality is an equality "$=$".

Let i be such that $\alpha_i \in (0, 1)$ and assume by way of contradiction that there exists $j \neq i$ such that $\alpha_j \neq \alpha_i$. If $\alpha_j \in (0, 1)$, then from (1) it follows that

$$(\alpha_j - \alpha_i) \frac{2}{n+2} \sum_{l=0}^{n-2} \sum_{\substack{K \subset I \setminus \{i,j\} \\ |K| = l}} \prod_{k \in K} \alpha_k \prod_{\substack{k \notin K \\ k \notin \{i,j\}}} (1 - \alpha_k) = 0$$

which is impossible if $\alpha_i \neq \alpha_j$. Similarly, one can show that $\alpha_j = 1$ and $\alpha_j = 0$ lead to a contradiction. Hence, $\alpha_1 = \alpha_2 = \ldots = \alpha_n =: \bar{\alpha} \in (0, 1)$.

Assume by way of contradiction that $\bar{\alpha} \neq 0.5$. W.l.o.g. let $\bar{\alpha} > 0.5$. Then, from (1) it follows that

$$0 \;\; = \;\; \sum_{l=0}^{n-1} \frac{2l - n + 1}{n+2} \sum_{\substack{K \subset I \setminus \{i\} \\ |K| = l}} \bar{\alpha}^l (1 - \bar{\alpha})^{n-1-l}$$

$$> \sum_{l=0}^{n-1} \frac{2l-n+1}{n+2} \binom{n-1}{l} (1-\bar{\alpha})^{n-1} = 0.$$

This contradiction proves the theorem.

$\square$

Appendix B: Instructions

In the following we present the instructions for the single as well as for the strategy game as they were given to the participants of the experiment.

A Game about the Movement of Security Prices

Welcome! You are participating in a game about the development of security prices. Your payoff depends on your success in the game.

Instructions

Participants

Altogether there are 5 players in your group.

Overview of the game

The game is played for 100 periods. In each period you have to predict whether the price of a security goes up or down. You get a positive payoff if your prediction is correct, otherwise you do not get a payoff.

Your Endowment and Actions

In each period you get 1 point which you can place on any of the following alternatives:

A: the security price goes up

B: the security price goes down

Your Payoff

At the end of each period you receive a payoff of 20 ECU (Experimental Currency Units) if you correctly predicted the movement of the security price in that period. That is you get 20 ECU if either you put 1 point on A (the security price does up) and the security price went up or you put 1 point on B (the security price goes down) and the security price went down. Otherwise you get 0 ECU.

The Determination of the Security Price Movement

Whether the security price goes up or down in a period is a result of the decision of all players and the throw of a fair dice which has seven sides with 0,1,...,5,6, points. All sides are equally likely.

After all players have put their point on either A (the security price goes up) or B (the security price goes down) the dice is thrown. Afterwards the total number of points on A and on B is determined. The points on the dice are added to the sum of the points which the players placed on A. 6 - the points on the dice is added to the sum of the points which the players placed on B.

The security price goes up if the total number of points on A (the security price goes up) is larger than the total number of points on B (the security price goes down). Otherwise the security price goes down. Since the maximal sum of points for an alternative is 11, the security price goes up if the points for alternative A (the price goes up) are at least 6. The price goes down if the points for alternative B (the price goes down) are at least 6.

Your Information

At the end of each period you are informed about the movement of the security price and your payoff in this period. You do not get any information about the decisions of the other players or the result of the throw of the dice. In addition the prices of all previous periods are displayed.

Tables

The tables on the following page summarize the determination of the security price movement depending on the decisions of all players and the throw of the dice.

Table 1: Total Number of Points on A (the security price goes up)

Points on the dice	Number of persons who choose A (the security price goes up)					
	0	1	2	3	4	5
	Number of persons who choose B (the security price goes down)					
	5	4	3	2	1	0
0	0 Points	1 Point	2 Points	3 Points	4 Points	5 Points
1	1 Point	2 Points	3 Points	4 Points	5 Points	6 Points
2	2 Points	3 Points	4 Points	5 Points	6 Points	7 Points
3	3 Points	4 Points	5 Points	6 Points	7 Points	8 Points
4	4 Points	5 Points	6 Points	7 Points	8 Points	9 Points
5	5 Points	6 Points	7 Points	8 Points	9 Points	10 Points
6	6 Points	7 Points	8 Points	9 Points	10 Points	11 Points

≥6 Points: Security price goes up

Table 2: Total Number of Points on B (the security price goes down)

Points on the dice	Number of persons who choose A (the security price goes up)					
	0	1	2	3	4	5
	Number of persons who choose B (the security price goes down)					
	5	4	3	2	1	0
0	11 Points	10 Points	9 Points	8 Points	7 Points	6 Points
1	10 Points	9 Points	8 Points	7 Points	6 Points	5 Points
2	9 Points	8 Points	7 Points	6 Points	5 Points	4 Points
3	8 Points	7 Points	6 Points	5 Points	4 Points	3 Points
4	7 Points	6 Points	5 Points	4 Points	3 Points	2 Points
5	6 Points	5 Points	4 Points	3 Points	2 Points	1 Point
6	5 Points	4 Points	3 Points	2 Points	1 Point	0 Points

≥6 Points: Security price goes down

Stages of a period

Every period (between 1 and 100) is identical:

1. You make your decision: 1 point on
   Alternative A: the security price goes up
   or
   Alternative B: the security price goes down.

2. A dice is thrown:
   The points on the dice are added to the sum of the points which the players placed on A.
   6 - the points on the dice is added to the sum of the points which the players placed on B.

3. Determination whether the security price goes up or down according to Tables 1 and 2.

4. You receive your payoff of 20 ECU or 0 ECU.

* 1 ECU corresponds to 1 Swiss centime.

Strategy game

In this game you indicate your choices in the games for all periods in advance. Decide what you choose in which situation. Your choice can for example depend on the current period, on 1, 2, 3, … or arbitrarily many pre periods. For each of these pre periods your decision might depend on the price in this period or whether your prediction was correct or not. To write down your strategy you can choose the following sheets. But you can also write down your strategy as you want. One game is played using your strategy and paid. 1 ECU corresponds to 20 Swiss centimes **(previous payoff times 20**).

1. period:

Please decide whether you put your point on A (the price goes up) or B (the price goes down).

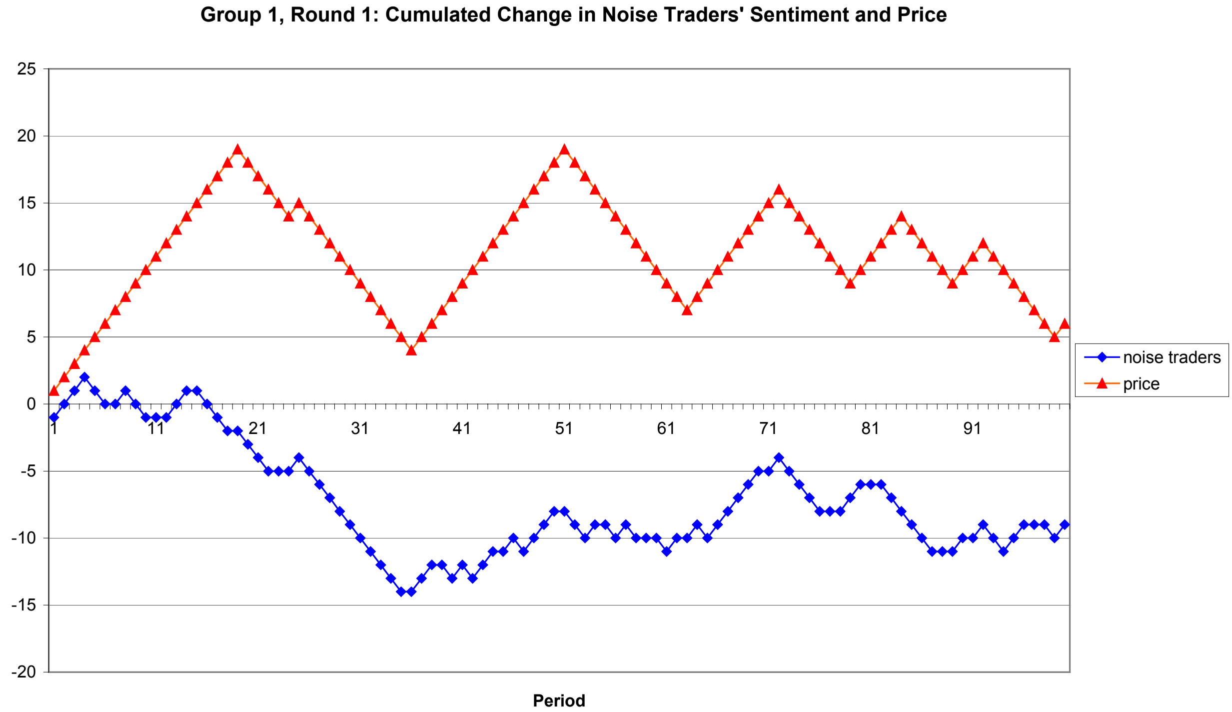
Applicable to Period:

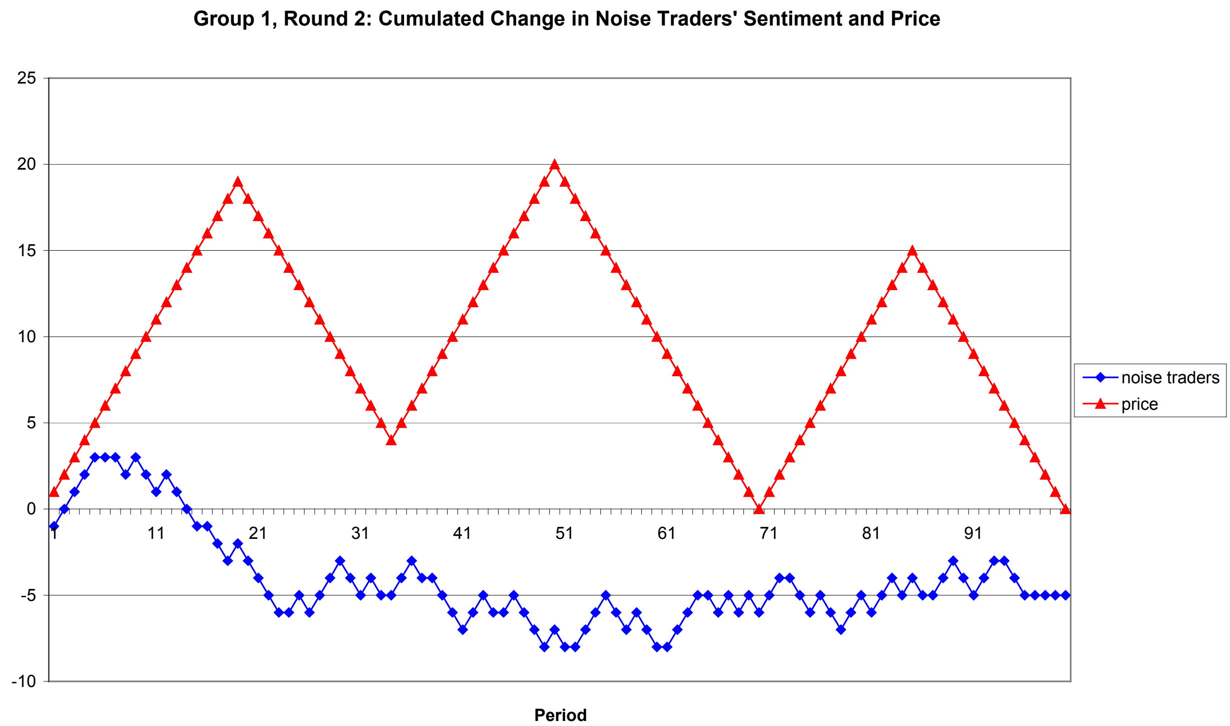
a) Decide when you change from the price goes up (A) to the price goes down (B).

b) Decide when you change from the price goes down (B) to the price goes up (A):

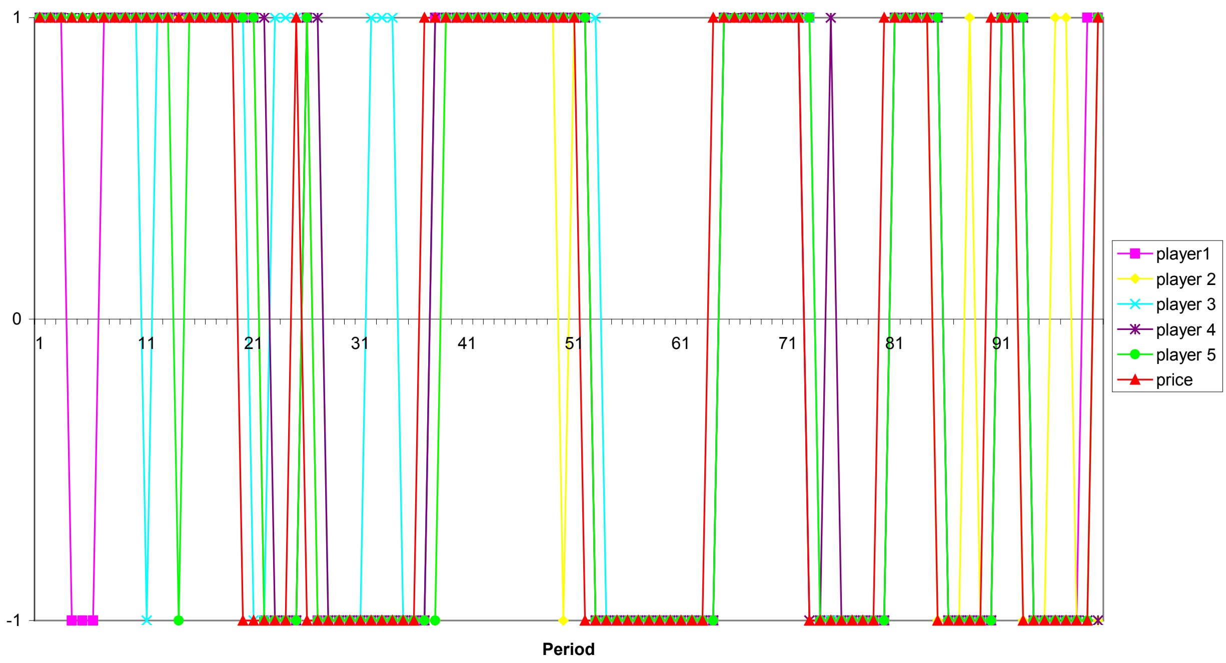
Appendix C: Experimental Results

The following figures show the experimental results for all groups and all rounds. See Figures 1a, 1b, 1c, for an explanation of the different charts.

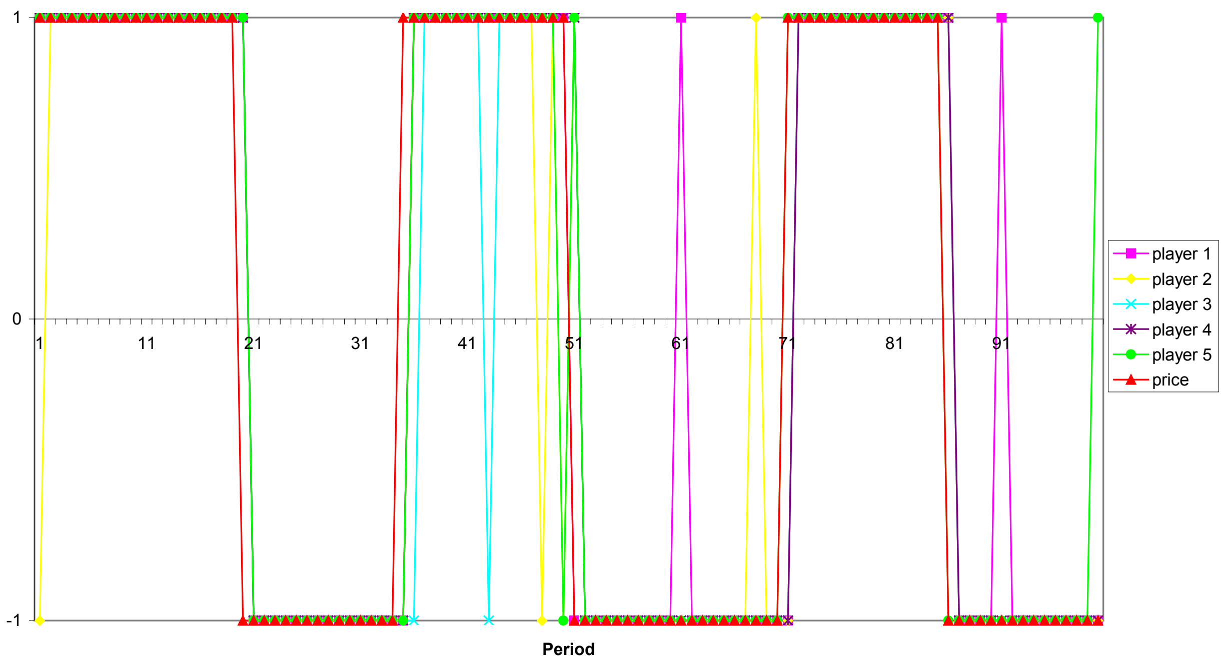




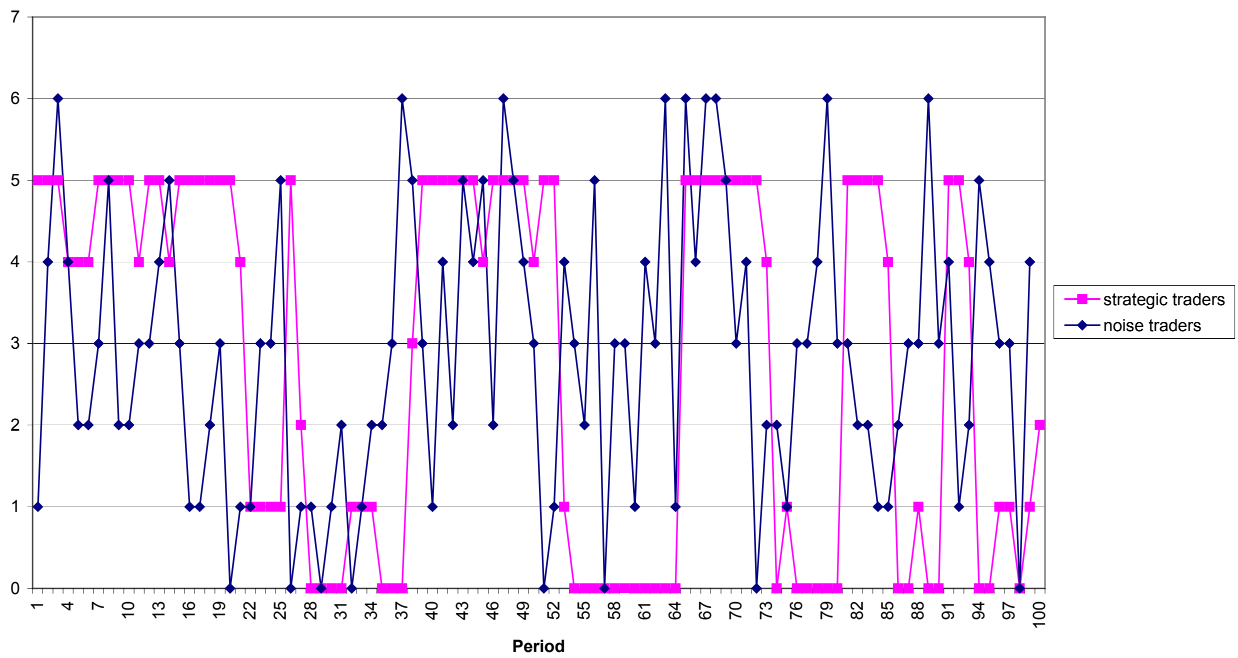
Group 1, Round 1: Price Change and Choices of Participants



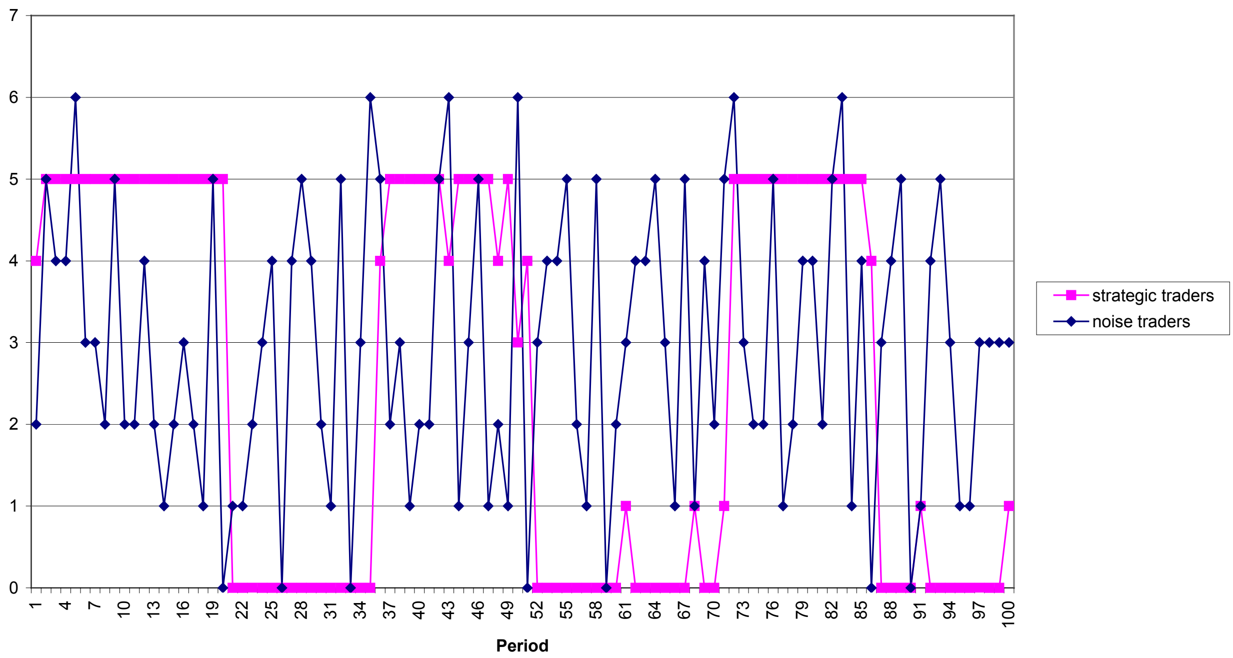
Group 1, Round 2: Price Change and Choices of Participants



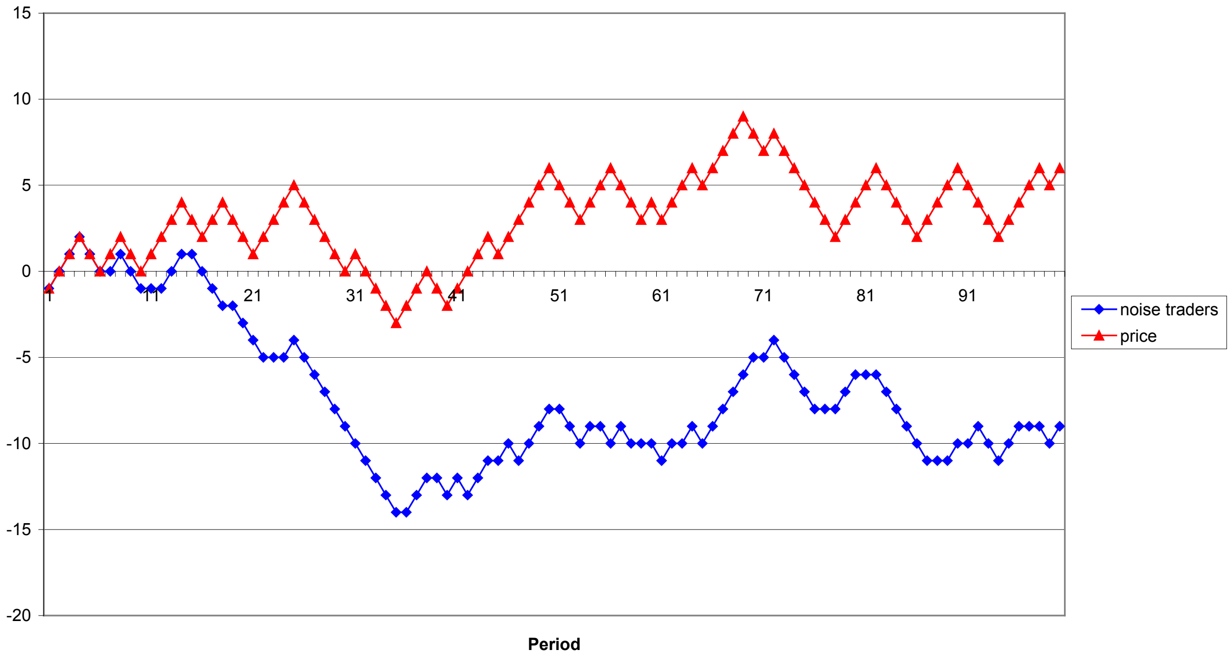
Group 1, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



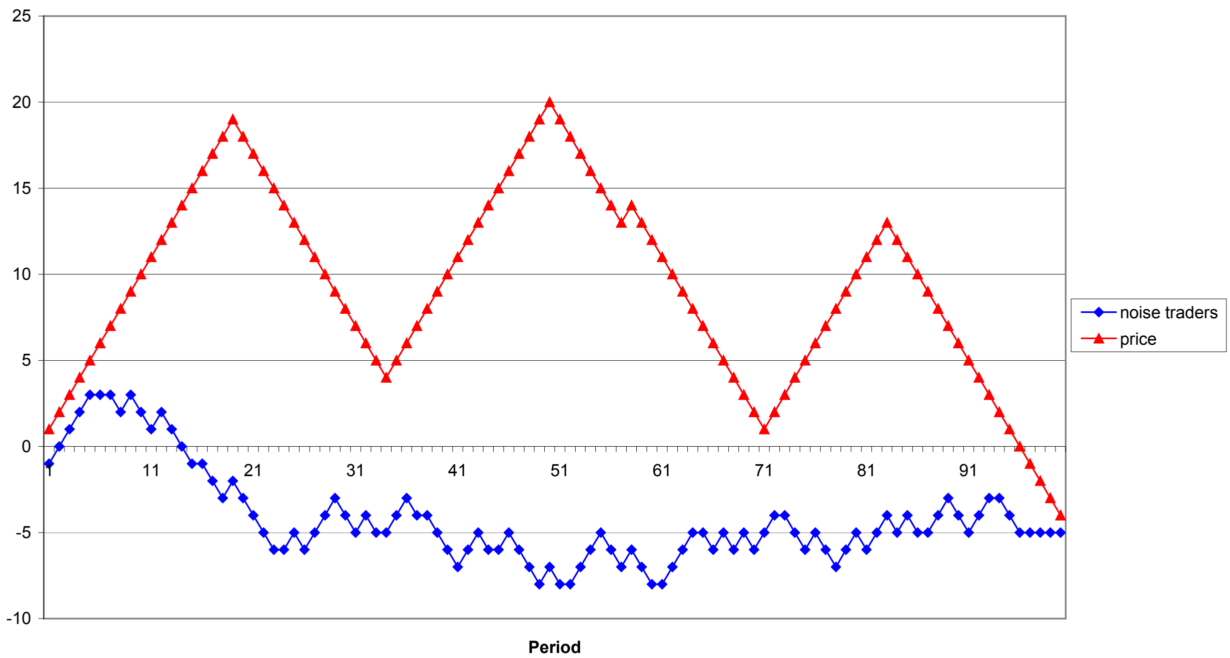
Group 1, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



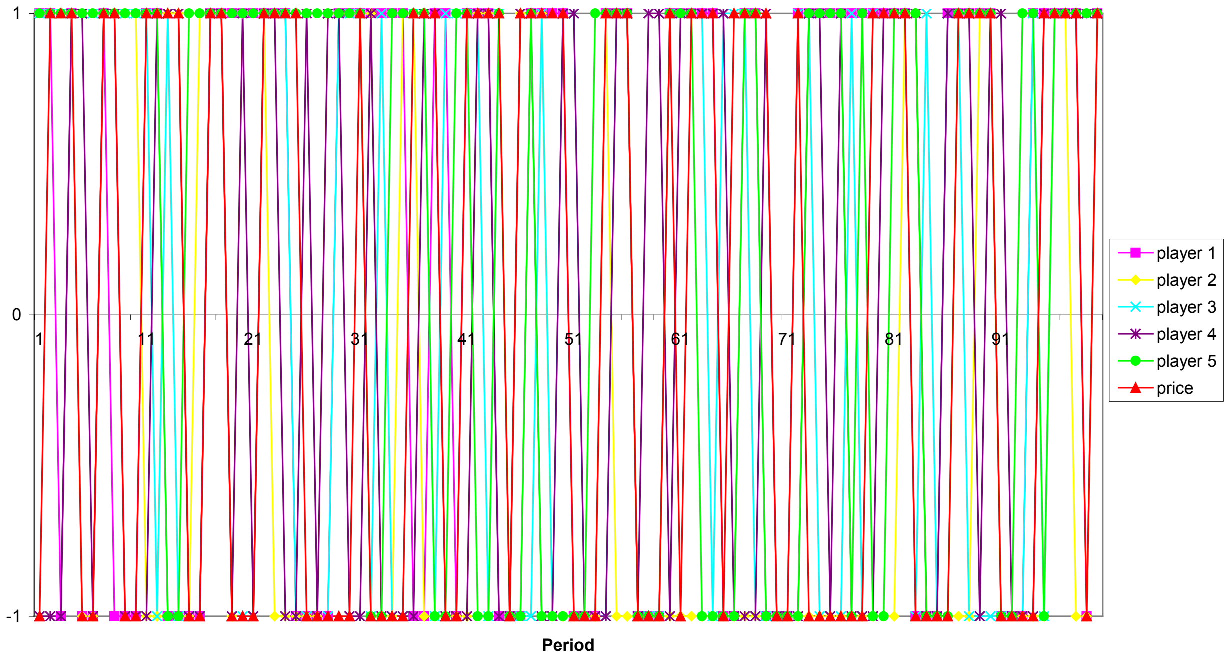
Group 2, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



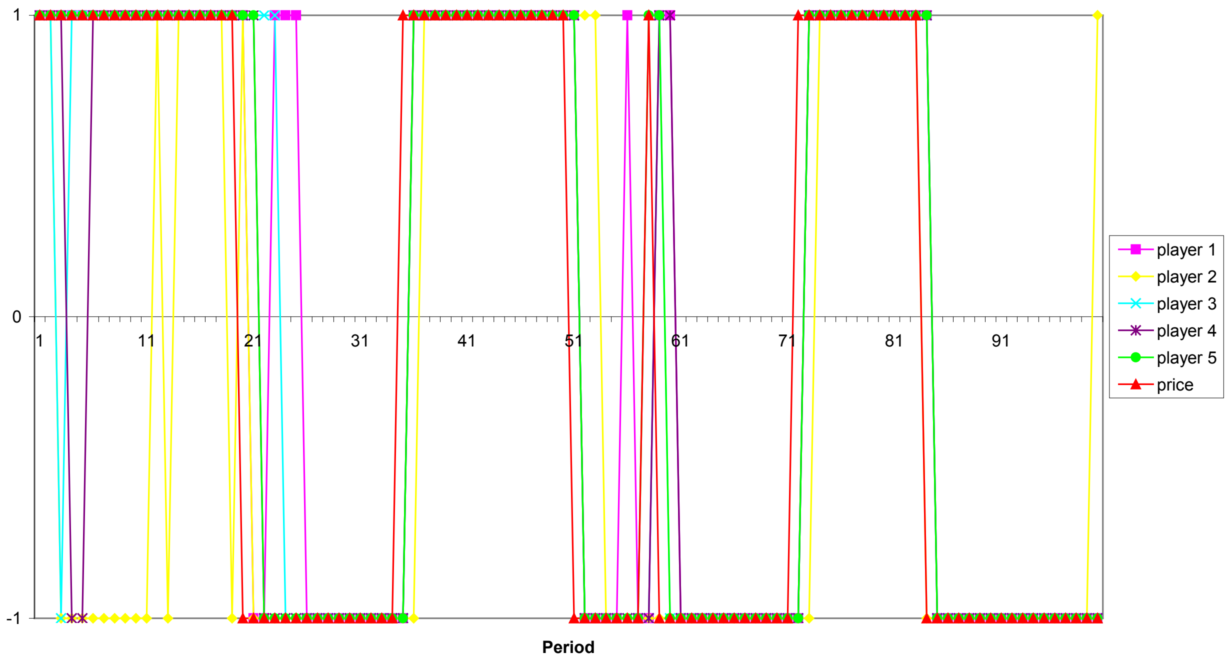
Group 2, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



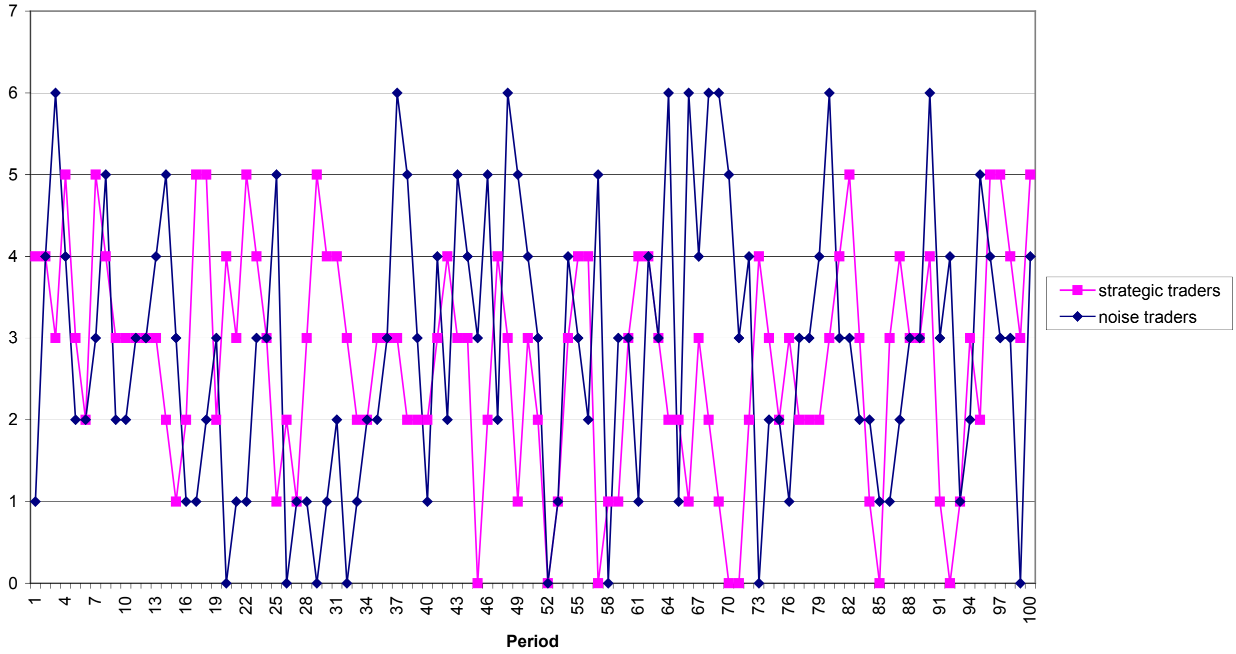
Group 2, Round 1: Price Change and Choices of Participants



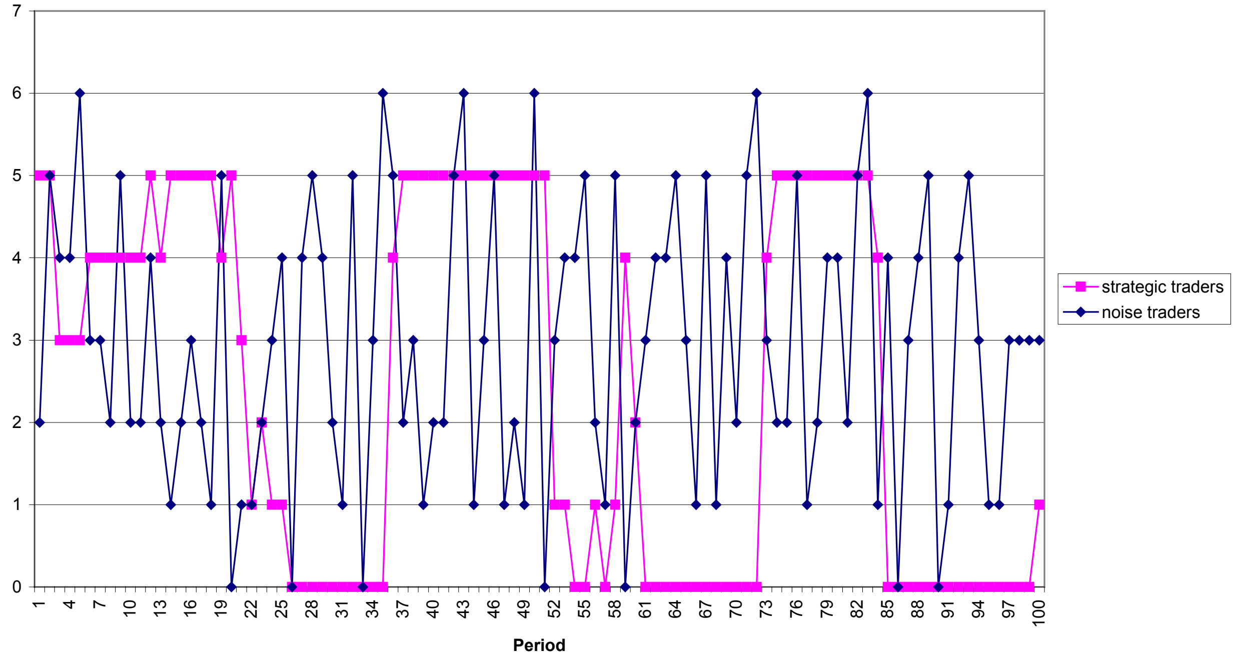
Group 2, Round 2: Price Change and Choices of Participants



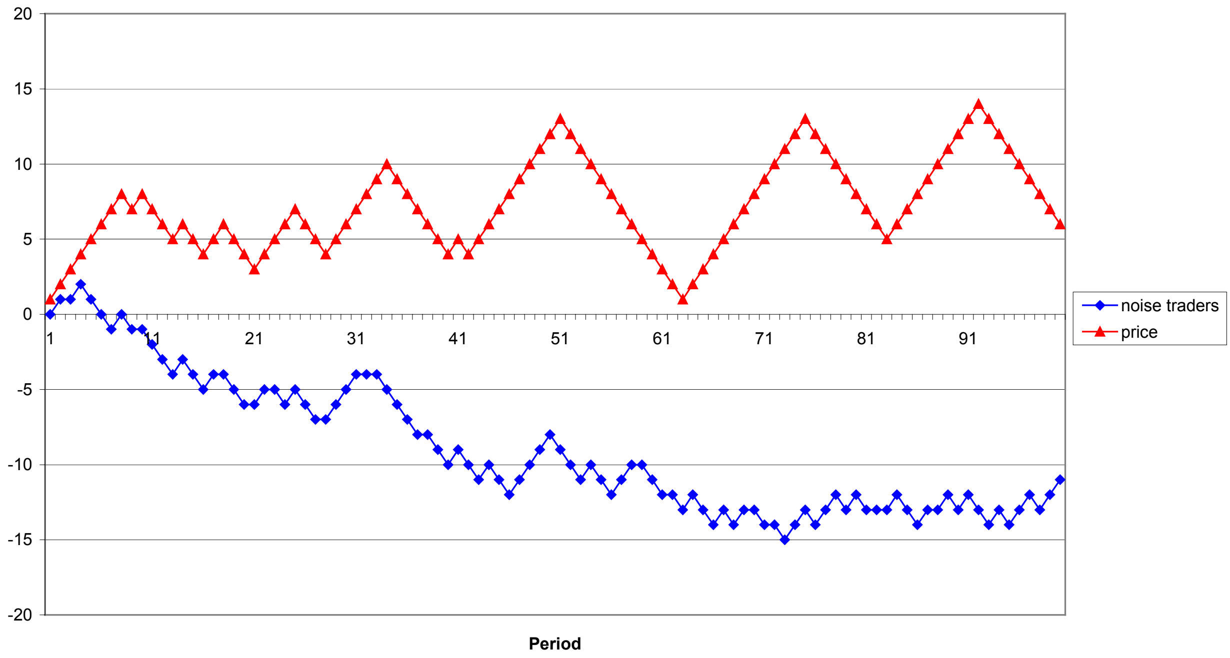
Group 2, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



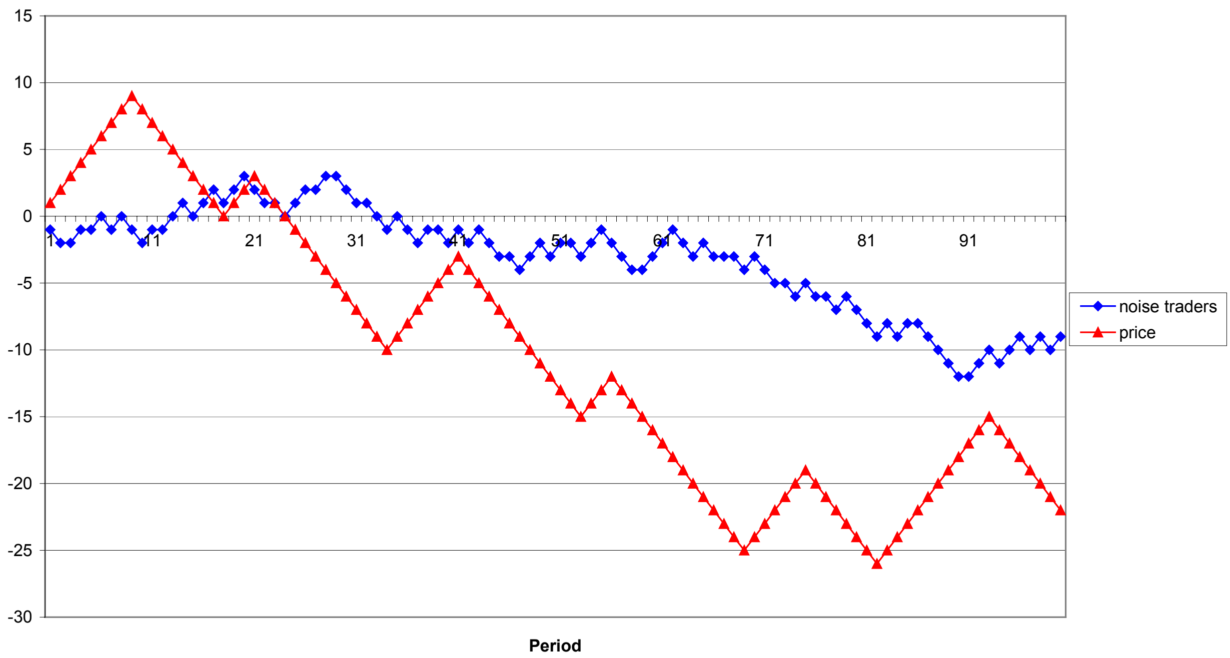
Group 2, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



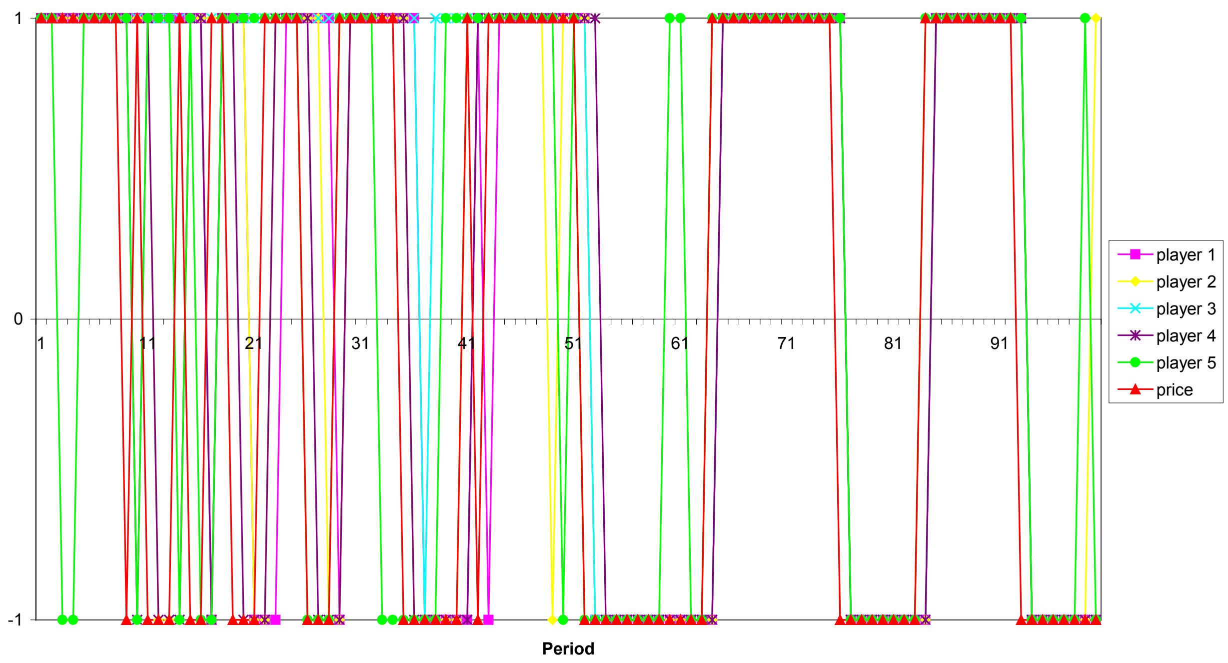
Group 3, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



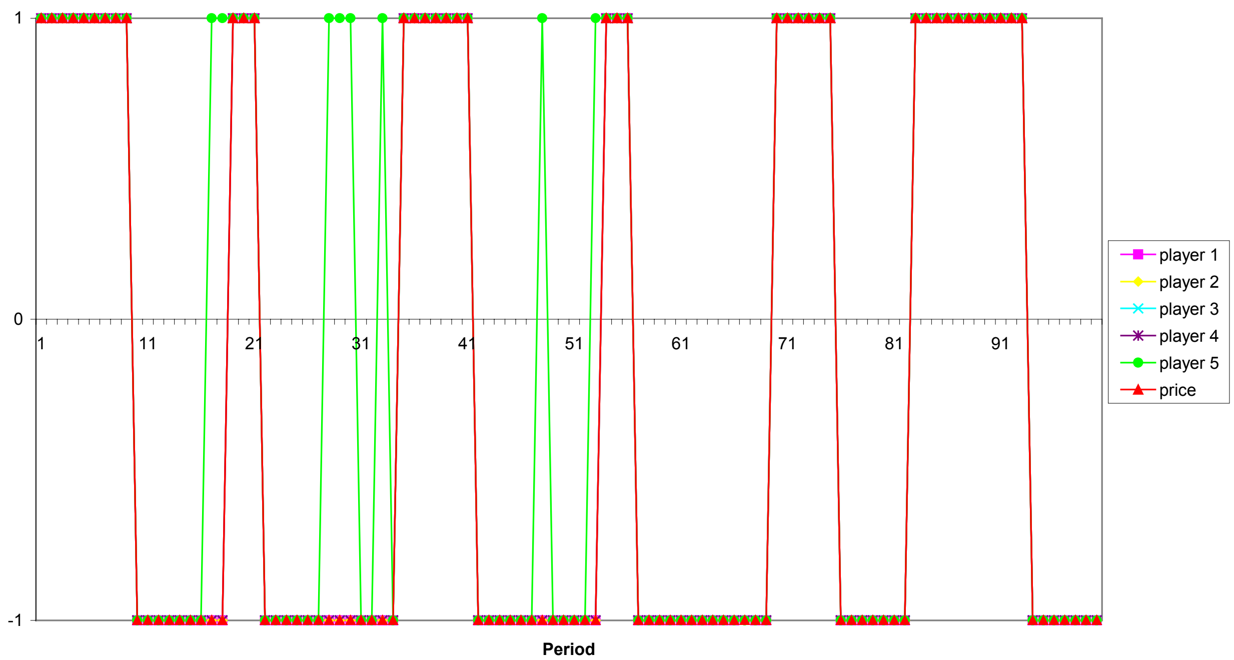
Group 3, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



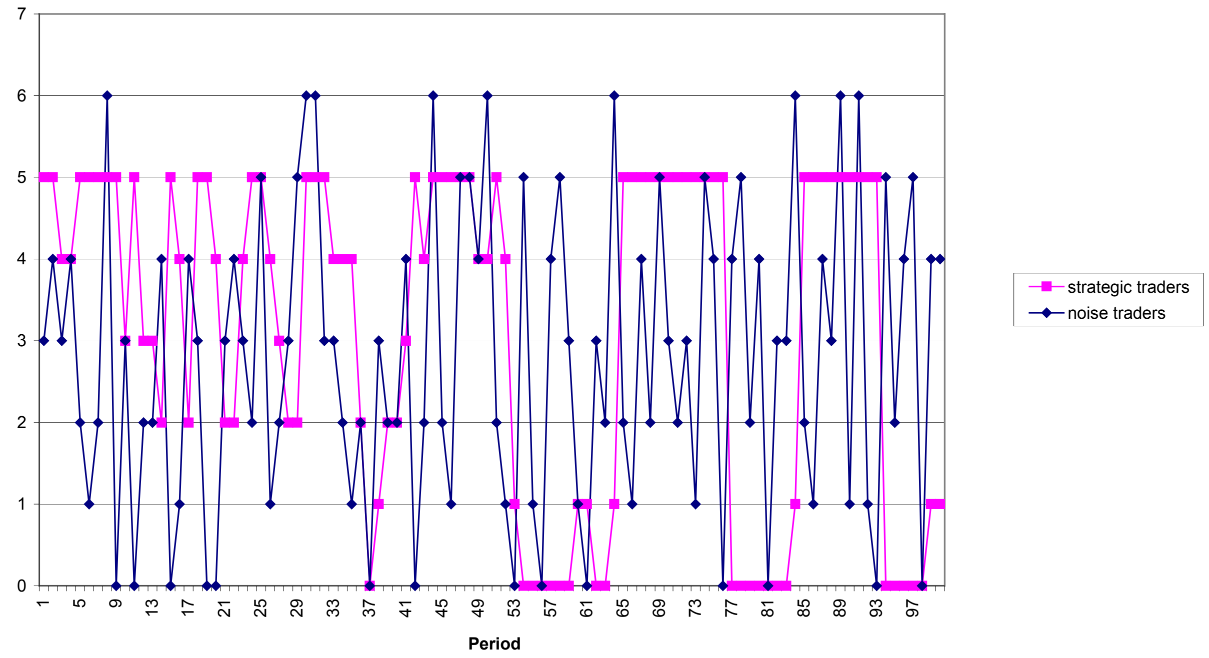
Group 3, Round 1: Price Change and Choices of Participants



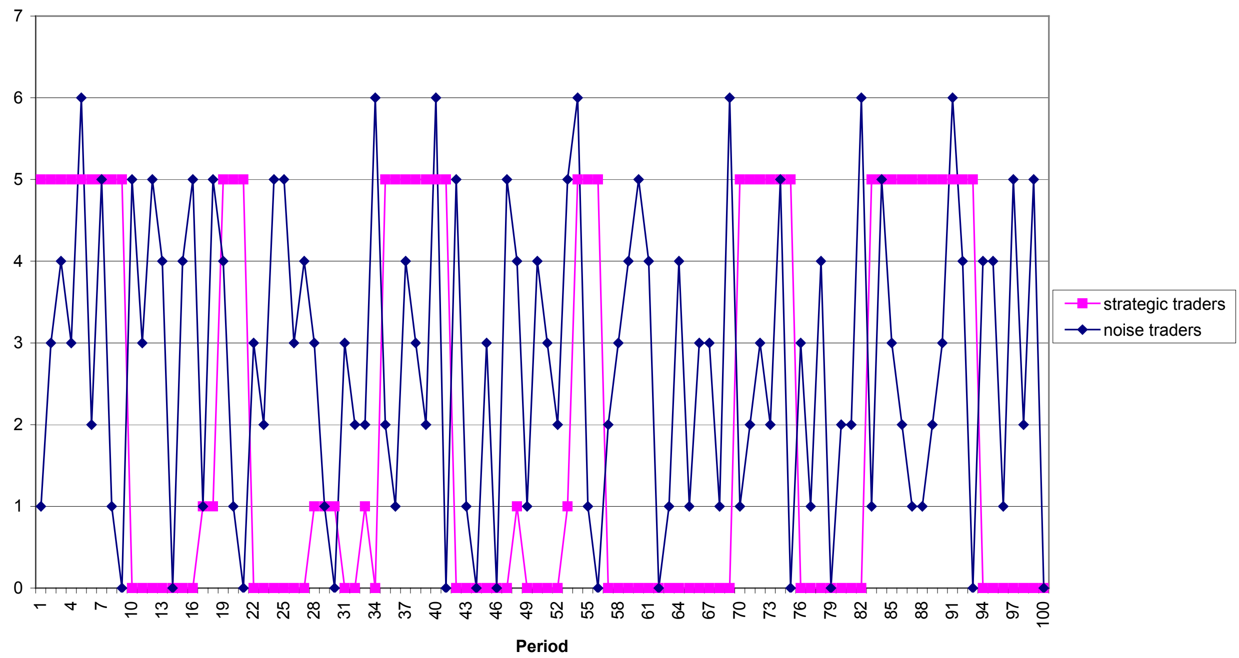
Group 3, Round 2: Price Change and Choices of Participants



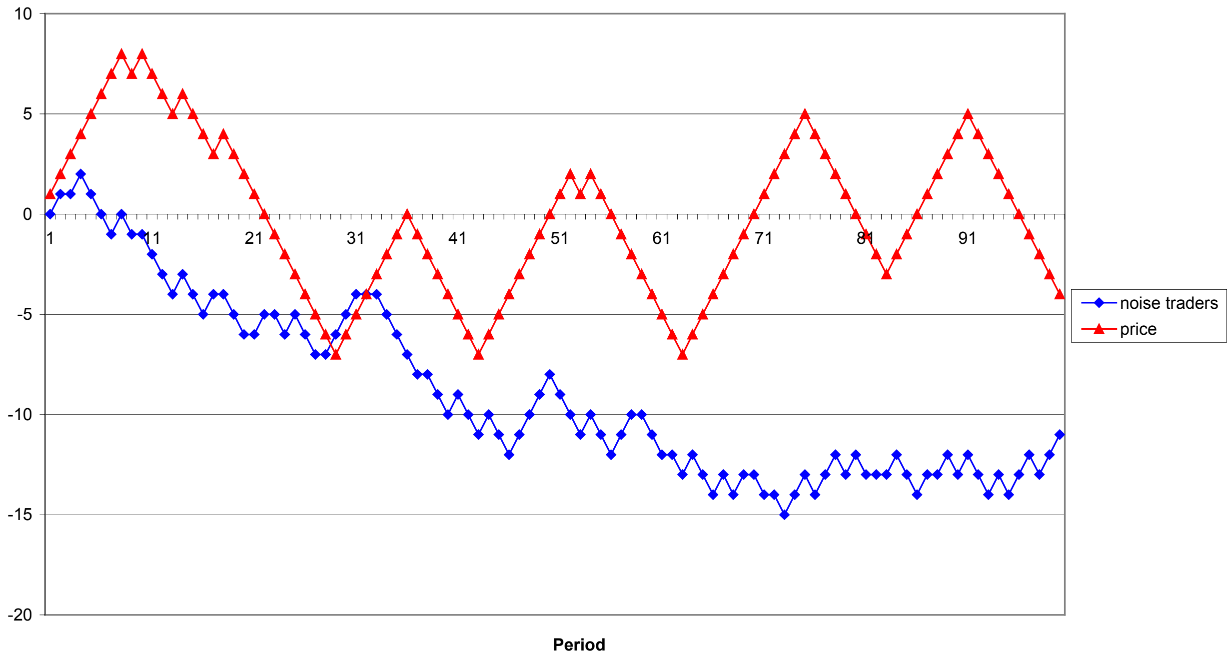
Group 3, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



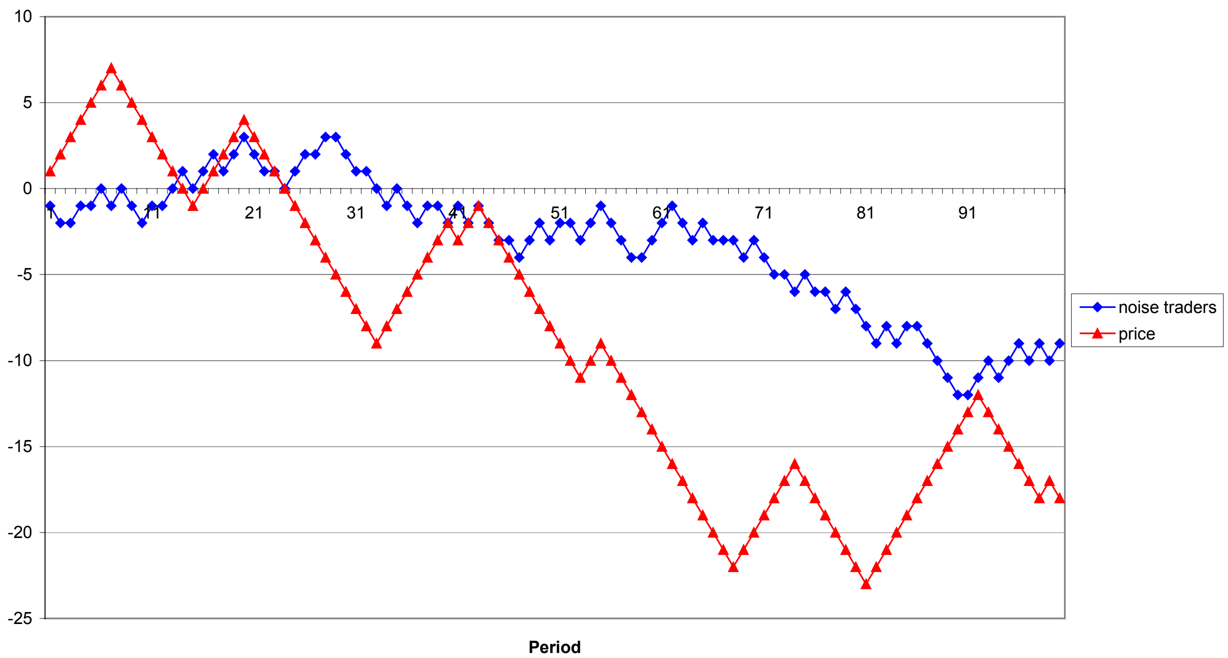
Group 3, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



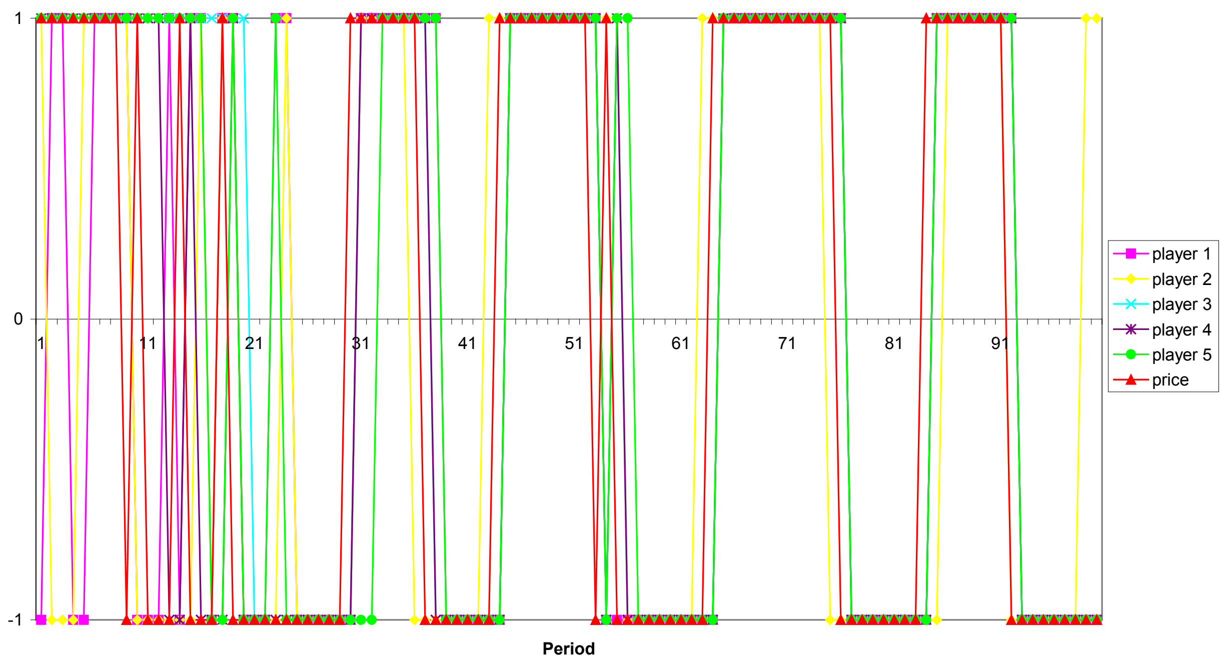
Group 4, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



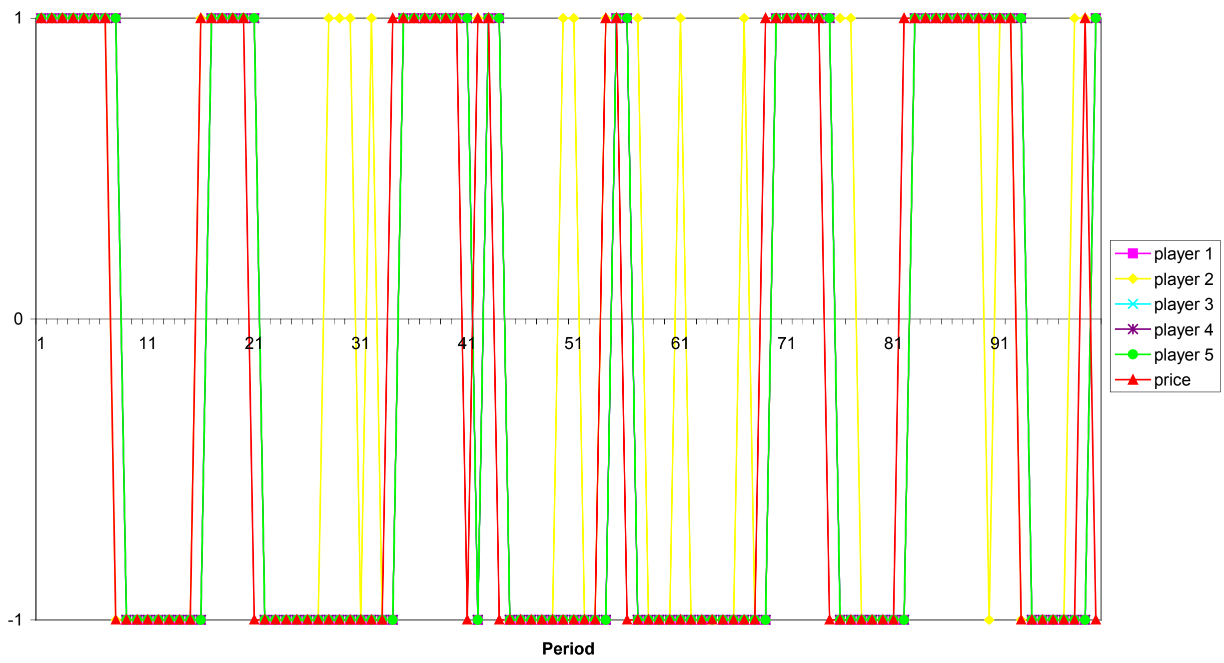
Group 4, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



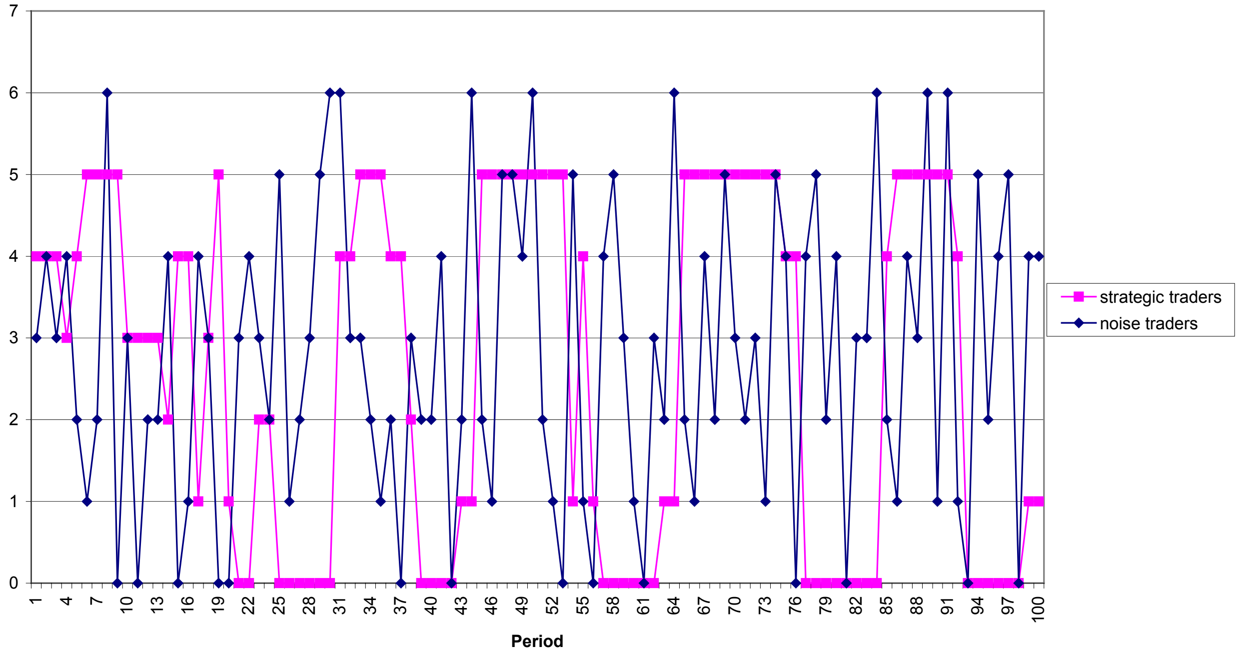
Group 4, Round 1: Price Change and Choices of Participants



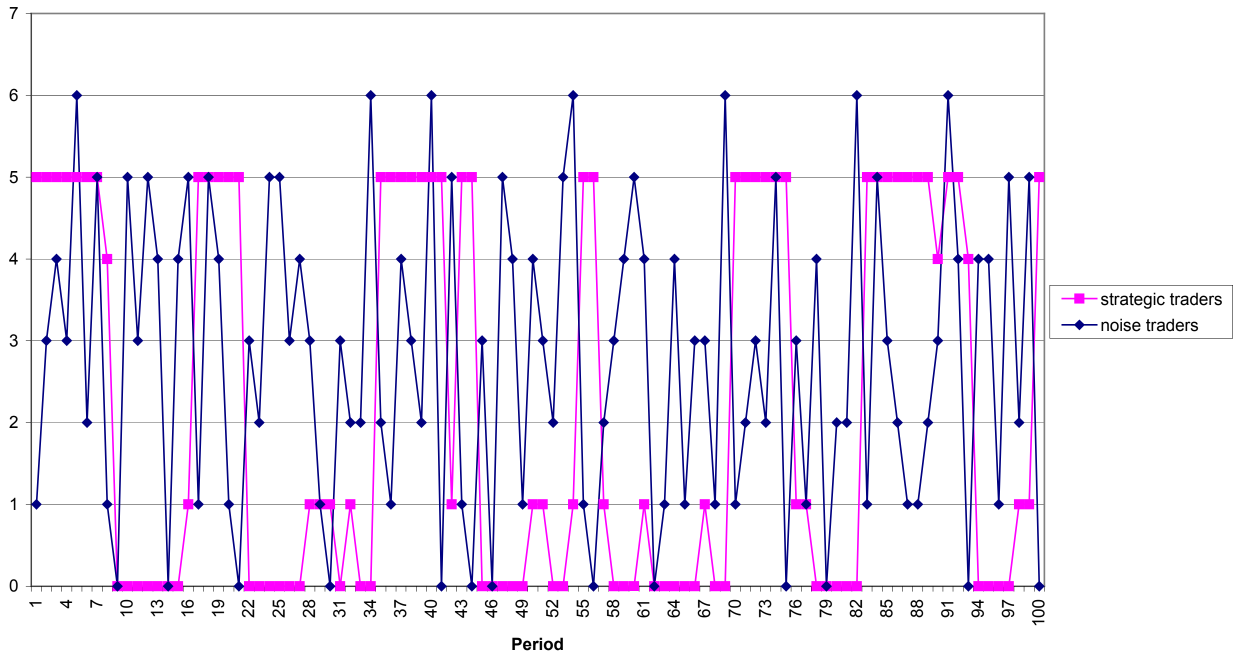
Group 4, Round 2: Price Change and Choices of Participants



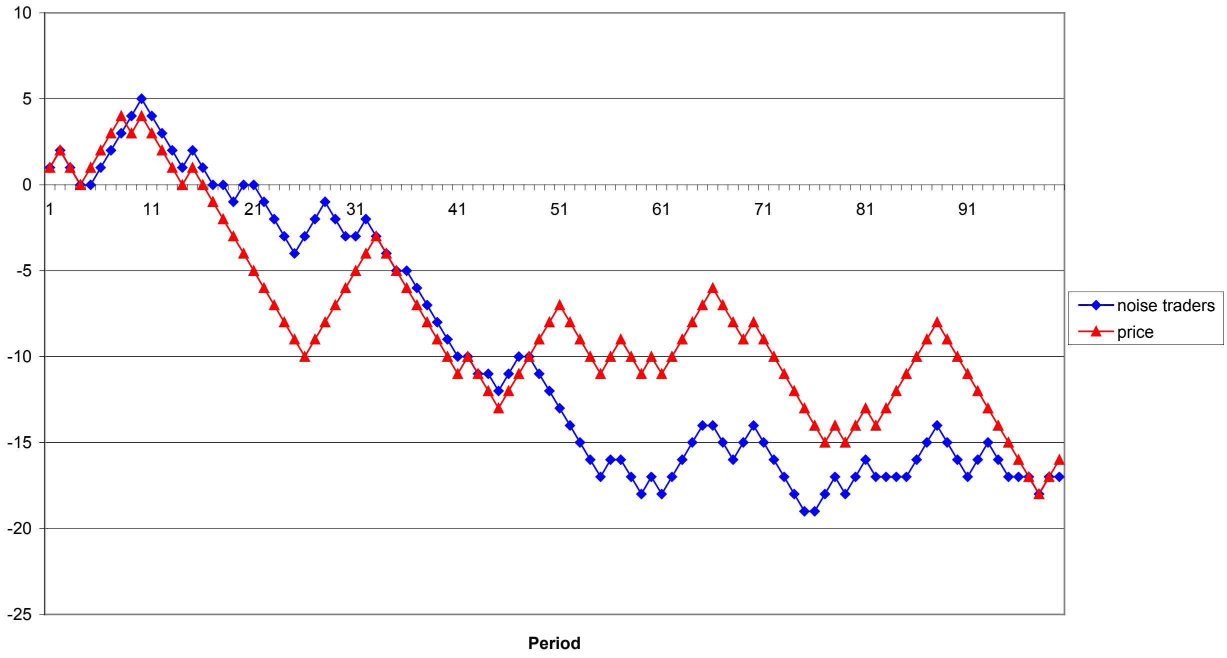
Group 4, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



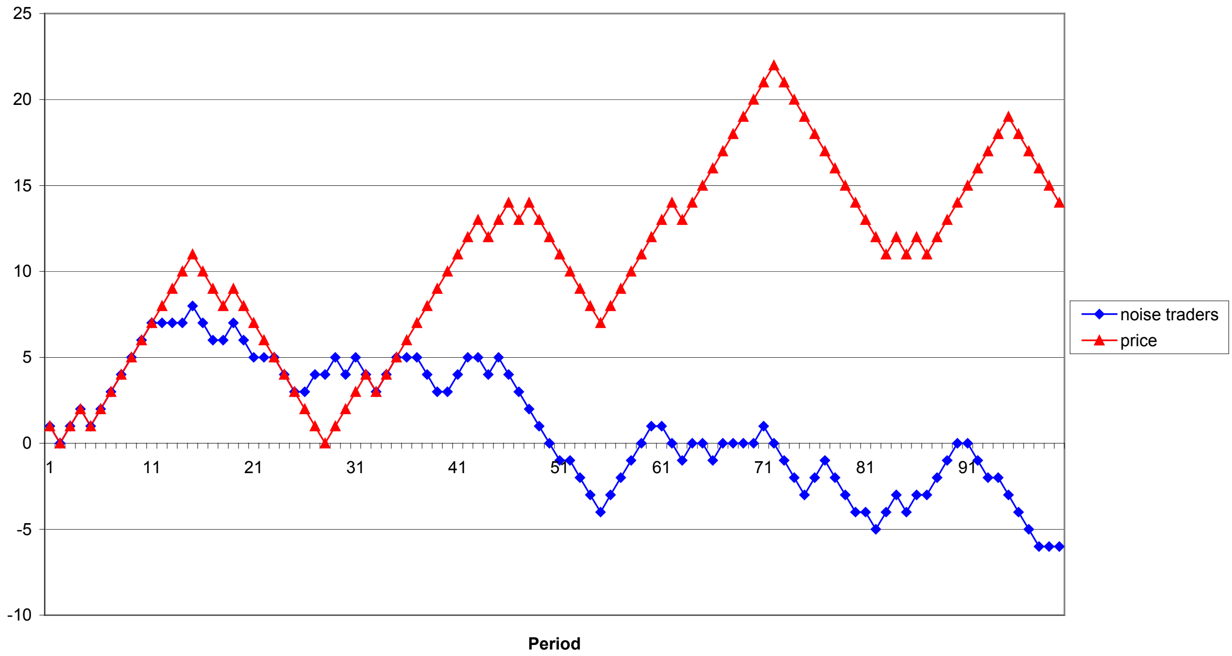
Group 4, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



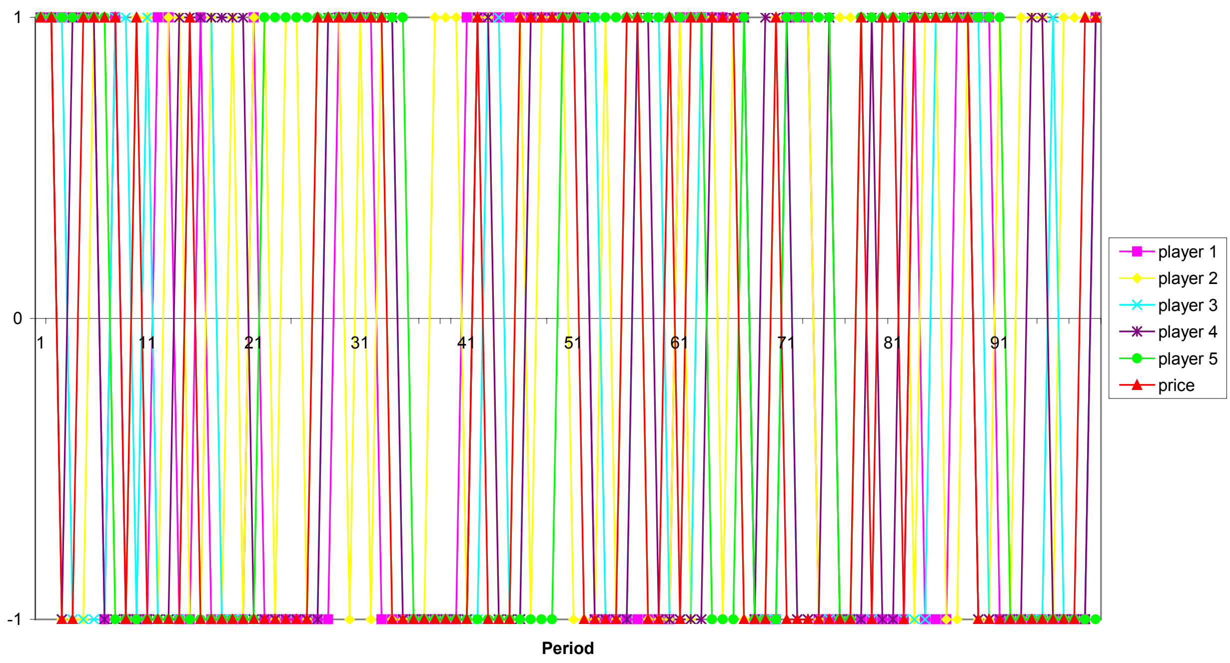
Group 5, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



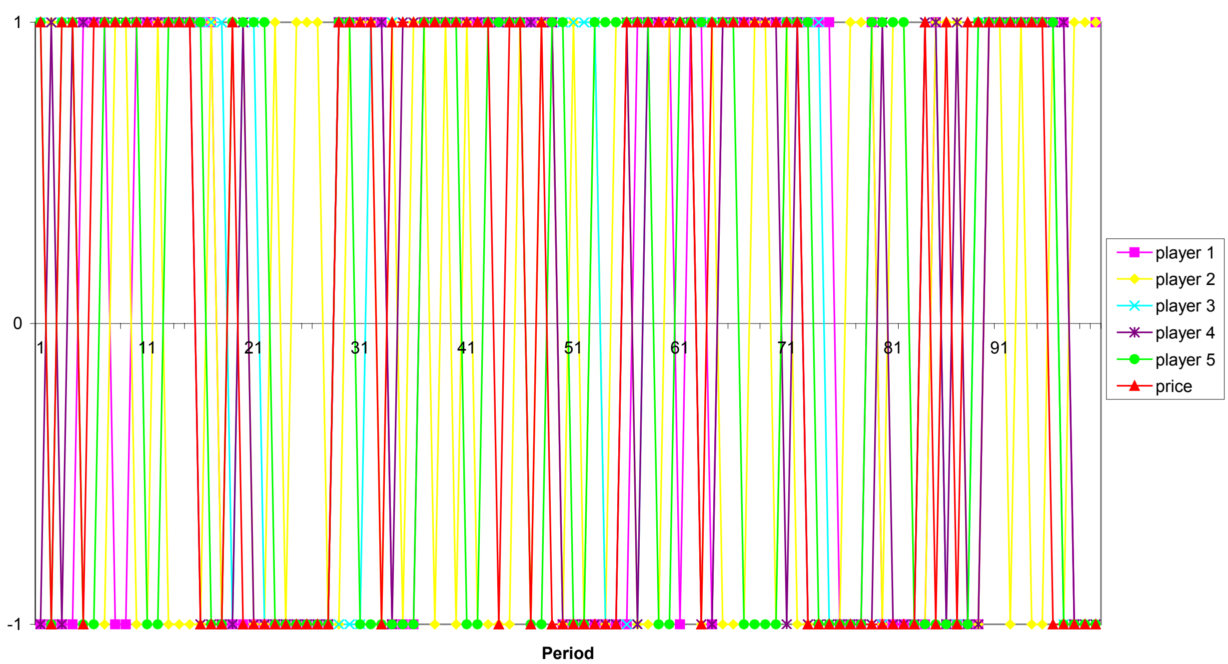
Group 5, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



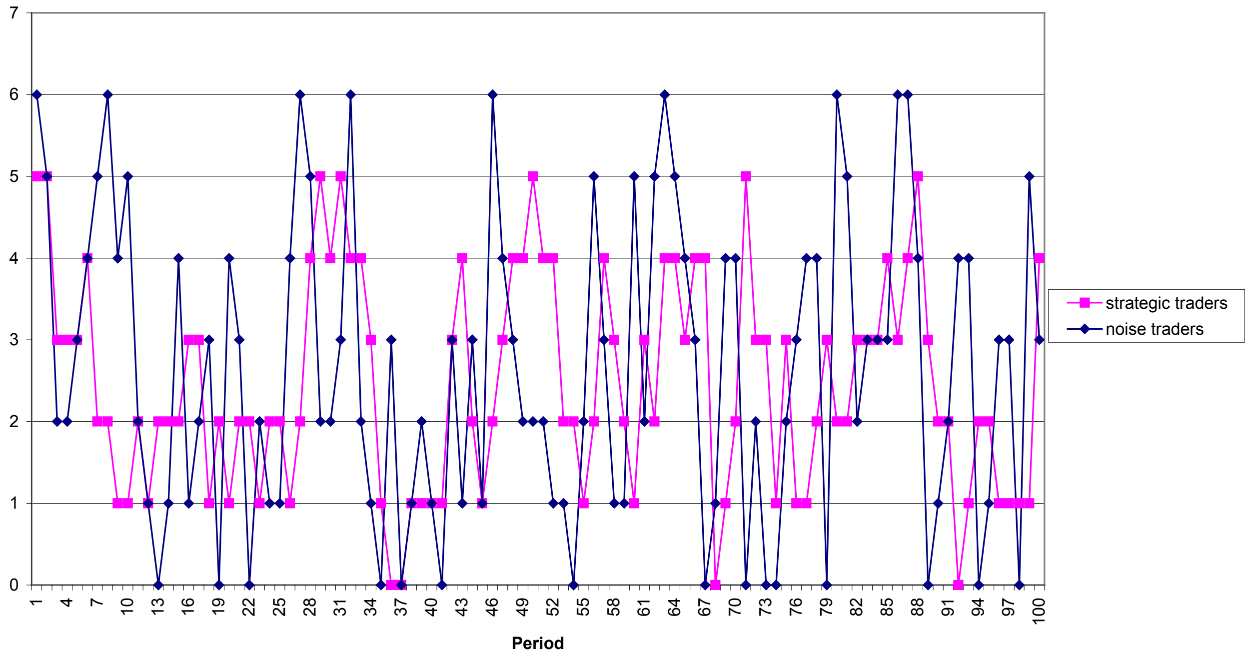
Group 5, Round 1: Price Change and Choices of Participants



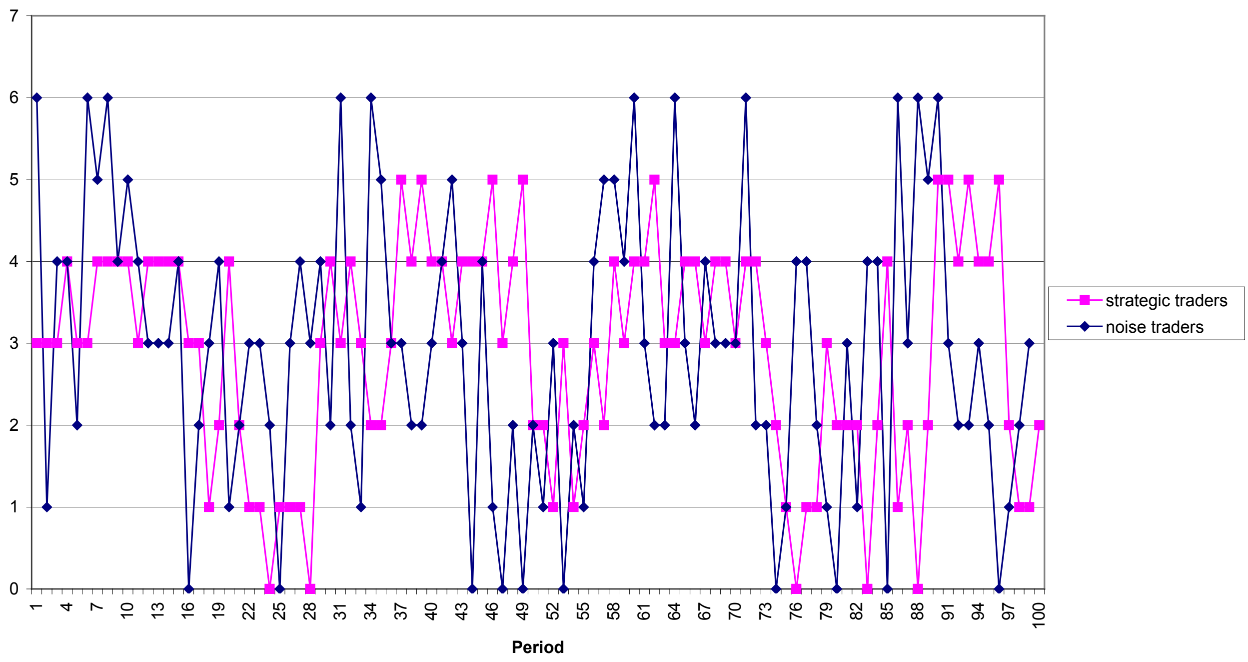
Group 5, Round 2: Price Change and Choices of Participants



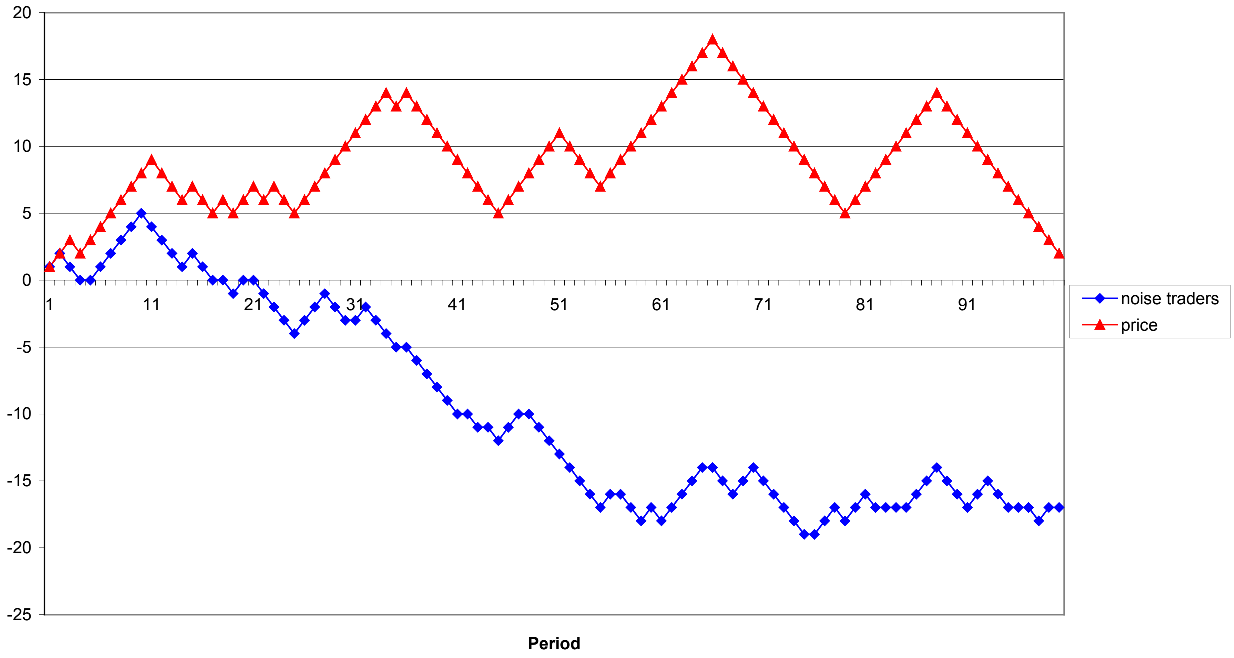
Group 5, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



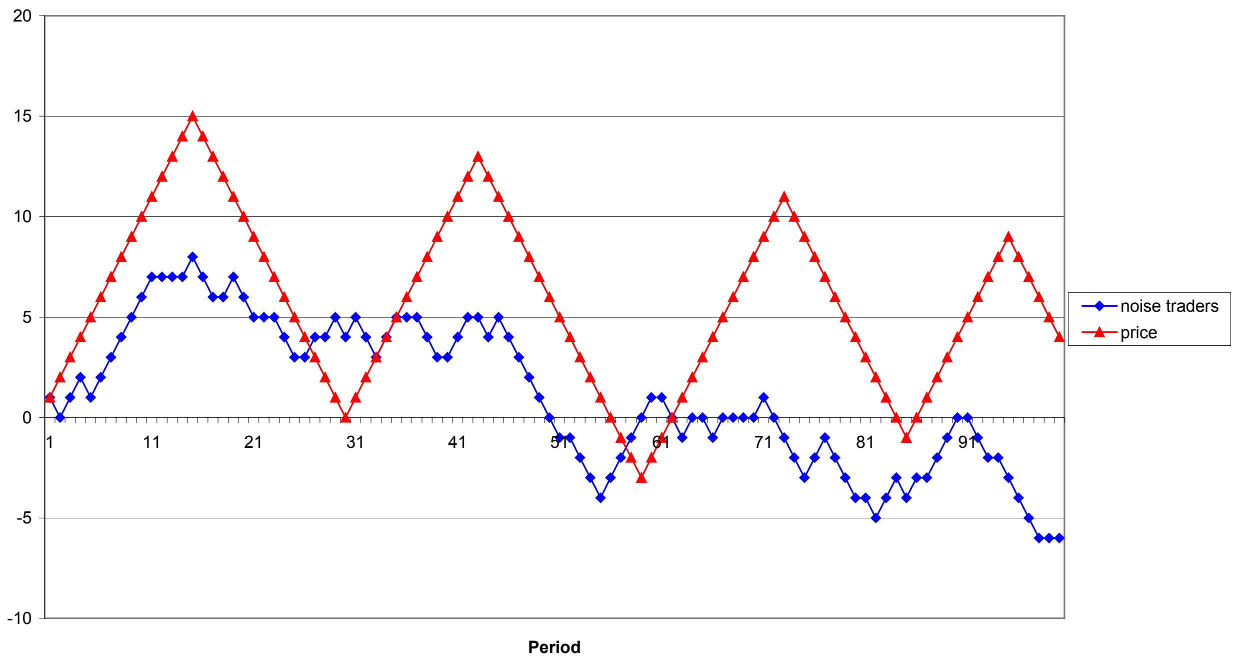
Group 5, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



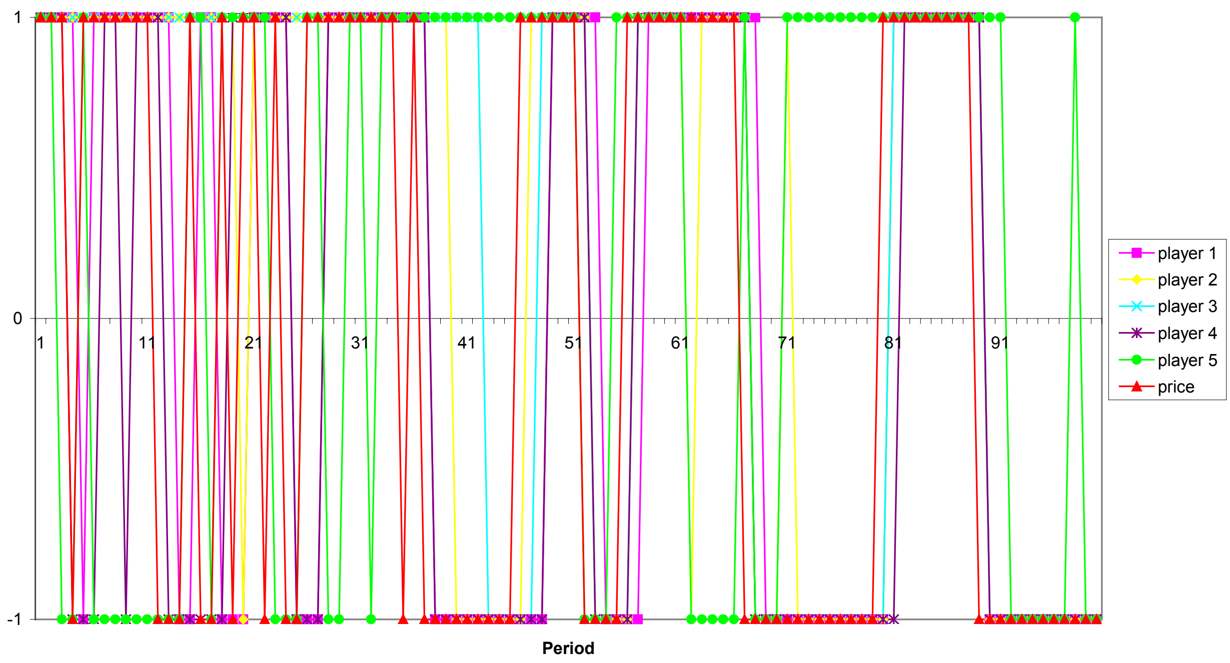
Group 6, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



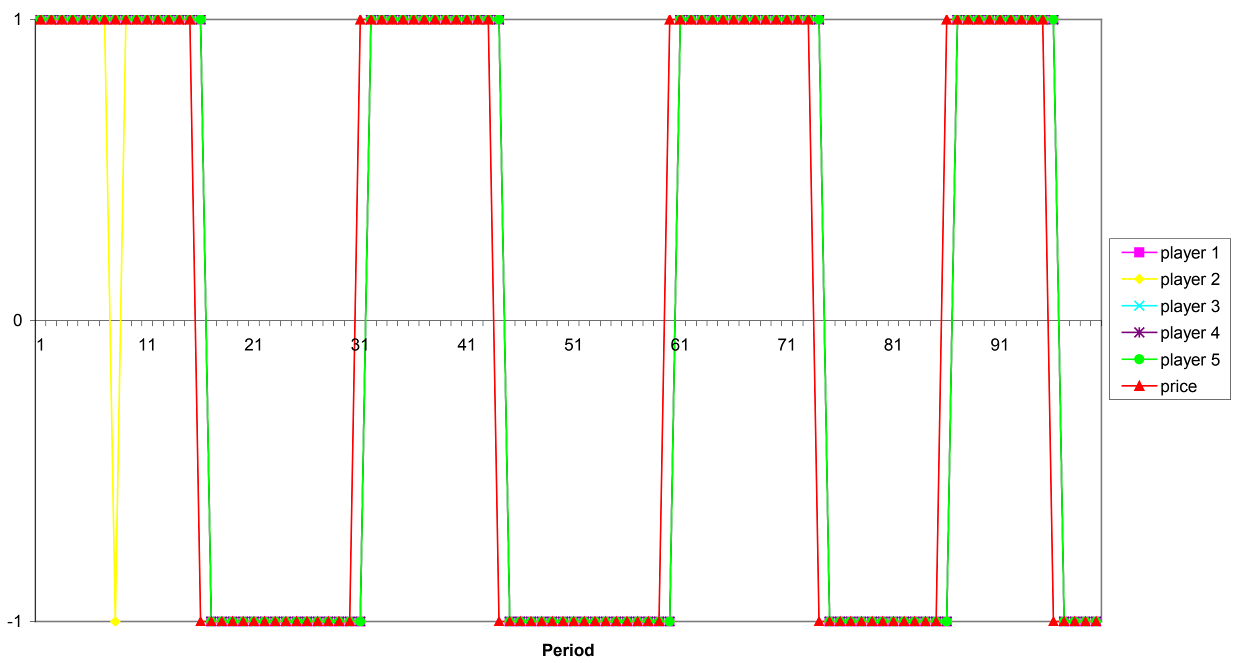
Group 6, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



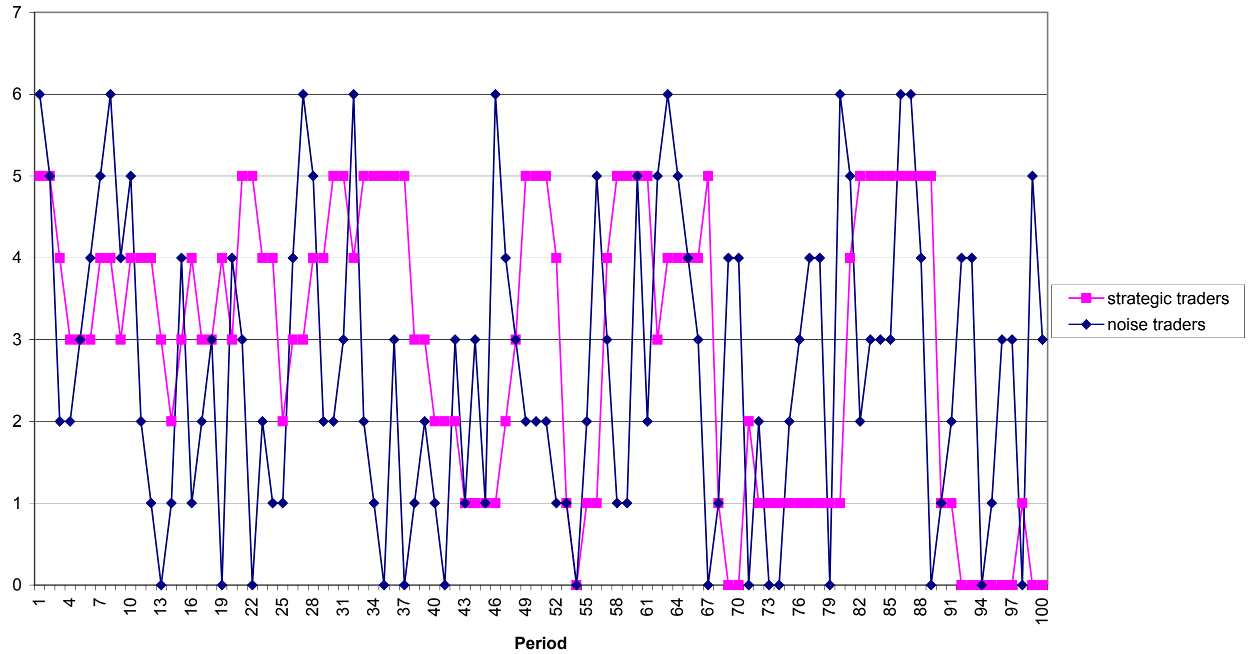
Group 6, Round 1: Price Change and Choices of Participants



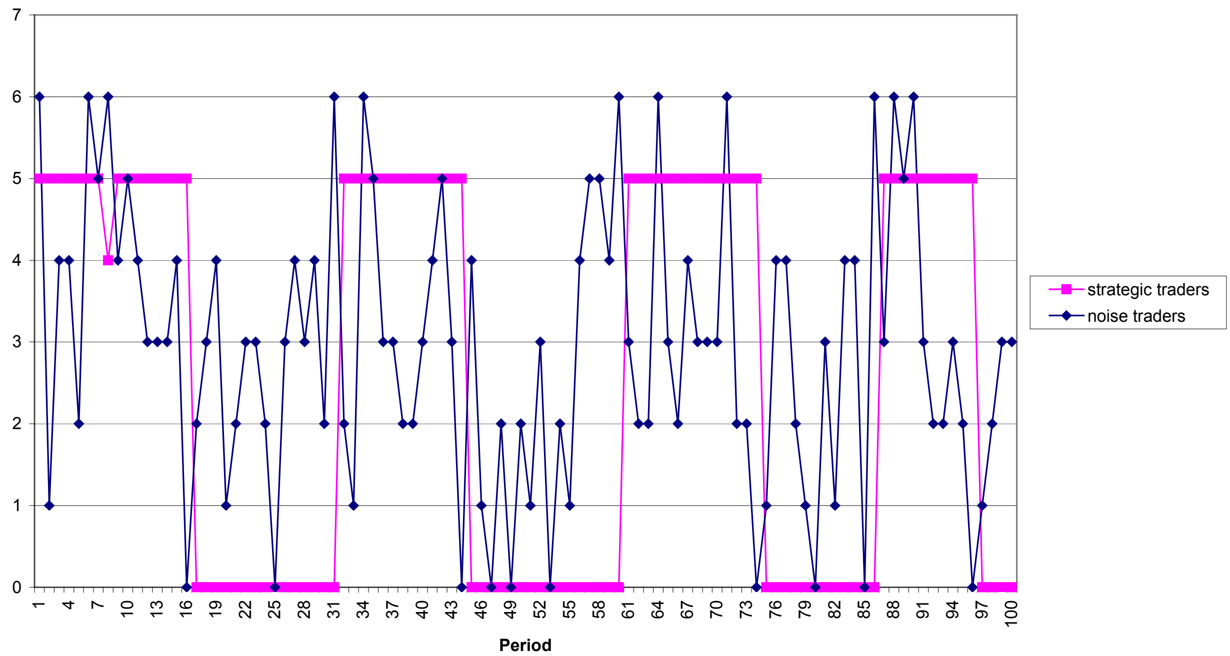
Group 6, Round 2: Price Change and Choices of Participants



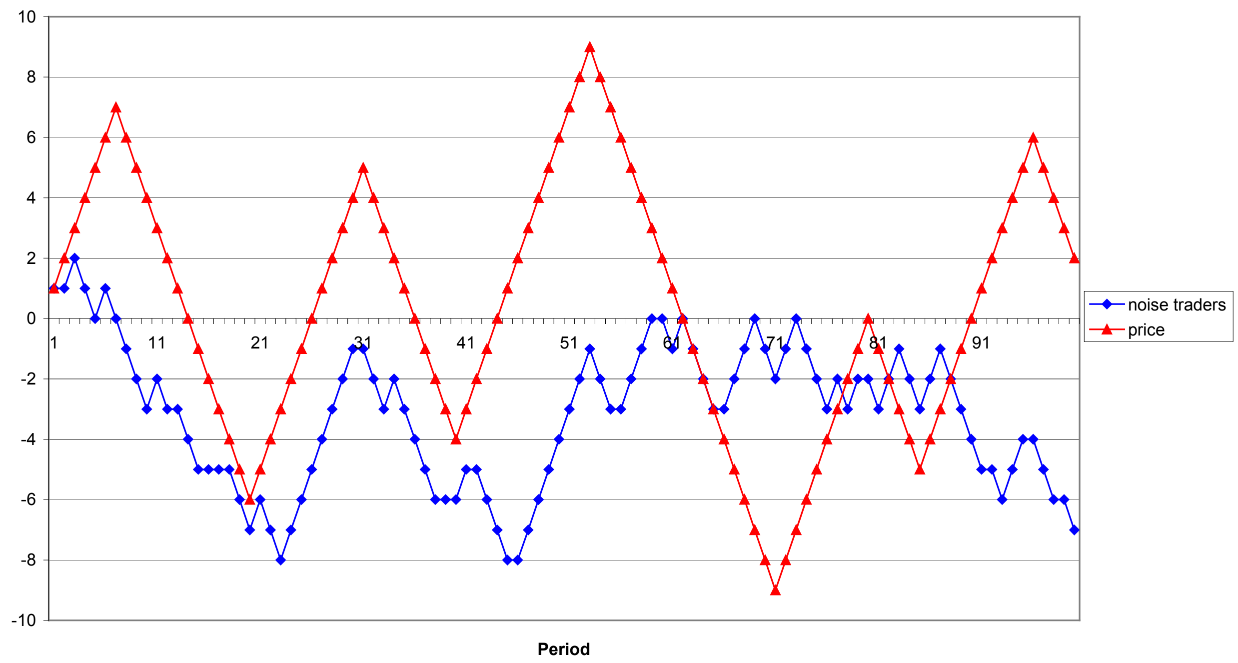
Group 6, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



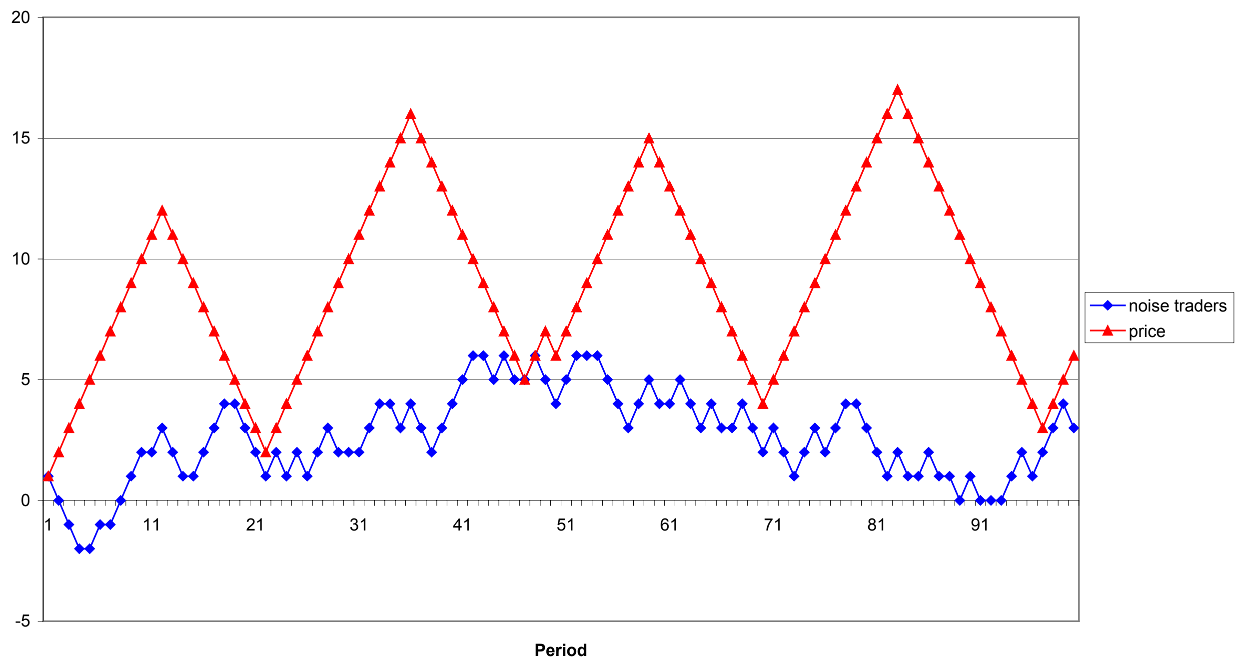
Group 6, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



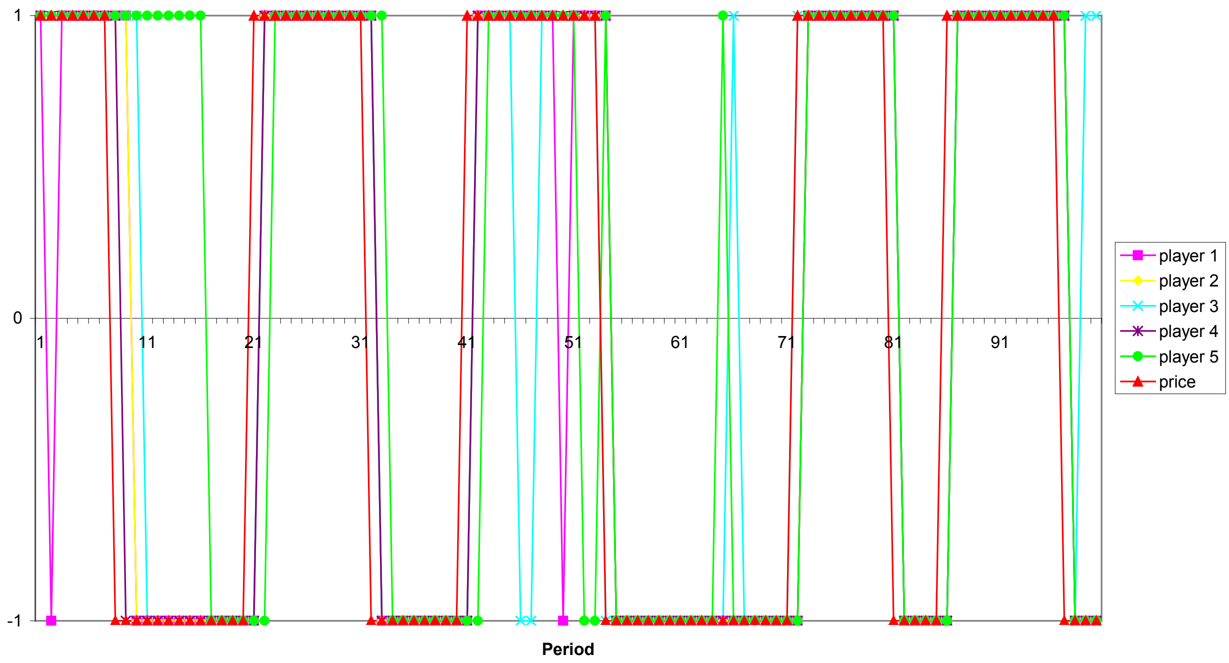
Group 7, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



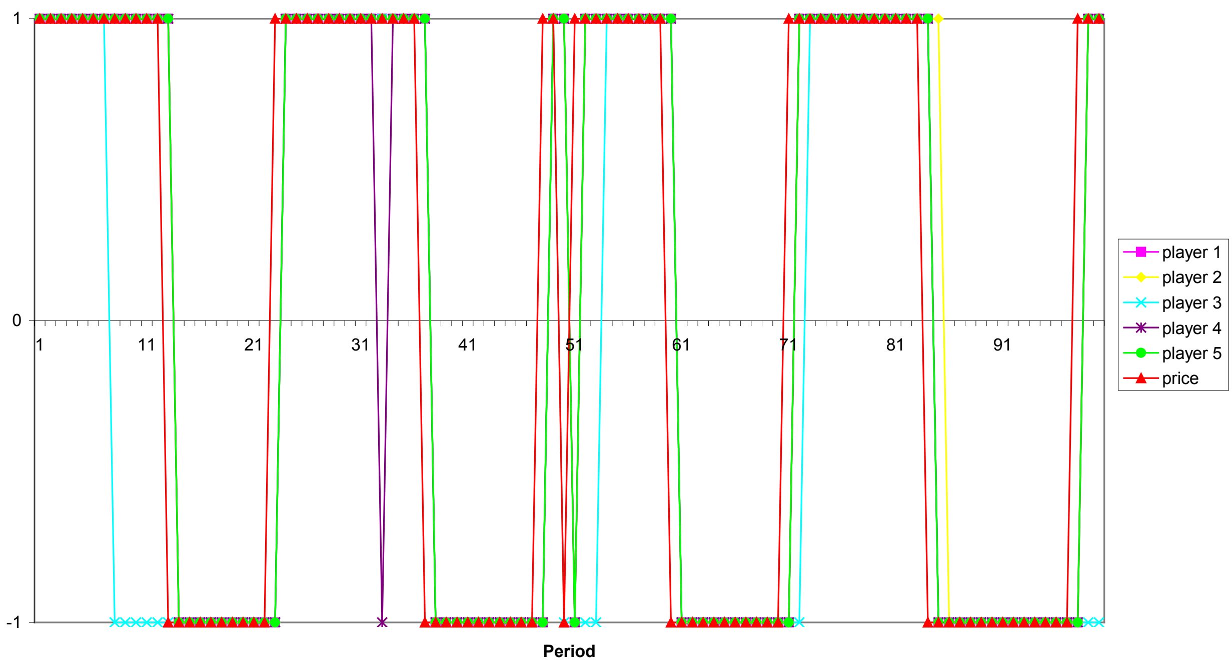
Group 7, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



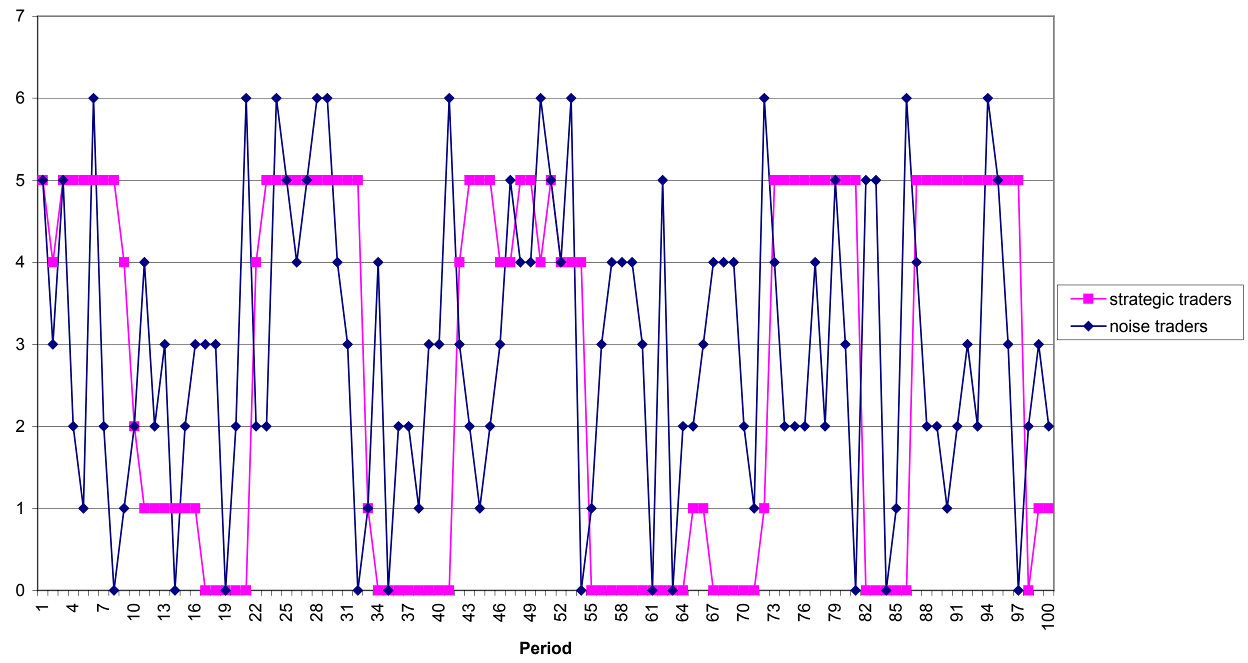
Group 7, Round 1: Price Change and Choices of Participants



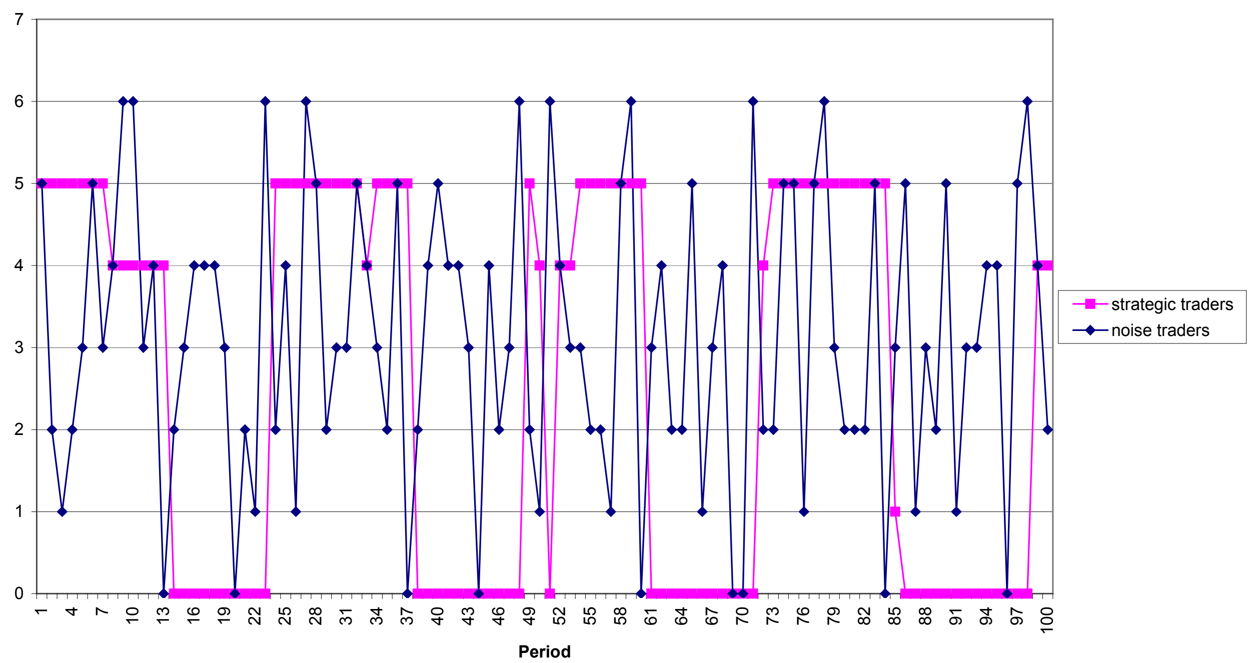
Group 7, Round 2: Price Change and Choices of Participants



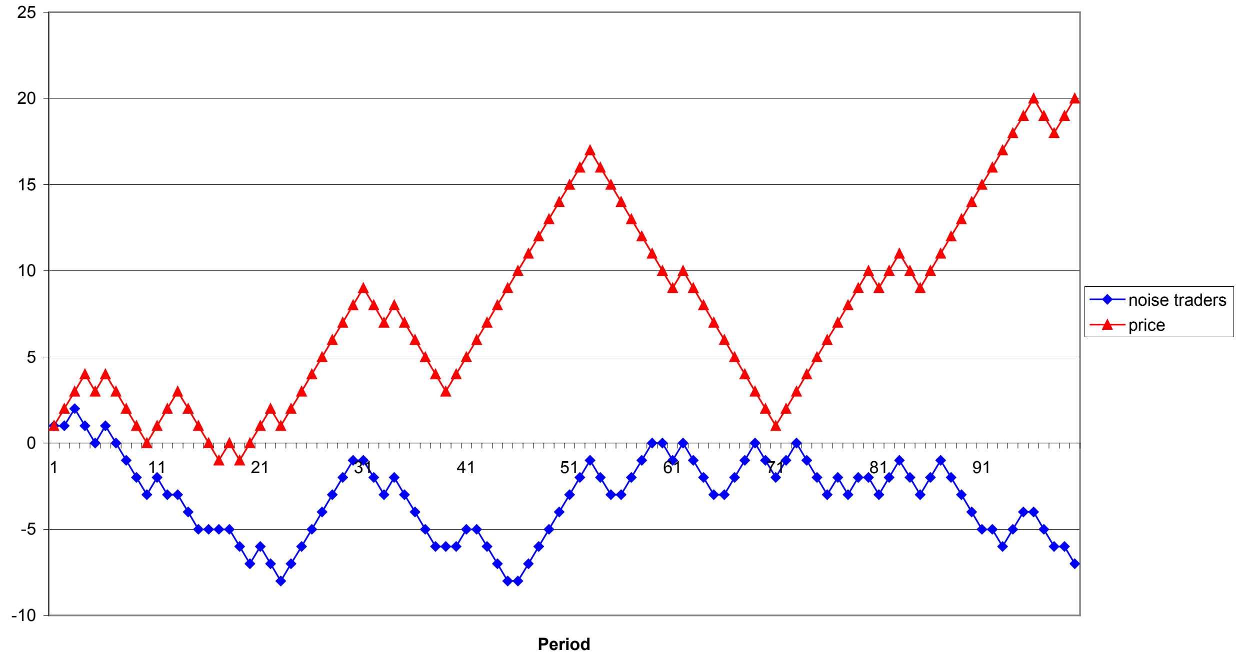
Group 7, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



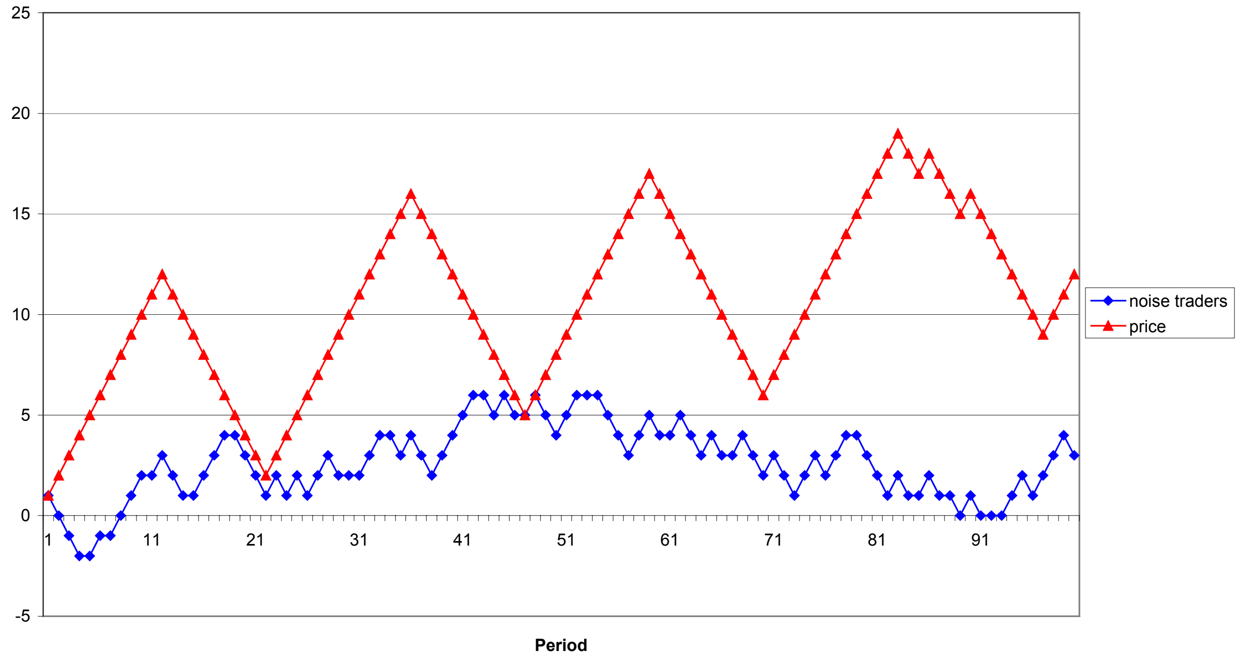
Group 7, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



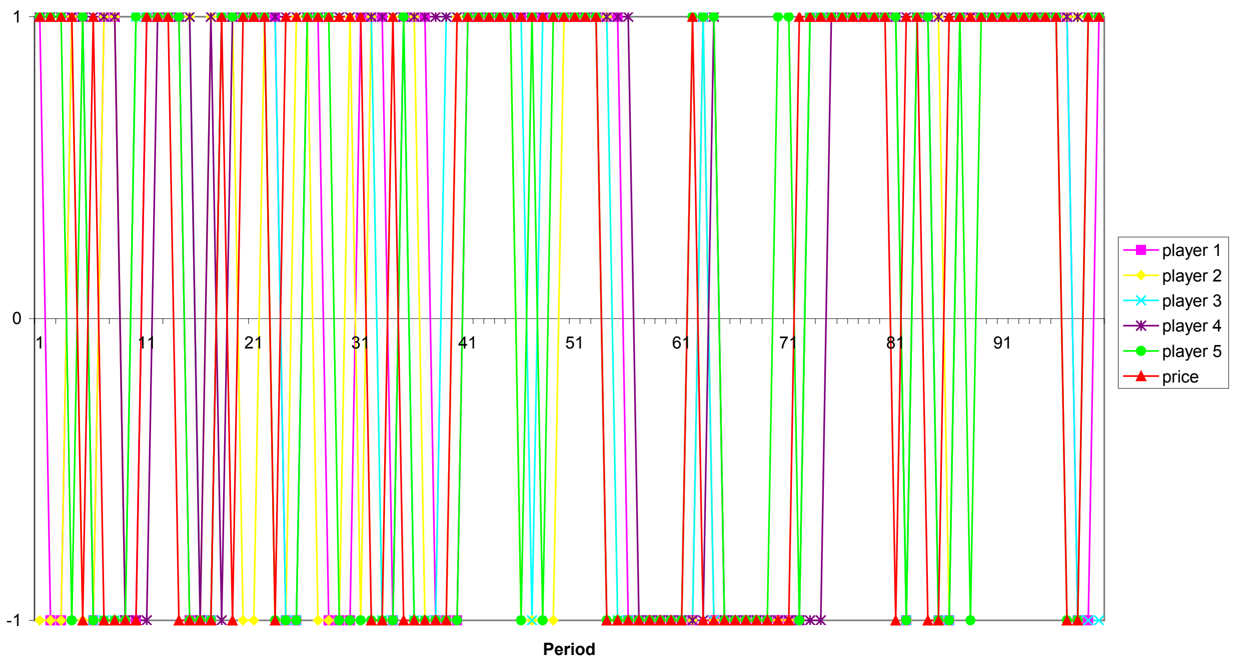
Group 8, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



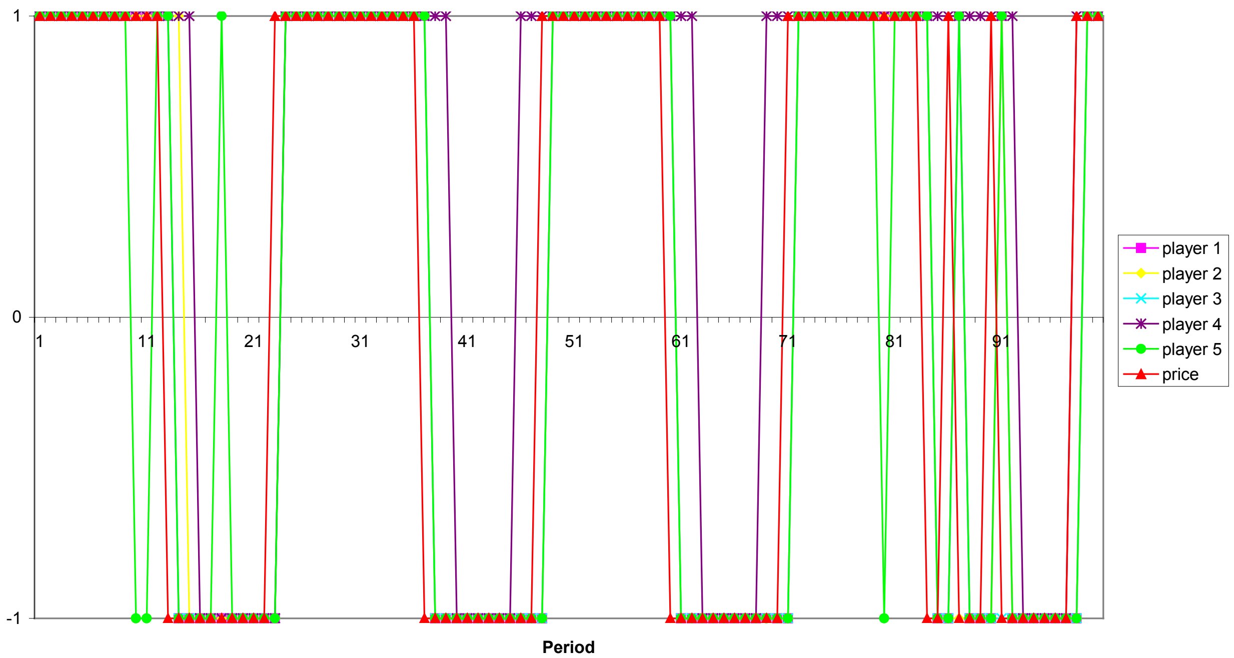
Group 8, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



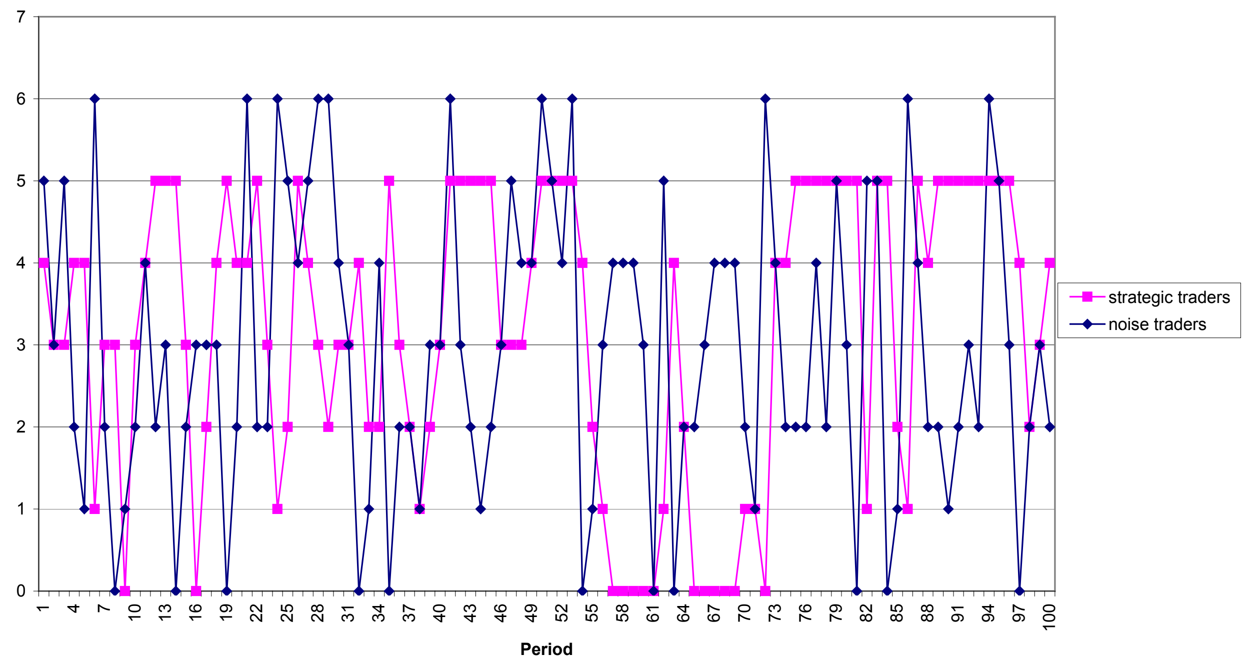
Group 8, Round 1: Price Change and Choices of Participants



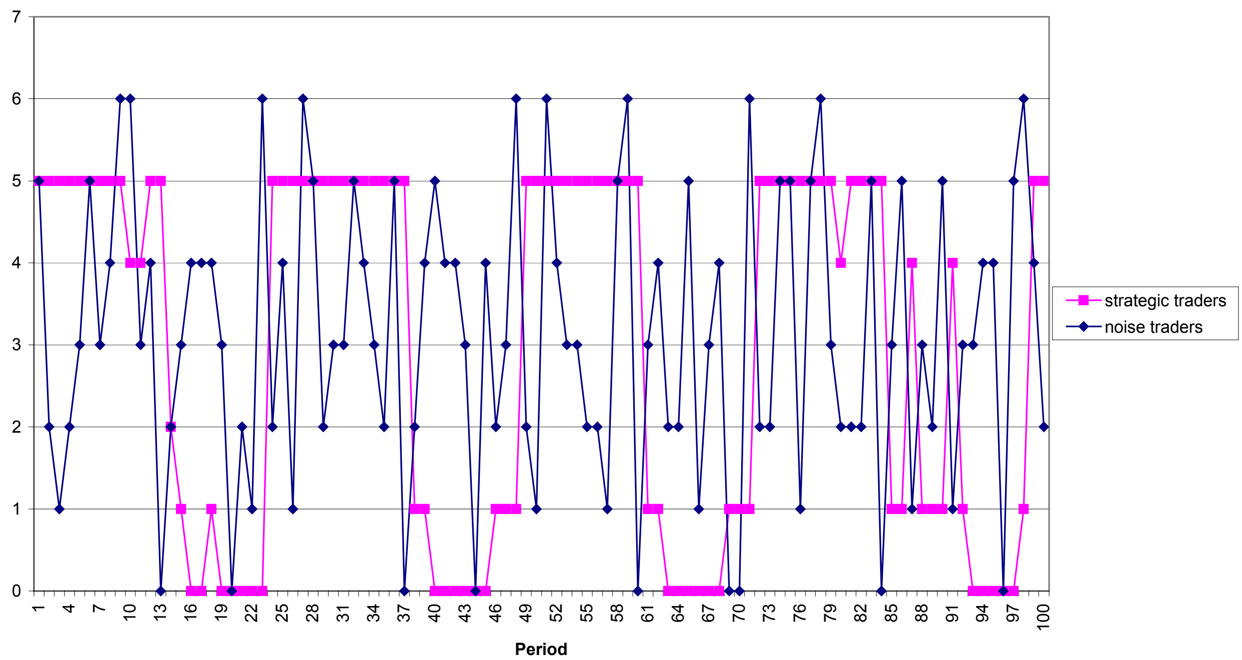
Group 8, Round 2: Price Change and Choices of Participants



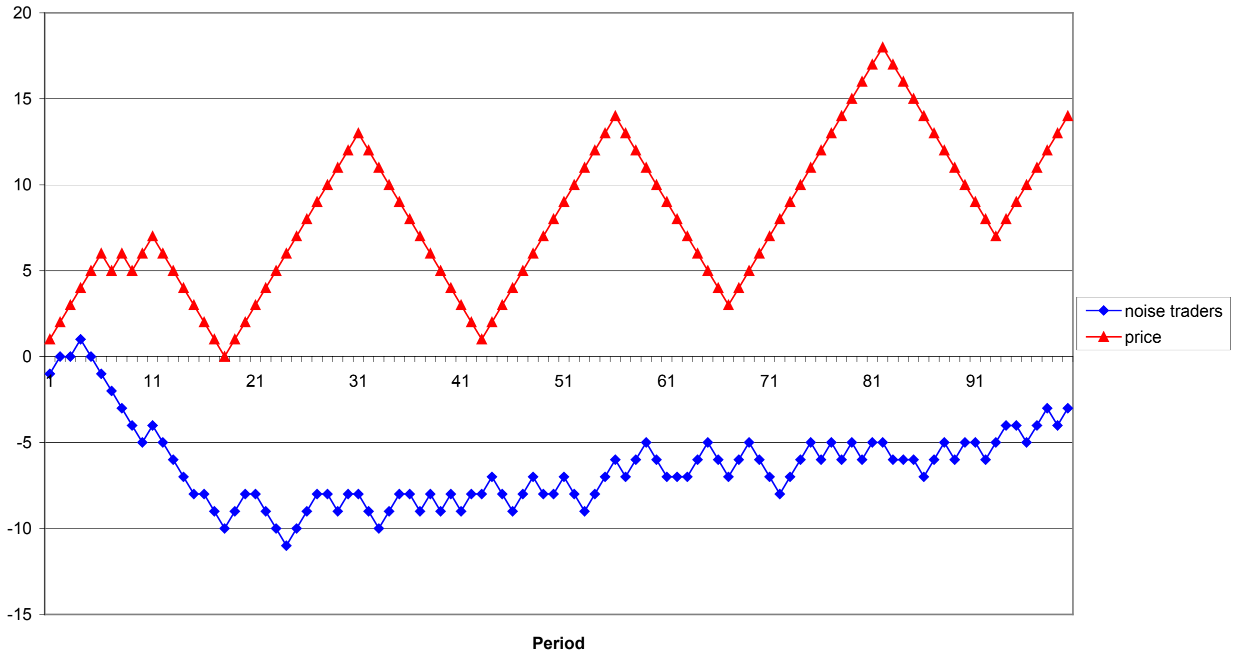
Group 8, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



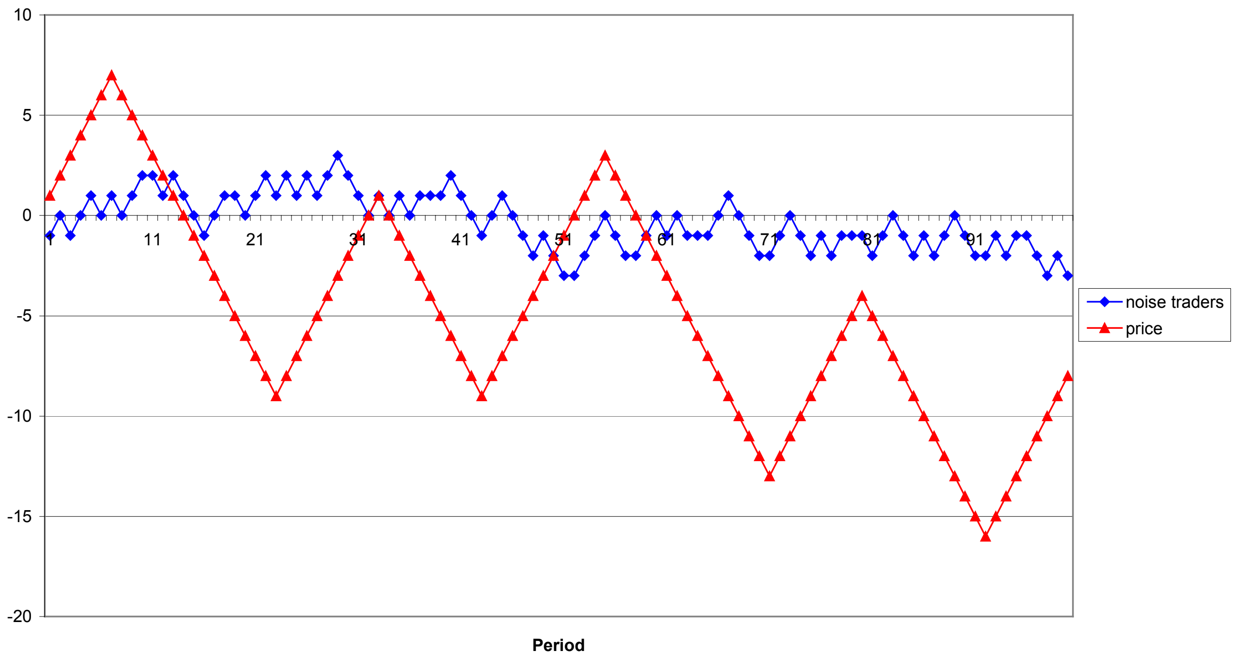
Group 8, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



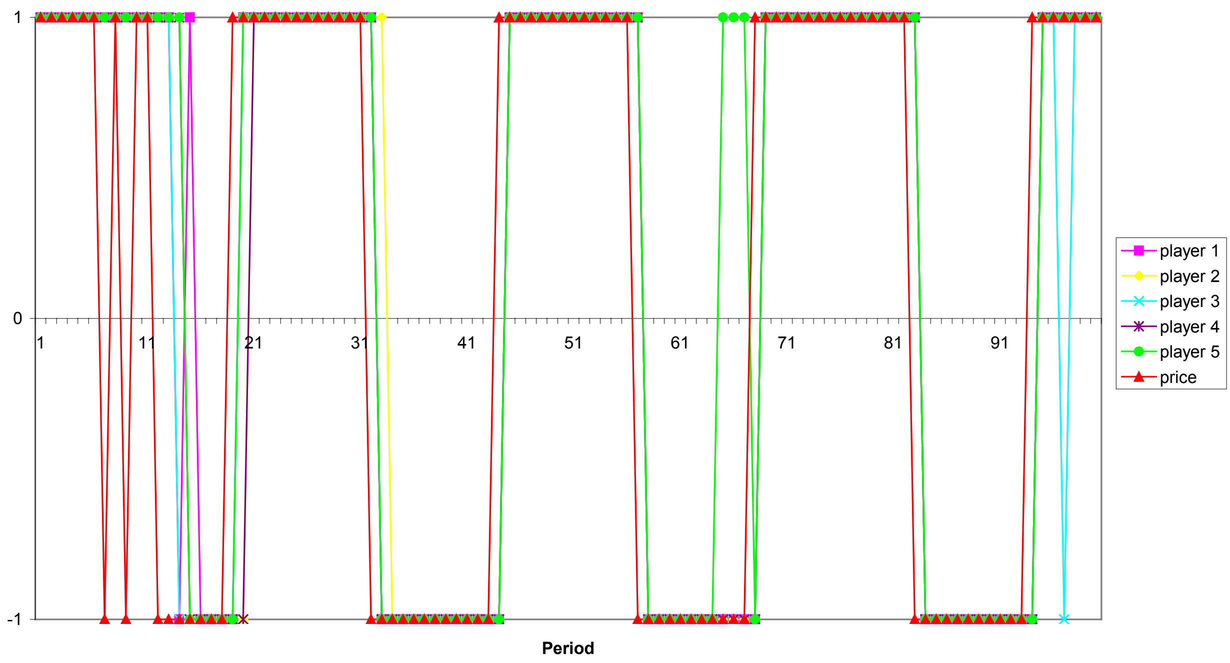
Group 9, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



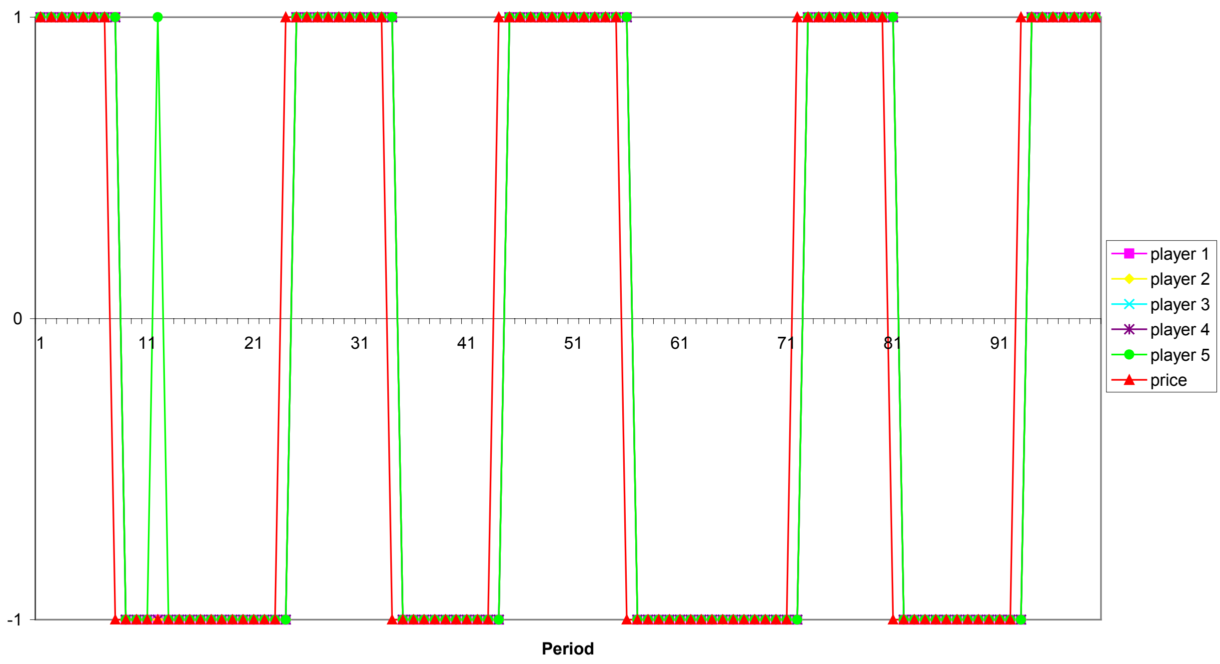
Group 9, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



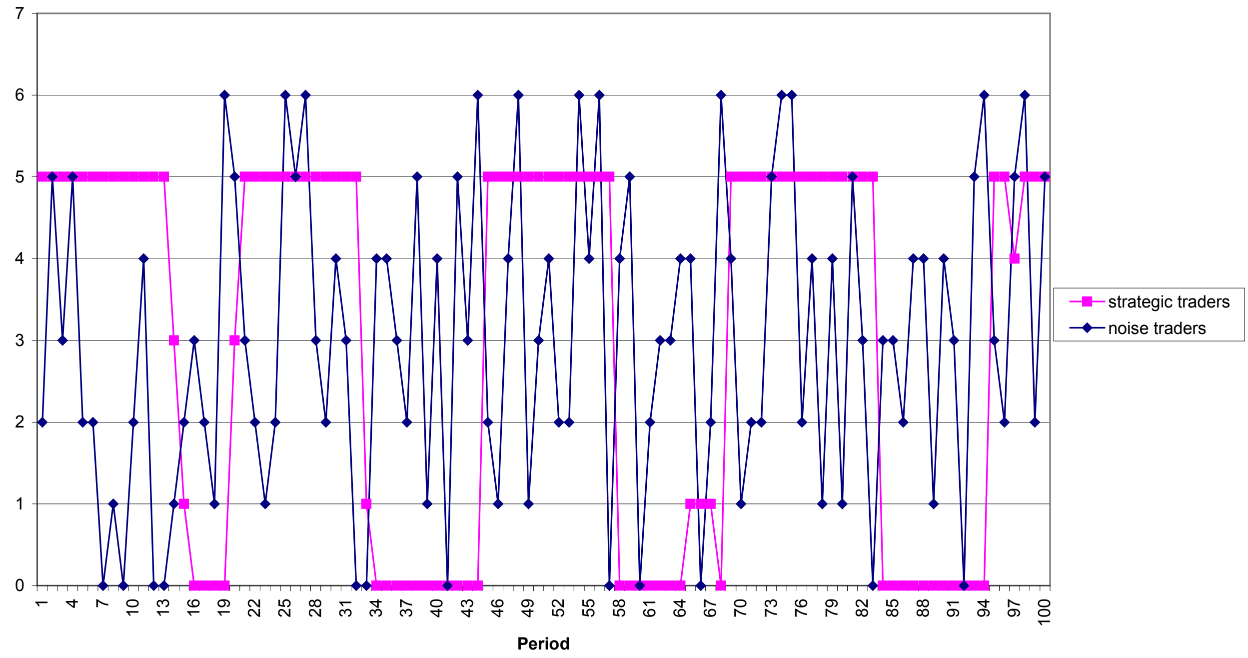
Group 9, Round 1: Price Change and Choices of Participants



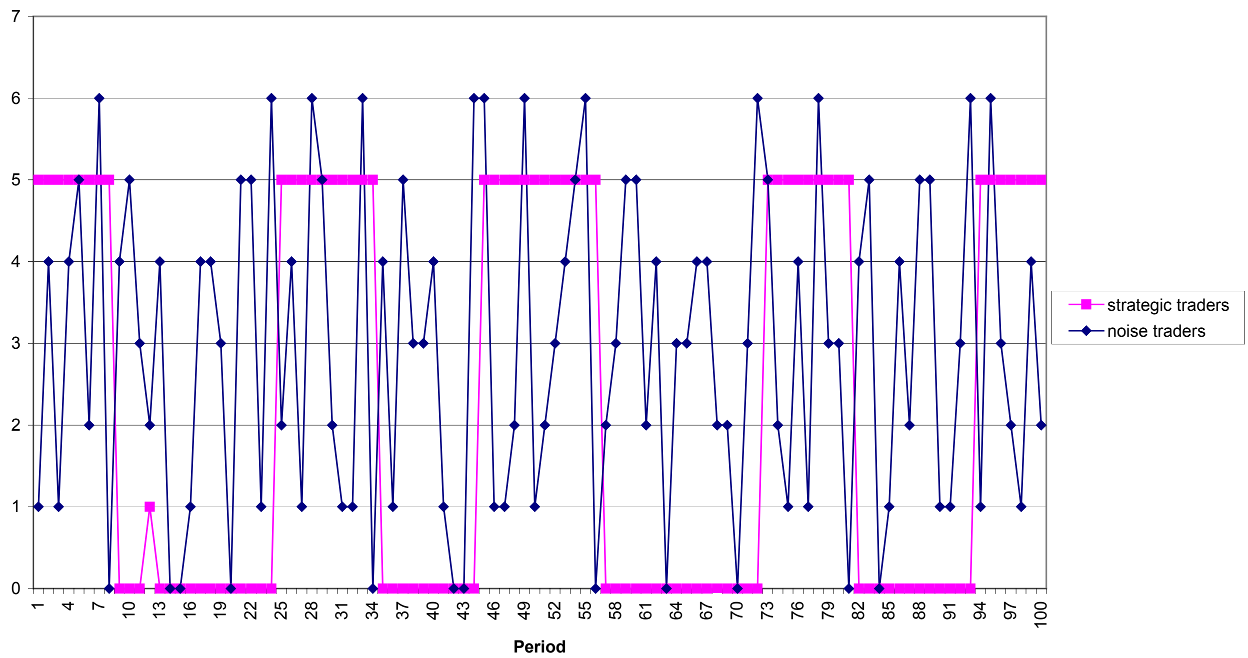
Group 9, Round 2: Price Change and Choices of Participants



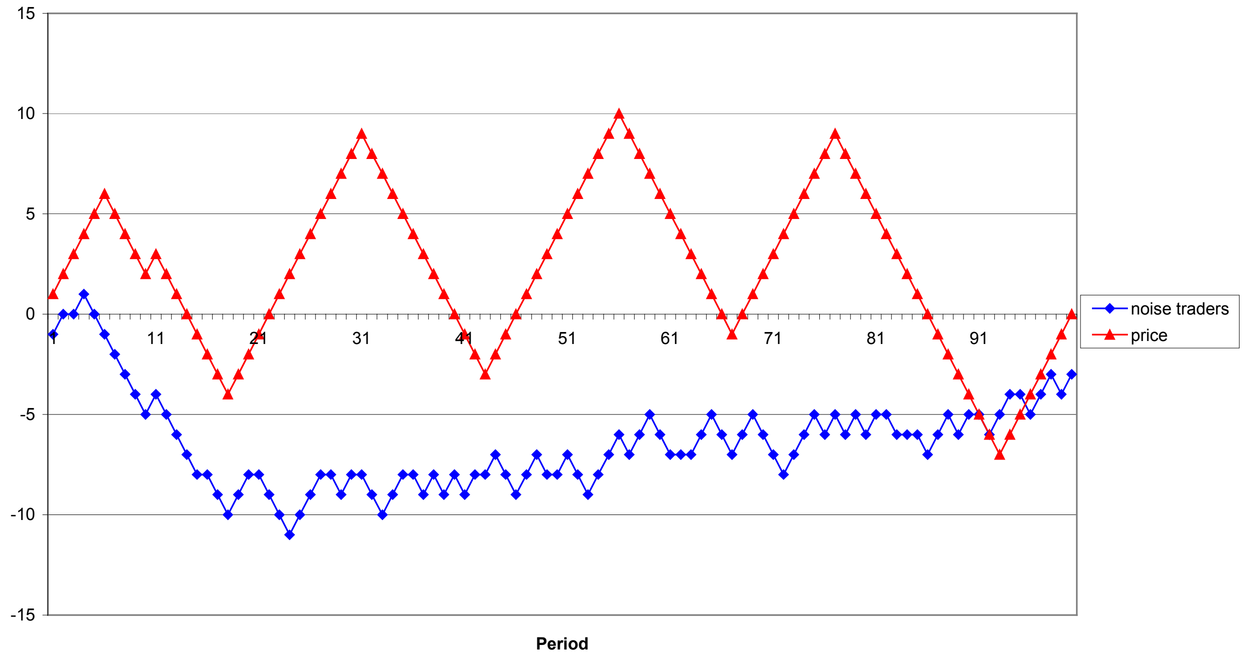
Group 9, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



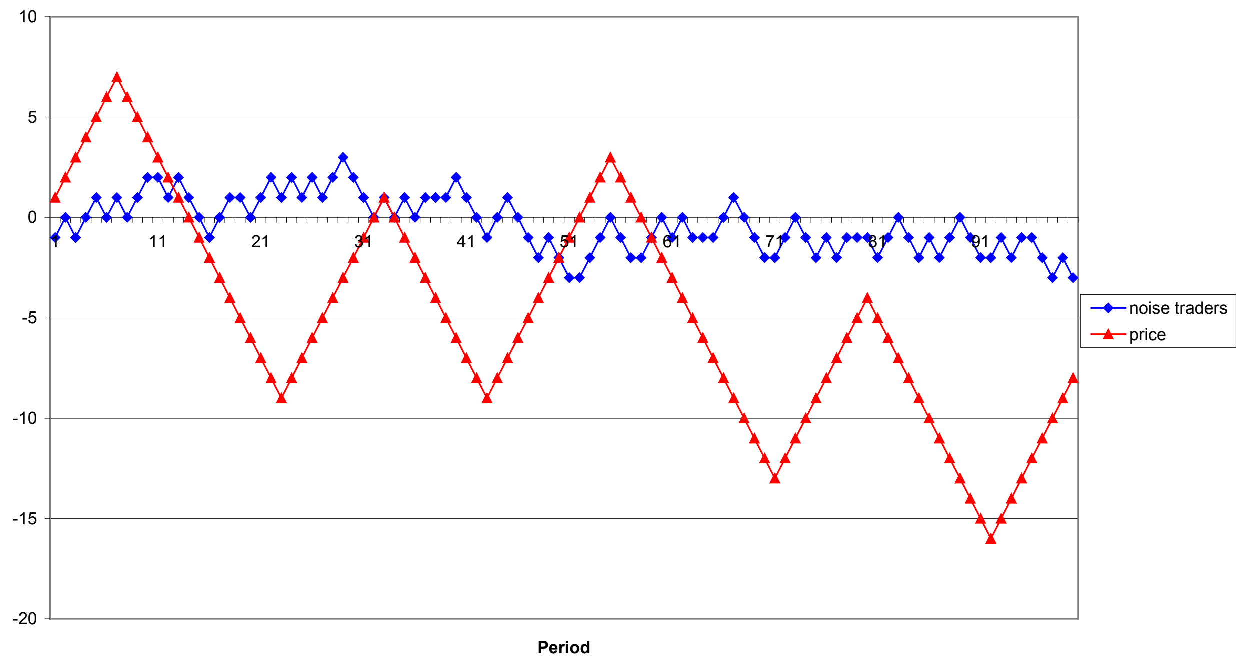
Group 9, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



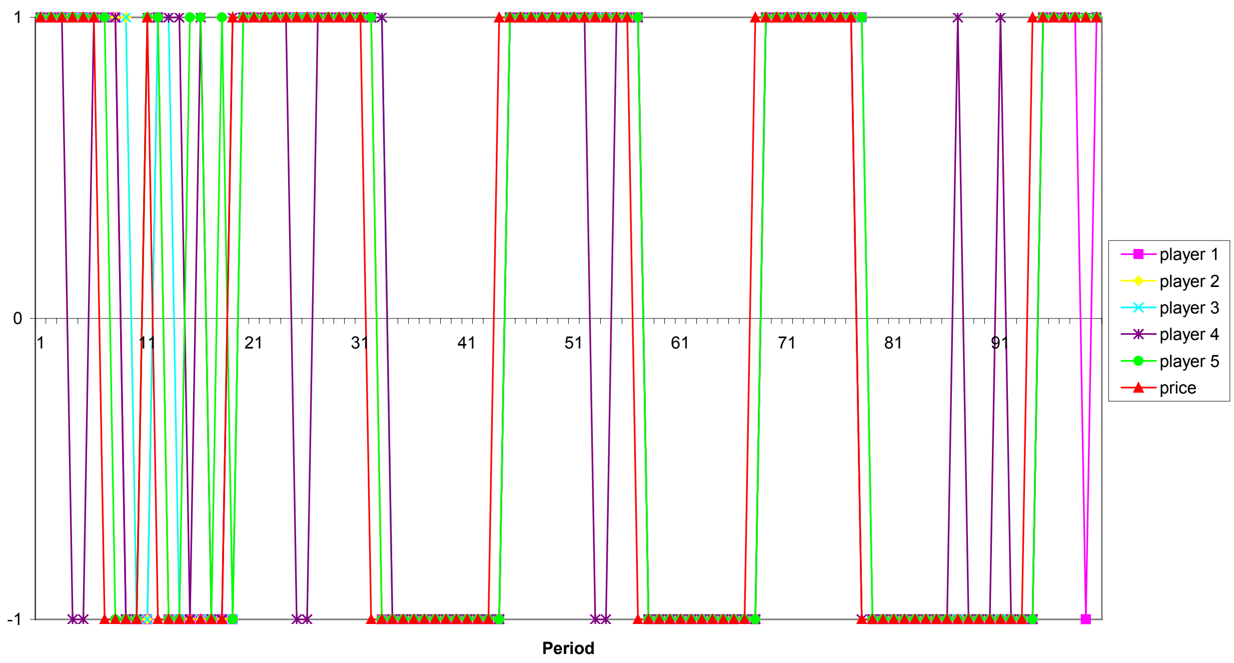
Group 10, Round 1: Cumulated Change in Noise Traders' Sentiment and Price



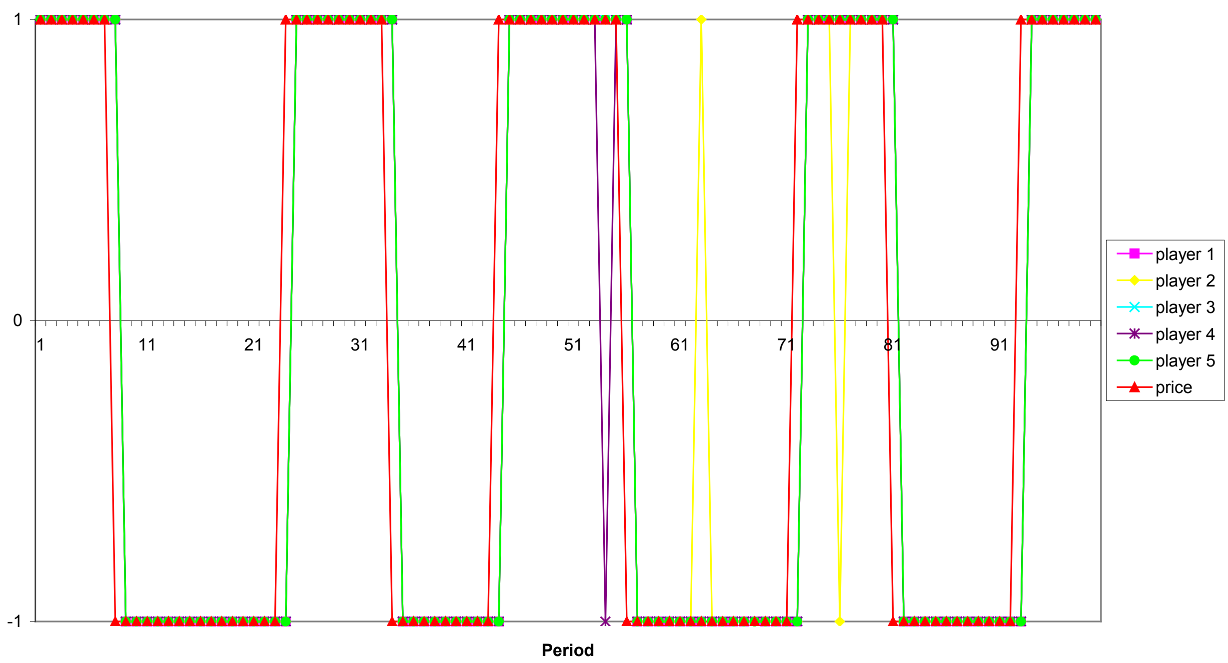
Group 10, Round 2: Cumulated Change in Noise Traders' Sentiment and Price



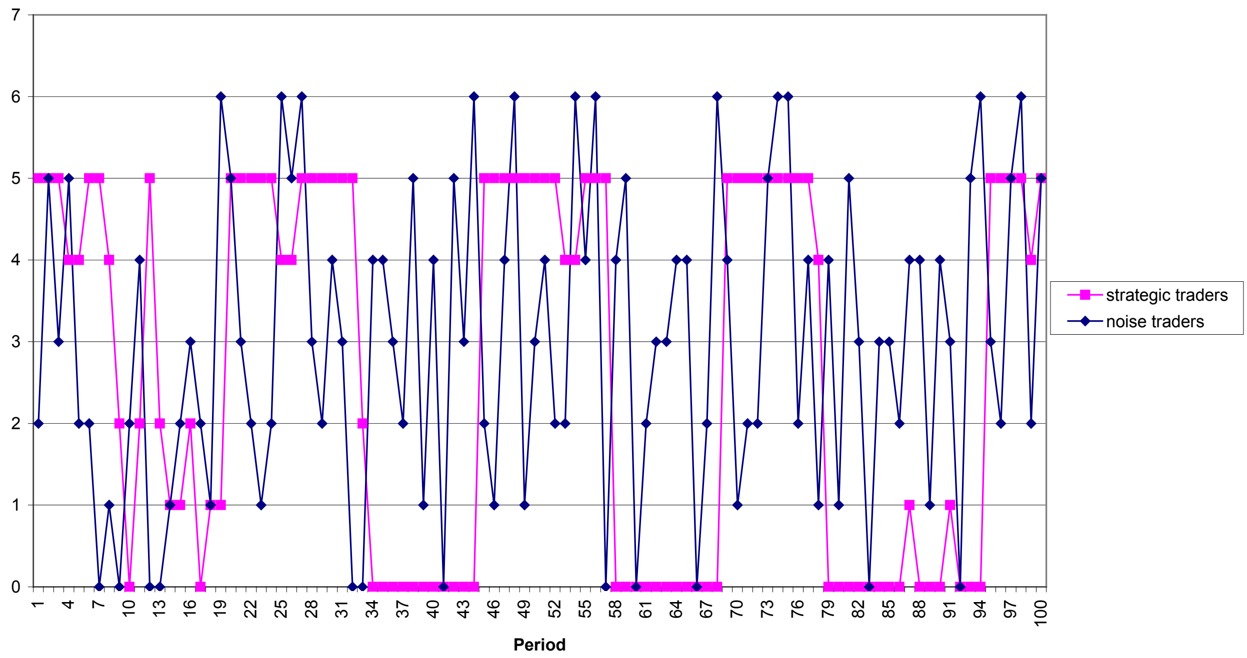
Group 10, Round 1: Price Change and Choices of Participants



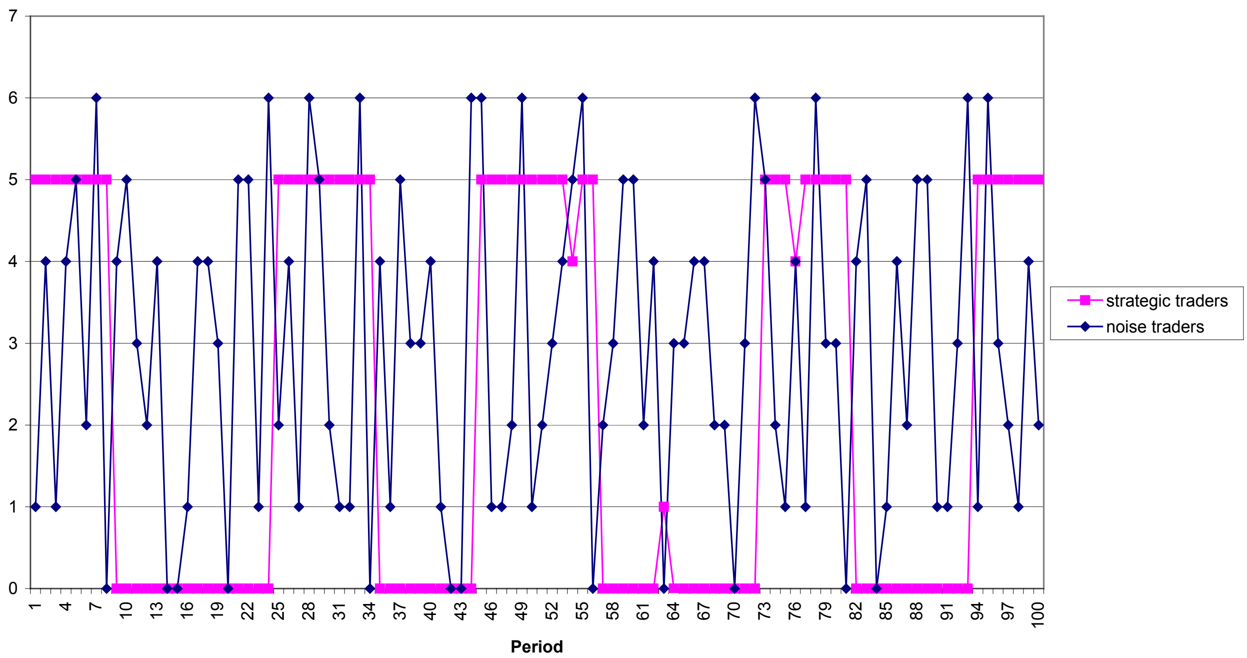
Group 10, Round 2: Price Change and Choices of Participants



Group 10, Round 1: Frequency of "Up" among Strategic Traders and Noise Traders



Group 10, Round 2: Frequency of "Up" among Strategic Traders and Noise Traders



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