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Does Information Matter? Some Experimental Evidence from a Common-Pool Resource Game

by

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Does Information Matter? Some Experimental Evidence from a Common-Pool Resource Game*

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Abstract

This paper analyzes the effect of the availability of information about the payoff structure on the behavior of players in a Common-Pool Resource game. Six groups of six individuals played a complete information game, while other six groups played the same game but with no information about the payoff function. It will be shown that the patterns of investment decisions in both treatments are remarkadly similar. In fact, it cannot be rejected that there is no difference in the investment decisions at the aggregate level between the two treatments. Furthermore, after arguing that the unique Nash equilibrium of the game does not organize the individual data, two individual learning models are studied: one following a marginal analysis (the Best-reply function) and one following an average analysis (the Average-reply function). However, the predictive value of such learning models is found to be poor.

JEL classification: C72; C91; D83; Q2.

Keywords: Common-pool resources; Nash equilibrium; Information; Learning.

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1. - Introduction

The intense field and experimental study that has arisen in the social sciences around the subject of Common-Pool Resources (CPRs) is a result not only of its intrinsic empirical importance, but also of the fact that it provides an attractive environment in which to analyze individual behavior. The effects of direct and indirect communication, sanction systems, experience, the danger of destroying the CPR, heterogeneity, different appropriation rules, the possibility of modifying the rules for allocation, uncertainty in the production capacity, and time dependence, are some of the questions that have been addressed in the experimental research (see Ostrom, Gardner and Walker 1994; Rocco and Warglien 1996; Keser and Gardner 1999; Walker and Gardner 1992; Hackett, Schlager and Walker 1994; Gardner, Moore and Walker 1997; Walker, Gardner, Herr and Ostrom 2000; Budescu, Rapoport and Suleiman 1995; Herr, Gardner and Walker 1997; and see also Ostrom 1990, 1998, 2000).

Two questions are analyzed in this experimental study of a CPR: first, the influence of information about the payoff structure on the exploitation pattern of players, and second, the nature of learning models used by players.

Two experimental treatments are run, one with complete information about the payoff structure and one with no information about it at all. In the latter treatment, all that is provided is a certain amount of qualitative information about the nature of the game. When modeling individual behavior it is crucial to know what type of information players use in the course of the game. Traditional game theory bases its concepts of equilibria on the assumption that players make use of an a priori analysis of the game in order to infer a complete strategy that ultimately ends in an equilibrium. Obviously, such an approach requires a high degree of information about the game. On the other hand, learning models are typically constructed as dynamic adjustment processes to contingencies that arise in the course of the game. The informational requirements of such learning models are typically lower. Note, therefore, that, while the a priori calculation of the theoretical equilibrium is possible in the complete information treatment, the second treatment admits the use only of some type of dynamic adjustment model. A comparison of behavior between the two treatments may, therefore, provide some conclusions concerning the value of ex-ante information about the payoff structure, and, of course, about the importance of the study of dynamic adjustment models for the understanding of actual behavior. This treatment configuration has apparently never been studied previously.

With regard to the second question to be addressed here, two types of dynamic adjustment models are analyzed: the Best-reply function and what will be called the Average-reply function. It will be argued that the later finds its roots in the economic literature. While the Best-reply function is derived from a marginal analysis of the decision problem, the Average-reply function is based on an average analysis. Therefore, two markedly different dynamic adjustment models with regard to their behavioral foundations will be confronted. Since the parameterization of the game is defined such that the implications arising from a marginal analysis are clearly separated from those of an average analysis, it is possible to make a clear contrast of the two models.

This paper is structured as follows. Section 2 introduces the CPR game, while the symmetric Nash equilibrium and the dynamic adjustment models are presented in Section 3. Section 4 deals with the experimental procedure. The experimental data are analyzed in Section 5, and finally, Section 6 concludes the paper.

2. - Description of the Game

The game to be studied draws from the baseline game used in Ostrom, Gardner and Walker (1994, Chapter 5; hereafter, OGW). For fifty periods, a group of six individuals plays a constituent game aimed at representing the appropriation problem in a CPR. Players are aware of the number of periods to be played. The game is symmetric and no communication between players is allowed. In the constituent game, players face the decision problem of distributing a fixed endowment (labeled k) between two markets, the CPR market (market 1) and a "private market" (market 2). The payoff derived by any one player from the CPR market depends on his/her investment, but also on the investments of the remaining players. In contrast to this, the payoff derived by any one player from the private market is contingent only upon his/her own investment decision.

The constituent game is denoted by $\Gamma = (N, X, u)$, where $i \in N = \{1, \ldots, 6\}$, x_i is player i's investment in the CPR market, $x_i \in X_i = \{5.00, 5.01, 5.02, ..., 30\}$, $x = (x_1, x_2, \ldots, x_6)$, and $X = X_1 \times X_2 \times \ldots \times X_6$. k=35 is the individual endowment, hence (35–x_i) is player i's investment in the private market. Player i's payoff function is

$$u_i(x) = \left(120 \sum_{i=1}^{6} x_i - 1.165 \left(\sum_{i=1}^{6} x_i \right)^2 \right) \frac{x_i}{\sum_{i=1}^{6} x_i} + (135 - 6(35 - x_i))(35 - x_i). \tag{1}$$

Then $u(x) = (u_1(x), u_2(x), \ldots, u_6(x))$. The first addend on the right hand side of (1) represents the CPR market. The fraction $x_i \Big/ \sum_{i=1}^{6} x_i$ denotes the i-th share of the group payoff in the CPR market (the expression in brackets). The second addend in (1) represents the private market. The payoff function in this market is specified as quadratic, instead of linear (as in OGW), in order to allow for a greater difference in the predictions of the learning models studied in this paper.

3. - Theoretical Hypotheses

3.1. – Symmetric Nash Equilibrium

In games where players do not have any information about the payoff structure, standard game theory does not provide any equilibrium prediction. The following argument, therefore, applies only to those games with complete information, that is, to Treatment I.

It is shown below that the constituent CPR game has one and only one *Nash Equilibrium*, which happens to be symmetric. By the application of backward induction, it can be seen that the equilibrium of the CPR game is at each period to play the symmetric Nash equilibrium (SNE), which constitutes the one and only *Subgame Perfect Equilibrium* of the CPR game. The SNE of the constituent game is calculated by assuming that the individual strategy space is the continuum between 5 and 30. Then, consider player i's Best-reply (B-r) function

$$b_i(x_{-i}) = \{x_i \in X_i : u_i(x_i, x_{-i}) \geq u_i(x_i', x_{-i}) \text{ for all } x_i' \in X_i\}, \text{for all } i \in N, \tag{2}$$

where $x_{-i} = (x_1, \ldots, x_{i-1}, x_{i+1}, \ldots, x_6)$. The individual B-r function can be obtained by

$$\frac{\partial u_i(x_i, x_{-i})}{\partial x_i} = 405 - 1.165 \sum_{\substack{j=1 \\ j \neq i}}^{5} x_j - 14.33 x_i = 0, \qquad \text{for all } i \in N, \tag{3}$$

and hence,

$$x_i^B(x_{-i}) = 28.26 - 0.08\sum_{\substack{j=1 \\ j\neq i}}^{5} x_j \,, \qquad \text{for all } i \in N. \tag{4}$$

The SNE is obtained by solving the equation system (4). Therefore, regarding the complete information treatment, the theoretical prediction for each of the 50 periods is the SNE that calls for an investment of $x_i^* = 20$ for all i = 1,…,6, and which translates into 279 talers of profits per individual and per period.

3.2. - Best-reply Function in the CPR Game

The B-r function was already introduced in the previous section for the case of the constituent CPR game. Now, the B-r function is formulated to be applied to the CPR game. According to this reaction function, players are payoff maximizers with respect to the observed investment level of the rest of players in the previous period. That is, as in Cournot's model of adaptation in oligopoly contexts, the Best-reply function describes a completely myopic behavior in the sense that players behave as if they expected what happened at time t–1 to happen at time t. Importantly, it is shown below that if players behave in accordance to this reply function, their investment decisions will converge towards the SNE.

For the formulation of the individual B-r function of the CPR game the variable time must now be incorporated. So, for all $i \in N$, (2) and (4) can be restated in the following terms

$$b_i(x_{-i,t-1}) = \{x_{it} \in X_{it} : u_i(x_{it}, x_{-i,t-1}) \geq u_i(x'_{it}, x_{-i,t-1}) \text{for all } x'_{it} \in X_{it}\}, \tag{5}$$

and

$$x_{it}^B(x_{-i,t-1}) = 28.26 - 0.08\sum_{\substack{j=1 \\ j\neq i}}^{5} x_{j,t-1} \,, \tag{6}$$

where x_{it}, $x_{-i,t}$ and X_{it} are defined as above, but framed in some $t \in T = \{1,\ldots,50\}$. Using matrix notation, the system of B-r functions can be written as

$$x(t) = A^B x(t-1) + B^B, \tag{7}$$

where

$$x(t) = \begin{bmatrix} x_{1t} \\ x_{2t} \\ \vdots \\ x_{6t} \end{bmatrix},\ x(t-1) = \begin{bmatrix} x_{1,t-1} \\ x_{2,t-1} \\ \vdots \\ x_{6,t-1} \end{bmatrix},\ A^B = \begin{bmatrix} 0 & -0.08 & \cdots & -0.08 \\ -0.08 & 0 & \cdots & -0.08 \\ \vdots & \vdots & \ddots & \vdots \\ -0.08 & -0.08 & \cdots & 0 \end{bmatrix}, \text{and } B^B = \begin{bmatrix} 28.26 \\ 28.26 \\ \vdots \\ 28.26 \end{bmatrix}.$$

Since the spectral radius of matrix A^B is lower than one, by known results on the global stability of dynamic systems in difference equations (see, e.g., Ortega and Rheinboldt 1970), it can be guaranteed that the SNE is globally stable with respect to the process of iteration described in (6).

3.3. – Average-reply Function

OGW (p. 121) report the following important finding: “Indeed, in postexperimental questionnaires we administered, we found that many subjects were using the rule of thumb “Invest more in Market 2 whenever the rate of return is above \$.05 per token. Then, when the rate of return fell below \$.05, they reduced investments in Market 2, giving rise to the pulsing cycle in returns that we observe across numerous experiments.”[1] This describes individual behavior in which opponents’ strategies are taken as given, the average payoffs of the two markets are considered, and more is invested in the market that shows a higher average payoff. The role of an average analysis in economic decision-making has been largely stressed in the literature. Baumol (1961) (see also Faulhaber and Baumol 1988) in a book dealing with the relationship between economic theory and business practice, devotes a section to the use of average payoffs in business. He points out that: “In business operations one often encounters rule-of-thumb calculations which serve as substitutes for the operations researcher’s optimality computations. When these business calculations are explicit, they are frequently made in terms of *average* rather than marginal quantities...” (*op. cit.*, p. 32, emphasis in the original). According to Baumol (1961, p. 33) this is because of “the difficulty of marginal data collection.” In the same vein, Jordan (1993, p. 1; see also 1989) stresses the paradox that “the basic ingredient of [management] accounting information continues to be the measurable transaction, actual or budgeted, rather than the more subjective concepts of marginal cost or opportunity cost favored by economic theory.” Furthermore, in individual repeated decision-problems where at each period the decision-maker must select one alternative from a set, the theory of melioration, which is structured on the basis of an average analysis, has found forceful support in numerous experimental studies (see, e.g., Herrnstein 1991, 1997, and Herrnstein and Prelec 1991). Therefore, the development and experimental exploration of a simple individual strategy structured on the basis of an average analysis is regarded here as being of sufficient interest. This will be referred as the Average-reply function (A-r).

For the formulation of the A-r function, consider that for every player i and all feasible opponents´ strategies, a pattern of behavior where more is invested in the market that provides

[1] In OGW’s experiments, Market 2 presents a fixed payoff per unit invested equal to \$.05.

higher average payoffs, leads to one and only one point where the average payoffs of the two markets are equalized. Therefore, the A-r function can be written in the following terms

$$\mu_i\left(x_{-i,t-1}\right)=\left\{x_{it}\in X_{it}:\frac{V_i^1\left(x_{it},x_{-i,t-1}\right)}{x_{it}}=\frac{V_i^2\left(x_{it}\right)}{\left(k-x_{it}\right)}\right\},\qquad \text{for all } i\in N, \tag{8}$$

where V_i^1 and V_i^2 denote the total payoff functions of the CPR market and the private market, respectively. Hence, (8) can be restated as

$$x_{it}^A(x_{-i,t-1})=\max\left\{5,27.21-0.16\sum_{\substack{j=1\\ j\neq i}}^{5}x_{j,t-1}\right\},\qquad \text{for all } i\in N. \tag{9}$$

Equation system (9) has one and only one solution, $x' = (15,\ldots,15)$, which translates into 527 talers of profits per individual and per period. This is called here the Average solution. For the strategy space that generates average-replies strictly greater than 5, the system of difference equations can be written as

$$x(t)=A^A x(t-1)+B^A, \tag{10}$$

where

$$A^A=\begin{bmatrix}0 & -0.16 & \cdots & -0.16\\ -0.16 & 0 & \cdots & -0.16\\ \vdots & \vdots & \ddots & \vdots\\ -0.16 & -0.16 & \cdots & 0\end{bmatrix},\qquad \text{and } B^A=\begin{bmatrix}27.21\\ 27.21\\ \vdots\\ 27.21\end{bmatrix}.$$

Note that for every point in the strategy space not considered for the formulation of (10), the system of A-r functions implies that in the next iteration a point is reached which belongs to the strategy space for which (10) is valid. Then, since the spectral radius of A^A is lower than one, x' is globally stable with respect to the process of iterations described in (9).

3.4. - Efficiency

It can now be seen that the A-r function describes a more efficient investment pattern, regarding the participants' payoffs, than does the B-r function. This can be shown by deriving the "Pareto-reply function" of the constituent game. By the Pareto-reply (P-r) function it is meant that function that gives the individual investment in the CPR market that maximizes group payoffs. That is, for all $i\in N$, the P-r function of the constituent game is

$$p_i(x_{-i})=\left\{x_i\in X_i:\sum_{i=1}^{6}u_i(x_i,x_{-i})\geq\sum_{i=1}^{6}u_i(x_i',x_{-i})\ \text{ for all } x_i'\in X_i\right\}. \tag{11}$$

Then,

$$\frac{\partial \sum_{i=1}^{6} u_i(x_i, x_{-i})}{\partial x_i} = 405 - 2.33\sum_{\substack{j=1 \\ j \neq i}}^{5} x_j - 14.33 x_i = 0\,, \qquad (12)$$

and hence

$$x_i^P(x_{-i}) = \max\left\{5, 28.26 - 0.16\sum_{\substack{j=1 \\ j \neq i}}^{5} x_j\right\}. \qquad (13)$$

Figure 1 shows the predictions of B-r, A-r, and P-r functions for any level of investment by opponents. While, for any given level of investment by the remaining players, the B-r function calls for the highest individual investment, the A-r function always calls for the lowest, and the P-r function falls between these two, but always closer to the predictions of the A-r line than to those of the B-r function. The intersection of the line with a 1/5 slope that departs from the origin with the three reply functions, gives the symmetric solutions for the three systems of reply functions: (i) B-r (that is, the SNE) calls for an individual investment of 20, which translates into 279 talers of individual payoff, (ii) A-r (average solution) calls for an individual investment of 15, with 527 talers of individual payoff, and (iii) P-r (Pareto solution) calls for an individual investment of 15.58, with 531 talers of individual payoff.

4. - Experimental Procedure

The experiment to be reported has been conducted at the Laboratory for Experimental Economics at the University of Bonn. Volunteer subjects, recruited through posters on campus, were primarily undergraduate economic and law students, but also students from other disciplines such as computer science and mathematics. The computerized program was developed using *RatImage* (Abbink and Sadrieh 1995). Six games, each with six participants, were conducted in each of the two treatments.

Instructions were handed out to subjects and read aloud. An English translation of the instructions for Treatment I is shown in the Appendix. Instructions for Treatment II were analogous to those of Treatment I, but of course, all information regarding the structure of payoffs were omitted. The following qualitative information was given to participants in Treatment II: "The payoffs you receive from Market 1 depend not only on the amount you invest *but also on the amount invested by the remaining members of your group*… In Market 2 the payoffs you receive on investments *depend only on the amount you invest in Market 2*…

The payoffs of each market period are independent of decisions in other market periods, and there is no randomness of any kind in the payoffs."

The period by period information on outcomes was the same in both treatments. That is, in Treatments I and II the players were informed of the previous group investment level in the CPR market, and each of his/her own total, average, and marginal payoffs in both markets, his/her own total payoffs for that period, and finally his/her own cumulative payoffs. Furthermore, players in both treatments were told that by clicking on "History", they would have access to this information for every past period. Hence, the SNE can only be computed in Treatment I. Best-reply and Average-reply can also only be precisely derived in Treatment I. However, since players are given information on the marginal and average payoffs per market and per period, an approximation to them can be obtained in both treatments.

The main computer screen, the one where players had to enter their investment decisions, was presented and explained to subjects. Subjects were told that individual decisions remained anonymous to the group, and that the game was symmetric.

After instructions had been read and questions answered, subjects were randomly assigned to independent and visually isolated cubicles equipped with computer terminals. No communication between subjects was allowed. No time restrictions were imposed. On average, a session, including the instructions phase, lasted less than one hour and forty minutes. Players were privately paid in cash directly after completing the 50 experimental periods. The capital balance was 4,000 talers in Treatment I, and 8,000 talers in Treatment II. The exchange rate was 0.0025 DM. Average earnings were around DM 53 (about 27 Euros).[2]

5. - Experimental Results

5.1. – Equilibrium Predictions

First of all, the predictive value of the SNE is analyzed. To this end, see the time-series of average investment in the two treatments, the time series of individual investment in two games, the distribution of investment decisions in each of the two treatments (Figures 2-6), and Table I where some descriptive statistics can be found.

Observation 1. Although at group level investments are slightly lower than those predicted by SNE, at individual level players do not play the SNE.

[2] The experimental data will be made available upon request.

Given the literature in CPR games, these results are not surprising (see, for example, Ostrom 1998 and Keser and Gardner 1999). Figure 2 and Table I clearly show that at the aggregate level the observed investment level comes close to that predicted by SNE, and hence, tends away from the Average solution. However, in Figures 3, 4, 5, and 6 it can be appreciated that the variability in individual behavior shows itself as extremely wide, indicating that players do not play the SNE (an investment of 20 in each of the 50 periods). In Section 5.2 behavior will be further explored on the basis of the dynamic adjustment models considered in this paper. Now, the two treatments are contrasted.

Observation 2. It cannot be rejected that there is no difference in the investment decisions at the aggregate level between Treatments I and II.

The two treatments are contrasted by considering the average of the investment decisions in the CPR market at the game level (hence, there are two samples, each with six independent observations). The Kolmogorov-Smirnov two sample test[3] is used to test at the 5% significance level[4] whether there is no difference in the average investment between the two treatments, against the alternative hypothesis of different average investments. It is important to note that the Kolmogorov-Smirnov two sample test is sensitive to any kind of difference in the distributions (that is, in location, dispersion, skewness, etc). The null hypothesis of equality cannot therefore be rejected ($mnD_{m,n}$=6, *P*-value equal to 20%). The same conclusion is reached when the two treatments are contrasted by considering the first, middle, and final third of the data separately ($mnD_{m,n}$=6, in the three cases). Hence, there is a high degree of robustness on these results.

Furthermore, two more games were run to ascertain whether this finding could be attributed to the fact that players, in both treatments, had information on average and marginal payoffs in both markets after each decision period. These two new games (Game 13 and 14) had an experimental design analogous to those already reported. In Game 13 six players had the same information as in Treatment II (minimal information treatment). Players in Game 14, however, had information only about the past group investment decisions, and each about his/her own total payoffs on each market. Figure 7 shows that the average time series of the games are again remarkably similar.

[3] See Siegel and Castellan 1988. Except when explicitly stated to the contrary, the tests used below follow the mentioned reference.
[4] The decision rule adopted in all the statistical tests is for a significance level of 5%.

Observation 3. Dispersion in the pattern of investment decisions in Treatment II is greater than that observed in Treatment I.

The Wilcoxon-Mann-Whitney test is used to ascertain whether the two treatments have the same dispersion, against the alternative hypothesis of a greater dispersion in Treatment II. The Wilcoxon-Mann-Whitney test is sensitive to differences in location. The null hypothesis is, therefore, rejected at the 1.3% significance level (W_x=25). By reproducing the analysis in the three blocks developed for Observation 2, it is now obtained that, while for the first and final third of the experiment the null hypotheses of equality of dispersion are rejected at significance levels below 0.25% (W_x=21 and W_x=22), in favor of a greater dispersion in Treatment II, the null hypothesis of equality cannot be rejected when the middle third is analyzed (W_x=30, *P*-value equal to 8.9%).

Therefore, although players in Treatment II present more variation in individual behavior (recall, however, that for the middle third there is no significant difference), presumably motivated by an exploratory process over the nature of the payoff functions, the investment patterns in the two treatments are equal throughout the whole experiment. These are provocative results. As mentioned previously, this finding has important implications for the way that individual behavior is modeled in game theory. These findings stress the importance of learning models, taken as dynamic adjustment processes, in understanding behavior in strategic environments like CPR games.

5.2. – Dynamic Adjustment Models of Individual Behavior

An analysis is now made of the predictive capacity of the dynamic adjustment models presented in Sections 3.2 and 3.3. Given Observation 2, no distinction between treatments is made for the following analysis (hence, it will include 12 independent observations). Note, furthermore, that the investment predictions of the dynamic adjustment models are calculated by substituting the observed value of the independent variable in the corresponding reply function.

Figure 8 clearly shows that the B-r function is much closer to the observed time series than is the A-r. In fact, by the end of the experiment, differences between the observed investment decisions and the predictions of B-r tend to diminish, while differences between the observed investment decisions and the predictions of A-r tend to increase. However, neither reply function adequately approximates the observed data.

Observation 4. It is rejected that there is no difference between the predictions of either of the two reply functions and the observed decisions.

First, note that the predicted time series by B-r and A-r show a downward tendency, while the observed time series shows an upward tendency. A non-parametric procedure, the Cox-Stuart test for trend (see Daniel 1990), is used to analyze the trends of the observed and predicted time series. The Cox-Stuart test for trend is a variation of the sing test that pairs data from the earlier part of the sequence, with data from the latter part, and analyzes whether there is a preponderance of plus or minus signs. Hence, to apply the Cox-Stuart test for trend, the averages of the investments per round of the observed and predicted data are calculated. Thus, the null hypotheses of no downward trend in the predictions of B-r and A-r are rejected at the 0.4% significance levels, while in the case of the observed data, the null hypothesis of no upward trend is rejected at the 0.5% significance level.
Furthermore, while predictions of B-r always lie above the observed values, predictions of the A-r always lie below (see Figure 8 and Table II). That is, either there is a persistent over-prediction or a persistent under-prediction. As a matter of fact, it can be concluded that neither the predictions of B-r, nor those of A-r, have the same central tendency than the observed data. That is, the Wilcoxon signed-ranks test is used to test whether the observed investments and the predicted investments by B-r and A-r come from the same population (or from populations with an equal median), against the alternative hypothesis which claims that predicted and observed data differ. Thus, the null hypotheses are rejected in both cases at the 0.04% significance level (T=0 in both cases[5]).

6. – Concluding remarks

This experiment reproduces the results obtained in previous CPR games in as much as it reveals that, although at aggregate level the observed time trend tends towards the symmetric Nash equilibrium (SNE), it cannot be concluded that subjects play the SNE at the individual level. It remains an open question why the SNE is a good predictor of aggregated behavior in CPR experiments, while systematically failing to explain individual behavior. The argument that it is the byproduct of the aggregation of heterogeneous behavior is not satisfactory, since

[5] T is the smaller sum of the like-signed ranks.

this does not explain why the aggregation is around the SNE as opposed to any other outcome.

It has been shown that it cannot be rejected that there is no difference in the investment decisions between the complete information treatment and the minimal information treatment. This result is interpreted as stressing the importance of the role that learning models, taken as dynamic adjustment processes, play in the understanding of behavior in repeated games such as these. One of the aims of this paper was, in fact, to explore the predictive capacity of dynamic adjustment models such as Best-reply, or Average-reply. The results, however, show that these models fail to explain the data, although the failure of the Average-reply function is much more significant.

7. - Appendix: Experimental Instructions

Description of the experiment:

There are 18 participants in this room. Participants will be divided into three independent groups of six. You will not know which of the people in the room belongs to your group.

The experiment in which you are participating is comprised of a sequence of 50 market periods. In each market period you will be asked to make an investment decision.

For each period you will be allocated an endowment of 35 talers. All other members of your group will also have an endowment of 35 talers. The total endowment for your group is 210 talers.

You will decide each market period how you wish to invest your endowment between two investment opportunities. You are allowed to use up to two decimal points in the distribution of your endowment. The instructions that follow will describe the two investment opportunities.

Investment opportunity one: Market 1

In Market 1 you are allowed to invest a minimum of 5 talers and a maximum of 30 talers.

The payoffs you receive from Market 1 depend not only on the amount you invest *but also on the amount invested by the remaining members of your group*.

You receive a percentage of the *total group payoff* dependent upon what share of the total group investment you make. For example:

If the group as a whole invests 50 talers in Market 1 in a period in which you invest 6, you will receive 12% (6/50) of the total group payoff.

The *total group payoff* in Market 1 is explained in Table A (those participants interested in the payoff formula will find it at the end of these instructions). Let's now discuss the meaning of the information given in the table.

The first column, labeled "Total Talers Invested by the Group in Market 1", gives example levels of total investment by the group in Market 1.

The second column, labeled "Total Group Payoff in Market 1", displays the actual total group payoff in Market 1 at various levels of group investment.

The third column, labeled "Average Payoff per Taler in Market 1", displays group payoff on a per taler (average) basis, at various levels of group investment.

The final column, labeled “Market 1 Additional Payoff”, displays information on the rate of change in the total group payoff associated with a small change in the group investment in Market 1.

Investment opportunity two: Market 2

Any of the initial 35 talers remaining after investing in Market 1 are automatically invested in Market 2.

In Market 2 the payoffs you receive on investments *depend only on the amount you invest in Market 2*.

Table B displays information on your possible payoff on Market 2 at various levels of your investment in Market 2 (again, those interested in the formula will find it at the end of these instructions).

The first column, labeled “Total Talers Invested by you in Market 2”, gives example levels of your investment in Market 2. Note that your investment in Market 2 is defined by your endowment (35 talers) minus your investment in Market 1.

The second column, labeled “Payoff from Market 2”, displays your actual payoff from Market 2 at various levels of your investment.

The third column, labeled “Average Payoff per Taler in Market 2”, displays your payoff at various levels of investment, but on a per taler (average) basis.

The final column, labeled “Market 2 Additional Payoff”, displays information on the rate of change in your payoff resulting from a small change in your investment in Market 2.

History:

During the experiment you will have the opportunity to see the results of all the previous periods by clicking on *History*.

Experiment Payoff:

For showing up you receive a 4000 talers payoff. Every 100 talers equals 25 pfennig. All the profit you make during the experiment will be totaled and paid to you privately in cash at the end of the experiment.

TABLE A

PAYOFFS FROM INVESTMENTS IN MARKET 1

Total Talers Invested by the Group in Market 1	Total Group Payoff in Market 1	Average Payoff per Taler In Market 1	Market 1 Additional Payoff
30	2551.5	85.05	50.1
35	2772.875	79.225	38.45
40	2936	73.4	26.8
45	3040.875	67.575	15.15
50	3087.5	61.75	3.5
55	3075.875	55.925	-8.15
60	3006	50.1	-19.8
65	2877.875	44.275	-31.45
70	2691.5	38.45	-43.1
75	2446.875	32.625	-54.75
80	2144	26.8	-66.4
85	1782.875	20.975	-78.05
90	1363.5	15.15	-89.7
95	885.875	9.325	-101.35
100	350	3.5	-113
105	-244.125	-2.325	-124.65
110	-896.5	-8.15	-136.3
115	-1607.125	-13.975	-147.95
120	-2376	-19.8	-159.6
125	-3203.125	-25.625	-171.25
130	-4088.5	-31.45	-182.9
135	-5032.125	-37.275	-194.55
140	-6034	-43.1	-206.2
145	-7094.125	-48.925	-217.85
150	-8212.5	-54.75	-229.5
155	-9389.125	-60.575	-241.15
160	-10624	-66.4	-252.8
165	-11917.125	-72.225	-264.45
170	-13268.5	-78.05	-276.1
175	-14678.125	-83.875	-287.75
180	-16146	-89.7	-299.4

TABLE B

PAYOFFS FROM INVESTMENTS IN MARKET 2

Total Talers Invested by you in Market 2	Payoff from Market 2	Average Payoff per Taler in Market 2	Market 2 Additional Payoff
(35-30)=5	525	105	75
(35-29)=6	594	99	63
(35-28)=7	651	93	51
(35-27)=8	696	87	39
(35-26)=9	729	81	27
(35-25)=10	750	75	15
(35-24)=11	759	69	3
(35-23)=12	756	63	-9
(35-22)=13	741	57	-21
(35-21)=14	714	51	-33
(35-20)=15	675	45	-45
(35-19)=16	624	39	-57
(35-18)=17	561	33	-69
(35-17)=18	486	27	-81
(35-16)=19	399	21	-93
(35-15)=20	300	15	-105
(35-14)=21	189	9	-117
(35-13)=22	66	3	-129
(35-12)=23	-69	-3	-141
(35-11)=24	-216	-9	-153
(35-10)=25	-375	-15	-165
(35-9)=26	-546	-21	-177
(35-8)=27	-729	-27	-189
(35-7)=28	-924	-33	-201
(35-6)=29	-1131	-39	-213
(35-5)=30	-1350	-45	-225

Markets 1 and 2 payoff functions

MARKET 1: If we define X as the total number of talers invested in market 1 by all group members, we can calculate the total group payoff as: Total group payoff of Market 1 = $120X-1.165X^2$.

MARKET 2: If we define x as the number of talers you invest in Market 1, then, your endowment (35) minus x is the number of talers you invest in Market 2. We can calculate your payoff from Market 2 as:

Your payoff of Market 2 = $(135-6(35-x))(35-x)$.

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FIGURE 1
DYNAMIC ADJUSTMENT MODELS OF INDIVIDUAL BEHAVIOR

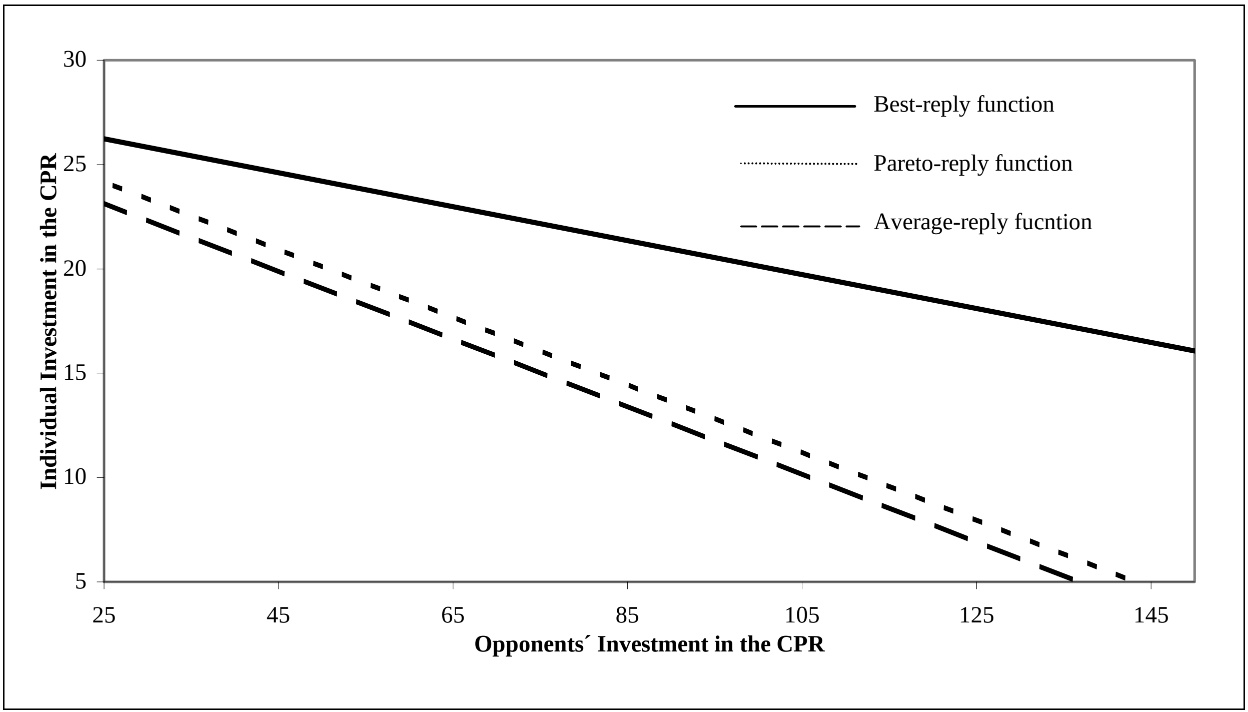

FIGURE 2
TIME SERIES OF AVERAGE INVESTMENT BY TREATMENT

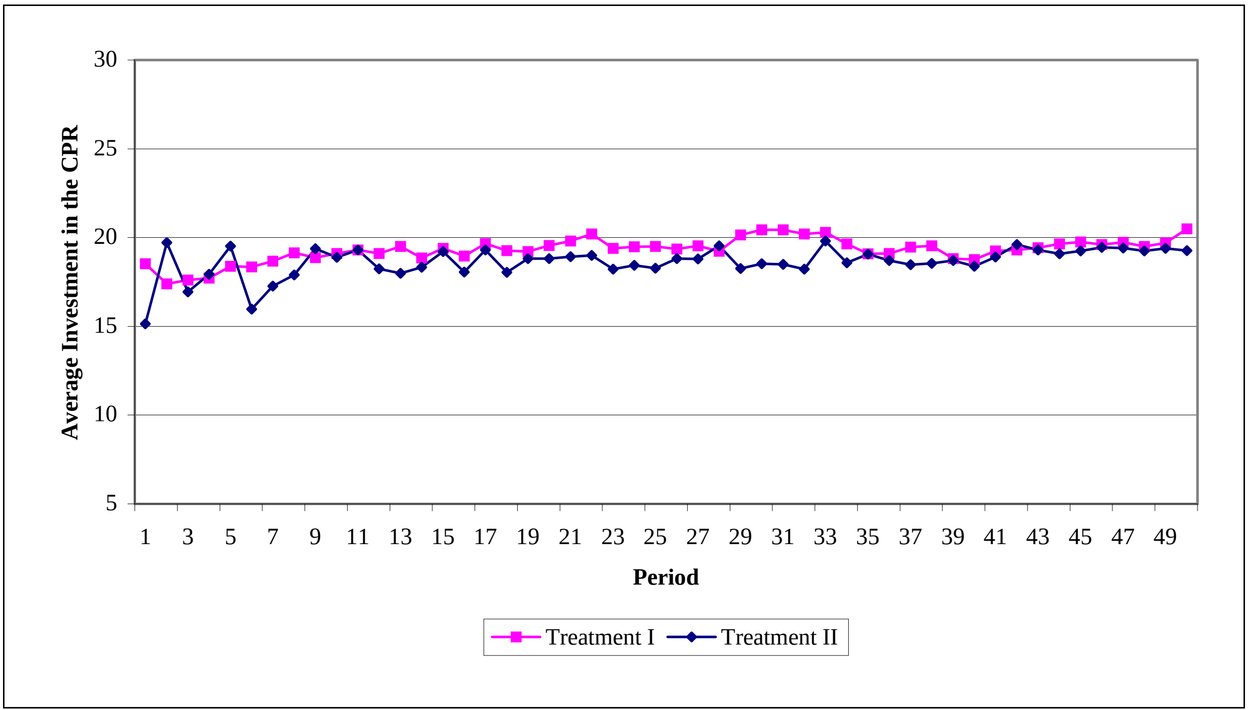

FIGURE 3
TIME SERIES OF INDIVIDUAL INVESTMENTS IN GAME 5 (TREATMENT I)

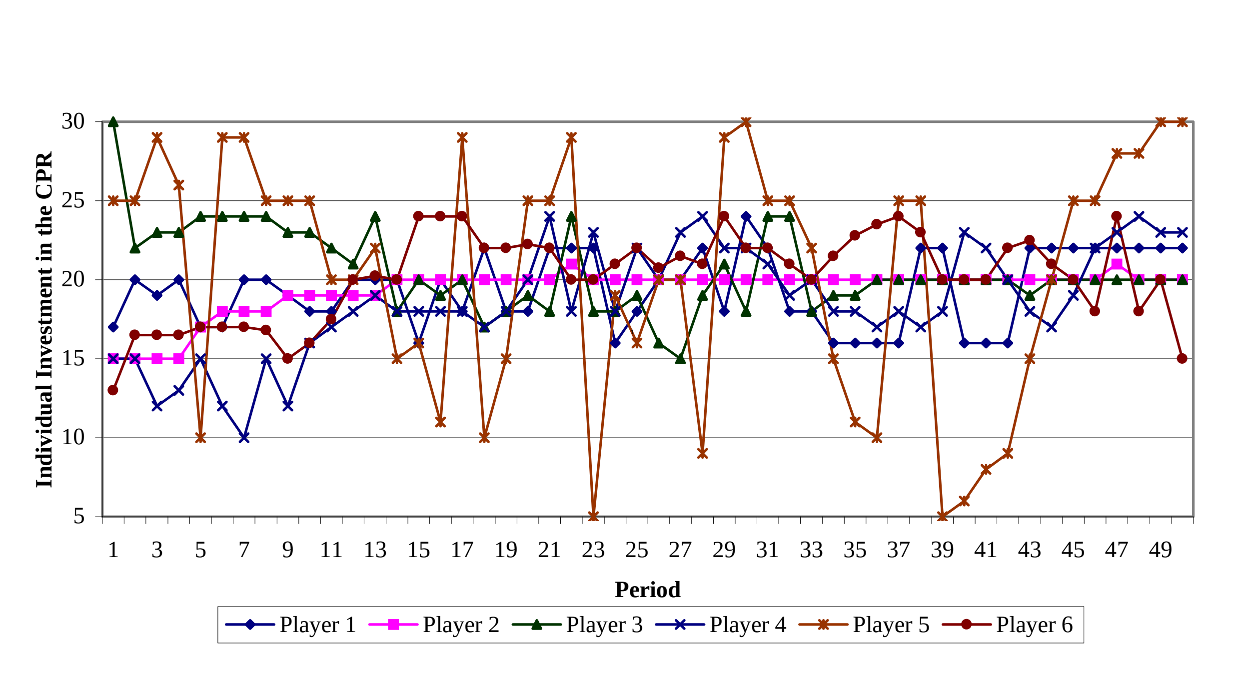

FIGURE 4
TIME SERIES OF INDIVIDUAL INVESTMENTS IN GAME 10 (TREATMENT II)

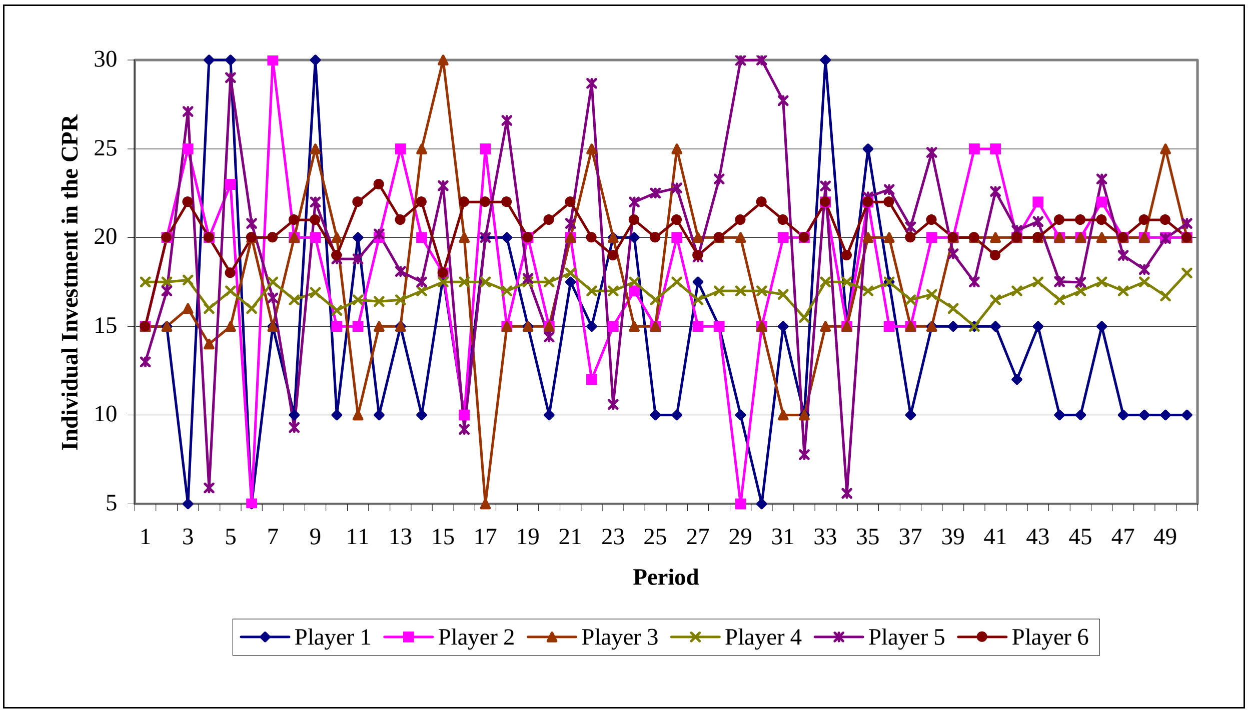

FIGURE 5
DISTRIBUTION OF INVESTMENT DECISIONS IN TREATMENT I

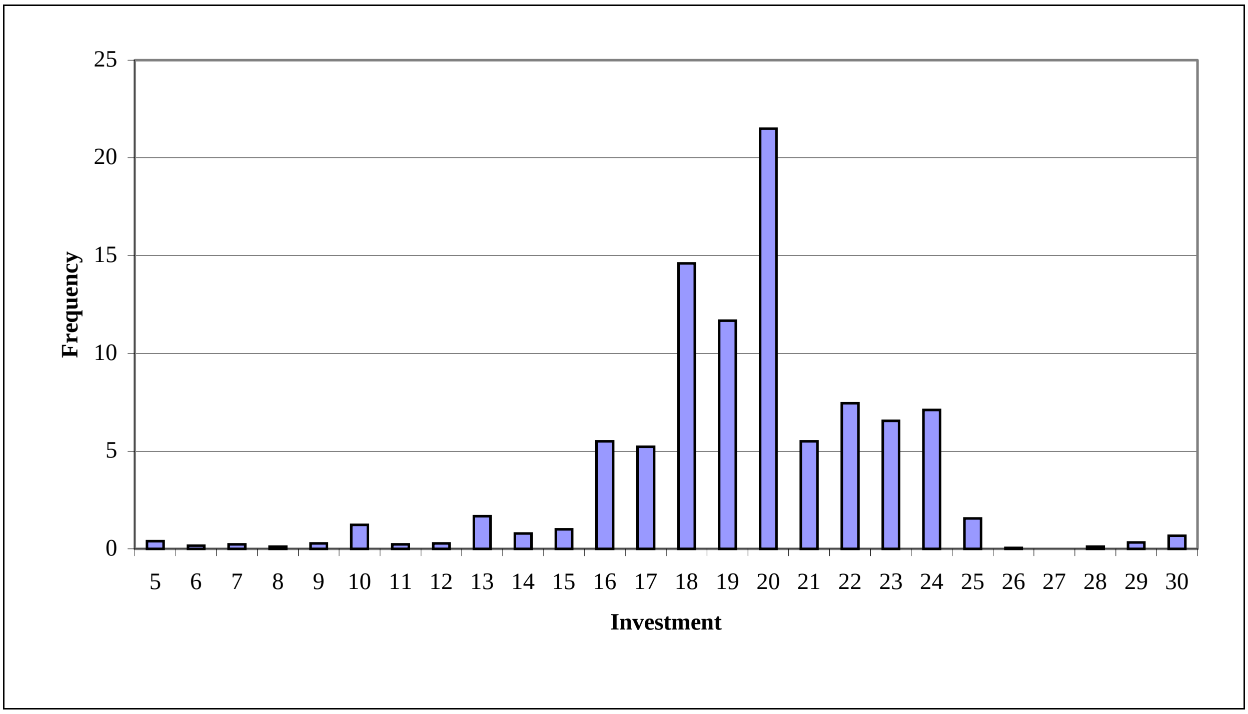

FIGURE 6
DISTRIBUTION OF INVESTMENT DECISIONS IN TREATMENT II

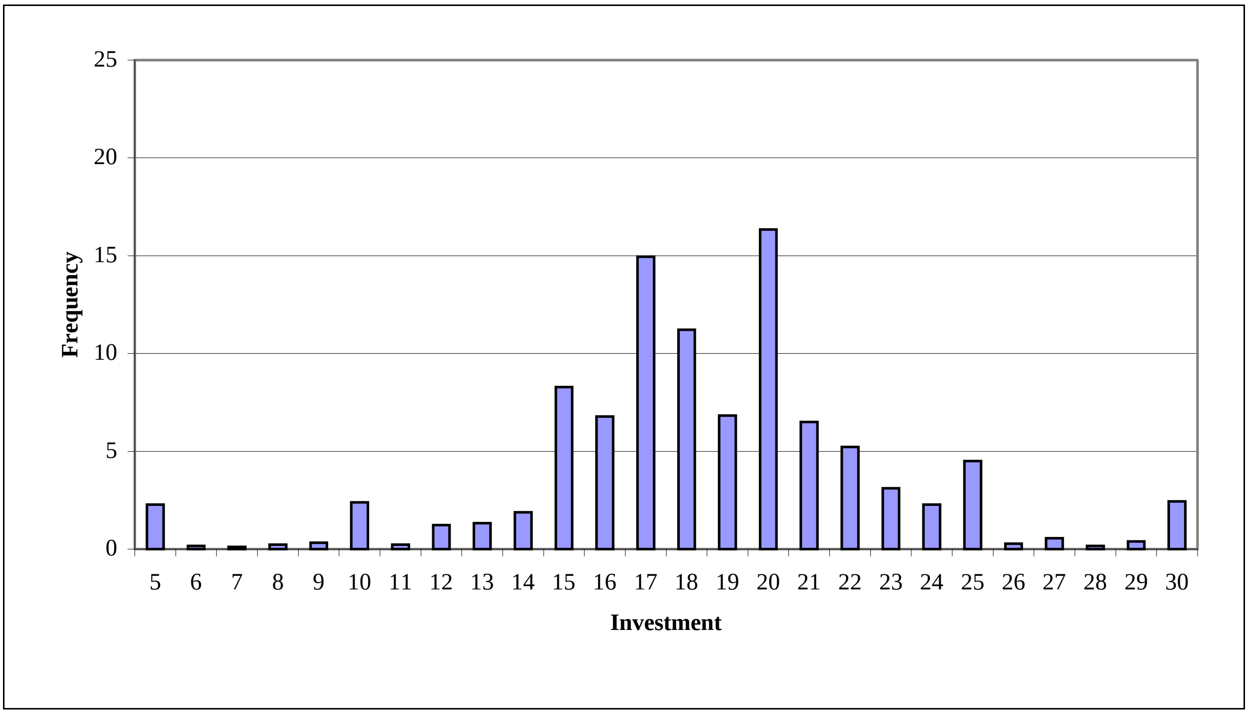

FIGURE 7
TIME SERIES OF AVERAGE INVESTMENT IN GAMES 13 AND 14

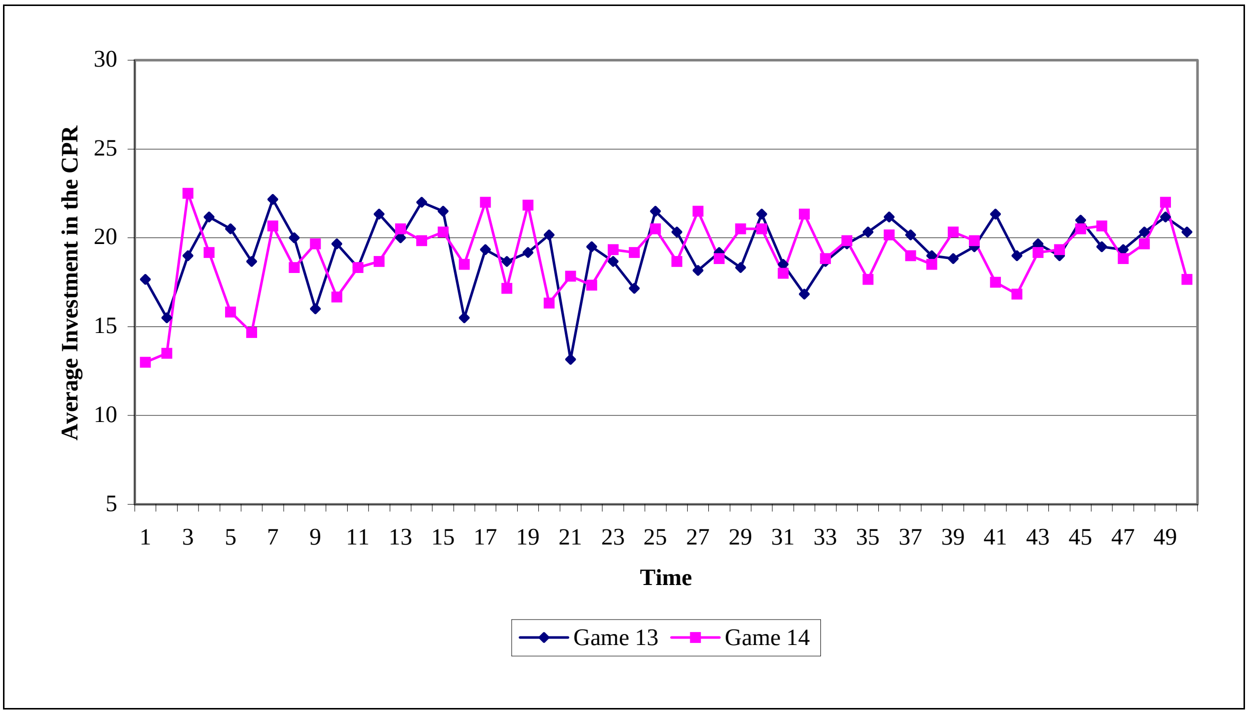

FIGURE 8
TIME SERIES OF AVERAGE OBSERVED INVESTMENT AND AVERAGE PREDICTED INVESTMENT
BY BEST-REPLY AND AVERAGE-REPLY

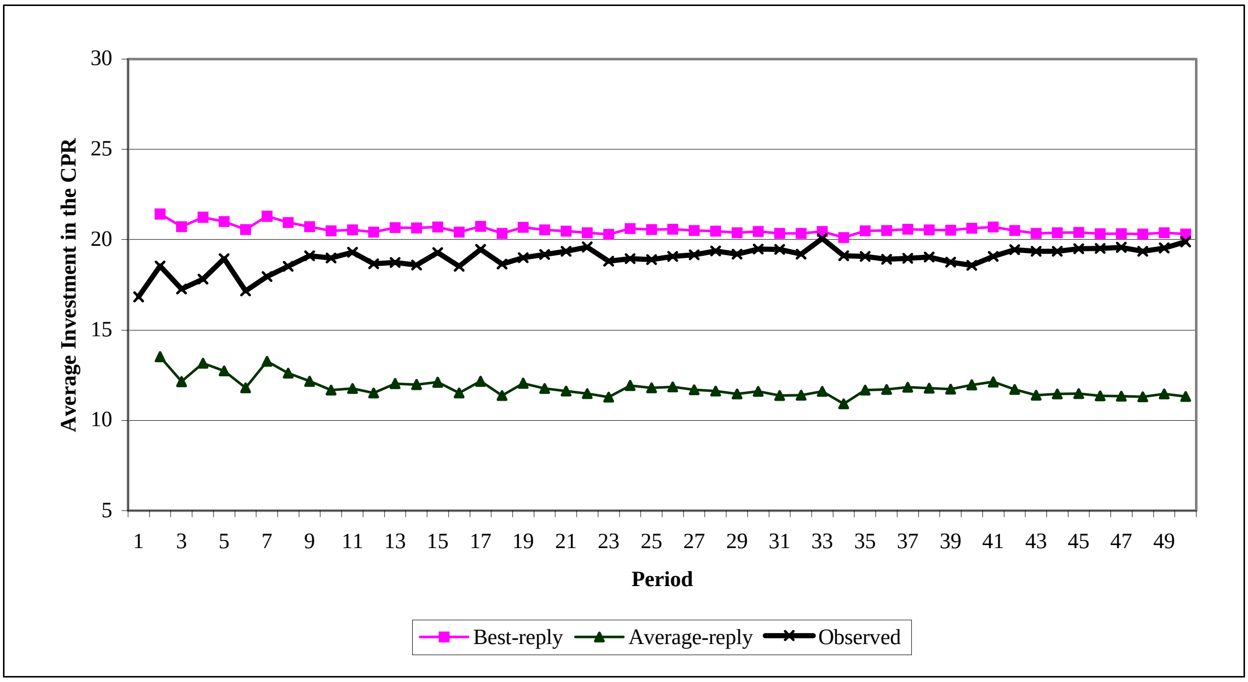

TABLE I
DESCRIPTIVE STATISTICS

GAME	1	2	3	4	5	6	TREAT I
All Periods							
Aver Inv	19.2	19.67	19.23	19.83	19.76	18.15	19.31
Stand Dev	2.571	2.778	3.258	3.53	3.975	3.764	3.395
First Third							
Aver Inv	18.521	19.93	17.69	20.08	19.24	16.96	18.73
Stand Dev	3.1214	3.673	4.135	4.255	4.186	4.427	3.966
Middle Third							
Aver Inv	19.336	19.91	20.01	21.34	20.27	17.65	19.75
Stand Dev	2.1822	2.271	2.464	3.027	3.539	3.696	2.863
Final Third							
Aver Inv	19.755	19.2	20.04	18.15	19.81	19.81	19.46
Stand Dev	2.1319	2.04	2.226	2.253	4.118	2.242	2.502

GAME	7	8	9	10	11	12	TREAT II
All Periods							
Aver Inv	17.93	19.5	18.5	18.1	19.51	18.25	18.63
Stand Dev	4.889	3.79	3.37	4.76	4.443	4.51	4.368
First Third							
Aver Inv	17.2	19.04	17.62	17.9	19.2	18.1	18.18
Stand Dev	6.437	5.491	4.668	5.52	6.29	4.65	5.509
Middle Third							
Aver Inv	18.18	19.75	18.84	18	19.5	17.8	18.68
Stand Dev	4.008	2.661	2.107	4.93	3.71	4.57	3.664
Final Third							
Aver Inv	18.41	19.64	19.16	18.3	19.8	18.8	19.02
Stand Dev	3.659	2.306	2.519	3.71	2.37	4.3	3.146

TABLE II
AVERAGE OBSERVED AND PREDICTED INVESTMENT PER GAME

	Observed	B-r	A-r
Game 1	19.22	20.47	11.62
Game 2	19.65	20.27	13.34
Game 3	19.23	20.45	11.6
Game 4	19.87	20.2	11.09
Game 5	19.77	20.25	11.18
Game 6	18.2	20.91	12.51
Game 7	17.97	20.99	12.67
Game 8	19.62	20.35	11.39
Game 9	18.65	20.74	12.16
Game 10	18.14	20.91	12.52
Game 11	19.52	20.33	11.35
Game 12	18.29	20.86	12.41