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Effort, Time and Competition: Essays on Games and Interactive Behaviors

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Effort, Time and Competition: Essays on Games and Interactive Behaviors

DISSERTATION

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DOCTOR OF PHILOSOPHY

in Economics

by

Wenhao (Zoe) Zhao

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DEDICATION

My husband Jiuzhou Qin, parents, friends, and advisers
for their support and candor, through the good and the bad.

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VITA

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ABSTRACT OF THE DISSERTATION

Effort, Time and Competition: Essays on Games and Interactive Behaviors

By

Wenhao (Zoe) Zhao

Doctor of Philosophy in Economics

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Professor John Duffy, Chair

This dissertation contains three chapters researching how individuals make decisions in an interactive game setting. Chapter 1 investigates principal-agent behavior under a company setting in which portions of subjects are assigned to be workers and others are managers. Managers decide how much to pay to the workers and workers decide the level of effort to contribute. Managers can earn positive revenue only if the workers' effort contribution surpasses certain criteria. When the threshold is high, we find that the workers tend to slack off as the high threshold is difficult to reach. The zero contribution and zero wage equilibrium becomes the dominant strategy under the high threshold setting while the positive contribution strategy is adopted more frequently when the threshold is low. Chapter 2 continues to adopt the same setting as the chapter 1. In this chapter, the wage payment is no longer paid in advance of workers' effort contribution. It becomes a form of bonus, in which workers are paid after their effort contribution. The outcome is that the after-contribution payment encourages workers to work harder and allows managers to spend less money compared to paying workers before their contribution. Chapter 3 studies agents' price prediction decision in the financial market. Agents with predictions close to the realized market price earn the higher return than others who make farther away predictions. A ranking system is given to agents to check their performance in the market. This ranking system approves to be misleading and make agents believe that they are doing the right predictions without checking the dynamic

market condition. As a result, their predictions in general are farther away from the real market price as compared to agents' performance in a market without the ranking. Thus, the contribution of this dissertation is twofold: the contribution of each individual Chapter to its subject and the collective contribution of all Chapters to understanding large group strategic interactions under specific treatments and conditions.

Chapter 1

Repeated Threshold Gift Exchange Game: An Experimental Evidence

Abstract

In the principle agent experiment, the binding production goal disincentivizes workers' other-regarding incentives. This type of goal setting-scheme has not yet been studied. When a pre-determined objective is challenging and cannot be achieved by a single worker, some groups converge to the theoretically predicted trigger strategy referred to as Nash equilibrium, in which the manager gives zero wage and workers devote minimum effort in the later periods of the game. This finding suggests that simple goal setting is not an effective motivating tool to improve workers' productivity. Moreover, subjects' beliefs about their teammates' choice patterns and their self-evaluations (if generous or not generous in effort/wage giving) in the repeated game will direct their effort/wage givings. For instance, workers who believe their coworkers are generous tend to contribute more effort regardless of their wage level. This study addresses the importance of in-group interactions among coworkers, specifically those which allow for belief-forming, as well as provides a rationale for hiring hard-working and generous workers. Generous workers who both

regard themselves as generous and behave in a generous manner will help improve the productivity of all workers in the team.

JEL Classification Code:C92, D23, J30, L23, M52

1.1 Introduction

The gift exchange game has previously been explored by many researchers (Fehr et al. 1997, Charness 2004, and Gachter and Falk 2002, etc.), specifically in the context of fairness concerns relevant to the principal-agent scheme. In the most basic scenario, the manager decides a certain wage for the workers, who then determine the effort they will contribute in order to help generate outputs for the manager. Even though the theoretical equilibrium predicts that selfish or self-regarding workers will contribute minimum effort and that the manager will pay zero wage after anticipating this behavior, experiments have consistently found that workers exert higher than minimum effort. This effort is matched by a positive wage paid back by the manager. Workers believe that it is fair for them to give out more than minimum effort when receiving this positive wage.

Nonetheless, the moral hazards faced by workers within the firm has not yet been fully explored. Within a firm, workers experience moral hazards, which originate from not only the manager but also from their fellow workers. This is especially relevant in environments where teamwork is essential to achieve the firm's production goal. Because most of tasks within a firm cannot be finished by an individual worker, cooperation and coordination are necessary to achieve a firm's production goal. Workers care if their payoffs are fair and the division of labor within the teams once a certain production goal has been established.

The work of Buchner et al.(2004) has previously explored teamwork among workers within the principal-agent framework. In their 2004 study, they conducted a ultimatum bargaining game between the manager and two workers in which workers do not consider the manager's behaviors in their decision making process and instead only coordinate with their fellow coworkers. In light of these findings regarding workers' behaviors, there is a need for further study of workers' decision making in the goal-setting environment, specifically environments in which workers face fairness concerns from both their fellow workers and their managers. While this situation is common within modern institutions, it has not yet been subject to in-depth academic study.

This project will therefore look deeply into subjects' decision making process within the principal-agent framework. In this context, the company's production goal is established and workers face fairness concerns not only from their coworkers, but also from their respective managers. Workers' decisions surrounding effort contribution change according to changes of magnitude in production goals. The results of this study will empower firms to implement more effective motivational policies, thus improving the efficiency of all their workers.

The environment in which goal setting occurs is an important motivating factor in raising 'fairness concerns' within a team of workers. Taylor (1911) has previously commented that "if workers accept hard and specific goals, their performance improves." Locke et al. (1981) have agreed, asserting that goal setting provides the motivation which ultimately enhances effort contribution, as well as positively influences strategy development. Such goals provide a clear standard of fairness in contribution, irrespective if it is established endogenously by the environment or within the firm itself (i.e., by workers). If the final product is the result of group effort, the final goal also serves as a division task. This means that the work involved in the task must be divided within the group, increasing the importance of positive intra-group interactions. Goal setting is therefore closely related to workers' fairness concerns, both from between workers and between the manager and workers, and is also likely to be a strong enhancer in improving workers' effort contribution. This project focuses on studying the binding goal-setting case, in which failure to reach the production goal will generate zero revenue for the manager. One real-life example of this type of binding threshold/goal setting assignment is found in automobile production. In order to produce a functional vehicle, workers must exert a certain amount of effort to assemble all the parts required for a car, as losing any individual part will render the vehicle unfit for use.

When considering workers' behaviors, this goal-/threshold-setting framework is related to the threshold public goods game. Workers contribute effort toward production goals until a certain threshold is reached in which goods are produced successfully (Cadsby and Maynes 1998, Van de Kragt et al. 1983, Rapoport and Eshed-Levy 1989, Issac et al. 1989). In the public goods game, subjects receive the rewards of successful production once this threshold is reached, which creates an incentive for worker contribution. In contrast, workers in the gift exchange game are paid a predetermined wage prior to their effort contribution. Their effort levels therefore do not affect their payoffs within specific time periods, and they are therefore not motivated to produce goods successfully. In this repeated game, workers' only motive to work hard is the risk of being objectively punished on the next round, that is, by receiving less pay from their managers. Moreover, subjects have no incentive to contribute more than the threshold requirement, as rewards in the public goods game are fixed once the contribution threshold is reached. In this experimental setting, the threshold serves as the lowest production bar and any contribution above this bar will generate higher revenue with respect to effort contribution. The resulting revenue belongs to the manager, who does not determine production but uses wage as a tool to encourage effort contribution. Therefore, a rational manager's goal is to encourage workers to give maximum effort while keeping the wage cost low to maintain high payoffs.

Furthermore, even through individuals' reciprocal characters directly determine their choices in the gift exchange game, their beliefs regarding their teammates' reciprocal nature (as gleaned through repeated interactions with both coworkers and the manager) may also influence their strategies within the repeated interactive game. Accordingly, this experiment will also assess participants' beliefs about the reciprocal characteristics of every individual, as well as how these beliefs reflected by participants' behaviors.

1.2 Model

In a gift exchange game with a successful contract between one manager and two workers, the payoff of the manager π is:

$$\pi_t = \begin{cases} 10(e_{it} + e_{jt}) - (w_t + w_t), & e_{it} + e_{jt} \geq \beta, \\ -2w_t, & e_{it} + e_{jt}, < \beta. \end{cases}$$

Every individual worker i's payoff is:

$$y_{it} = w_t - c(e_{it}).$$

The manager decides the wage w_t paid to workers at time period t, and the workers decide the effort exertion e_i. This effort exertion will directly affect the manager's revenue. Since the manager moves first, she bears the risk of production failure. Therefore, the manager's payoff is calculated as the generated revenue minus the wage cost that she paid to the workers. When a threshold of successful production $\beta > 0$ is reached, the manager risks production failure and earns non-positive revenue if the sum effort is below the threshold β.

To mimic the production environment in firms where teamwork is possible, we use two workers (i, j) instead of only one worker. This number of workers is the minimum needed to allow for coordination and cooperation. Workers receive wages and do not take part in the firm's profit-sharing process. They receive their wage at a certain time period even when production failure occurs, but the manager can use wage as a tool to punish worker's "laziness," reflecting realistic elements of production environments. The wage is pre-determined before workers participate in the production process in many situations. The manager is restricted to pay identical wage to both workers for the sake of simplicity. This can be justified when individual worker's effort contribution is not identifiable when regarding the final product produced through a team's combined work. The cost function is an increasing and concave function borrowed from Abeler et al. (2010), shown in Table 1.1. As the effort level increases, the cost of each unit of effort starts to increase in a nonlinear pattern.

Table 1.1: The Cost of Effort Function

e_{it}	1	2	3	4	5	6	7	8	9	10
$c(e_{it})$	0	1	2	4	6	8	10	13	16	20

In this standard one-shot game, a worker's strategy is a function of the manager's wage choice $e_i(w_t) = \mathbb{Z}[1, 10]X[0, 100]$. However, in the infinitely repeated game, subjects' cumulative payoffs are discounted at each time period with the time discount factor $\delta \in [0, 1]$. The manager acts to maximize the sum of single-period payoffs across all the time periods. The manager's utility function is:

$$U_m = \sum_{t=1}^{\infty} \delta^{t-1} \pi_t.$$

Besides, every individual worker i selects her effort $e^*_{it} \in \mathbb{Z}[1, 10]$ units in each time period to maximize her utility:

$$U_i = \sum_{t=1}^{\infty} \delta^{t-1} y_{it}.$$

The sub-game perfect equilibrium is a more appropriate concept for describing the equilibrium in this repeated game, as this game is sequential with perfect and complete information. Workers move after the manager and they know the exact wage paid to them before they make decisions. It is therefore rational to take into account the sequential nature of the game. Especially when the manager makes the decision, it is inevitable for her to consider what workers will do afterwards through backward induction. This is captured by the sub-game perfect equilibrium but not the Nash-Equilibrium.

This new model proposes key features that have not been captured by the original gift exchange game. First, this game allows workers to cooperate with each other. The manager's revenue is determined by cumulative effort. The joint effort also determines if the production is successful. The lower than threshold joint effort will cause the manager to receive zero revenue. Second, repeated interactions more accurately reflect real-life situations. In real life, workers consistently interact with the same manager for several time periods.

In a game that is infinitely repeated, two sets of strategies are especially salient. One is the non-cooperative strategy and the other is the cooperative trigger strategy:
Manager:

- **zero-wage**: always gives zero wage ($w_t = 0$) in every time period t and under any e_{it} given by workers.

- **positive-wage**: selects $w_1 = w^* \in [\frac{c(\frac{\beta}{2})}{\delta}, 5\beta]$ in period t=1, and then continue to select $w_t = w^*$ if workers always choose $e_{it'} = e_{jt'} \geq \frac{\beta}{2}$ in each time period $t^{'} < t$. Otherwise, the manager plays the one-shot game Nash-Equilibrium $w_t = 0$.

Workers:

- **non-cooperative** (**non-coop.**): always exert the minimum effort $e_{it} = 1$ in every time period t under all situations no matter what wage is offered.

- **cooperative** (**coop.**): if the manager sets $w_t \geq w^*$ for both workers in this period and all prior periods, then choose $e_{it} = e_{jt} = \frac{\beta}{2}$; else choose $e_{it} = e_{jt} = 1$.

There are many asymmetric equilibrims that can be reached by workers only if workers' joint effort $e_i + e_j \geq \beta$. This project is focused on the symmetric equilibrium for reasons of simplicity. Moreover, since those asymmetric equilibriums has the similar features as the symmetric equilibrium, the proof for the asymmetric equilibrium will be similar as the proof of the symmetric equilibrium case.

In the repeated gift exchange game, the equilibrium exists. The first proposition aims to show that a cooperative trigger strategy equilibrium also exists under certain determined time discount factor δ.

Proposition 1. *a) In the infinitely repeated game, the strategy (**zero-wage**, **non-coop.**, **non-coop.**) is a sub-game perfect equilibrium.*

*b) Under a given $\beta \in \mathbb{Z}[3, 20]$, and the time discount factor $\delta \in [\frac{c(\frac{\beta}{2})}{5\beta}, 1]$, there exists a non-empty set of optimal wage $w^* \in [\frac{c(\frac{\beta}{2})}{\delta}, 5\beta]$ allowing the strategy (**positive-wage**, **coop.**, **coop.**) to be another sub-game perfect equilibrium.*

Proof. a) In every single sub-game of this infinitely repeated game, the strategy (**zero-wage**, **non-coop.**, **non-coop.**) is a Nash-Equilibrium. Workers do not have the incentive to give more than minimum effort $e_{it} = 1$ because exerting an extra unit of effort is costly. Additionally, her choice of effort does not increase her payoff at that certain time period t. In order to maximize the payoff, a worker's optimal strategy is to exert the least effort. By anticipating this result through backward induction, the best response for the manager is to give 0 wage. Therefore, the strategy (**zero-wage**, **non-coop.**, **non-coop.**) is the Nash-Equilibrium in every single sub-game. As a result, it is the sub-game perfect equilibrium for the entire game.

b) In the cooperative strategy, the manager's utility without deviation is:

$$U_m(\textbf{positive-wage}, (\textbf{coop.}, \textbf{coop.})) = \frac{1}{1-\delta}(10\beta - 2w^*).$$

If the manager wants to deviate, the ideal choice is to deviate in the first time period. Otherwise, her payoff from deviation is discounted as time goes by. Besides, the sequential nature of the game implies that the manager's deviation will trigger workers' deviating response $e_{it} = 1$. Therefore, her utility is:

$$U_m(\textbf{zero-wage}, (\textbf{coop.}, \textbf{coop.})) = 0.$$

Manager will not deviate and continue to give $w_t = w^*$ if:

$$U_m(\textbf{positive-wage}, (\textbf{coop.}, \textbf{coop.})) \geq U_m(\textbf{zero-wage}, (\textbf{coop.}, \textbf{coop.}))$$

$$10\beta - 2w^* \geq 0$$

$$w^* \leq 5\beta.$$

For individual worker i, her utility function under the cooperative strategy set is:

$$U_i(\textbf{coop.}, (\textbf{positive-wage}, \textbf{coop.}) = \frac{1}{1-\delta}(w^* - c(\frac{\beta}{2})).$$

On the other hand, if the worker i deviates, her optimal choice is to deviate at the first time period due to the time discounting. Because she acts after the manager, she will receive the wage w^* in time period t and wage 0 ever after:

$$U_i(\textbf{non-coop.}, (\textbf{positive-wage}, \textbf{coop.}) = w^* - c(1) - \frac{\delta}{1-\delta}0.$$

The worker i will stick to play $e_i = \frac{\beta}{2}$ if:

$$U_i(\textbf{coop.}, (\textbf{positive-wage}, \textbf{coop.}) \geq U_i(\textbf{non-coop.}, (\textbf{positive-wage}, \textbf{coop.})$$

$$\frac{1}{1-\delta}(w^* - c(\frac{\beta}{2})) \geq w^*$$

$$w^* \geq \frac{c(\frac{\beta}{2})}{\delta}.$$

Therefore, the discount factor δ satisfies $\delta \geq \frac{c(\frac{\beta}{2})}{5\beta}$ such that the set of $w^* \in [\frac{c(\frac{\beta}{2})}{\delta}, 5\beta]$ is non-empty.

■

The non-empty range of w^* is determined to allow the cooperative equilibrium to exist. The lower bound $w^* = \frac{c(\frac{\beta}{2})}{\delta}$ is the minimum wage that workers are willing to receive to play toward a cooperative equilibrium. In this case, the manager takes all the revenue for herself. Workers want to receive a higher wage when the effort cost increases and when the discount for future payoffs is stronger(smaller δ). If the wage is below the lower bound, it is not enough to cover the present value of the workers' discounted effort cost. On the other hand, the upper bound $w^* = 5\beta$ is the highest amount that the manager is willing to pay to stay in the cooperative equilibrium. Her revenue increases with the threshold β, so that she is able to pay a higher wage with a larger β.

The equilibrium illustrated so far is when subjects demonstrate self-interest or self-regarding preference. The self-regarding subjects make their decisions only in regard to their own payoffs and always act to maximize personal benefits. However, subjects may hold different preferences when making decisions. This other set of preferences are called other-regarding preferences. Other-regarding subjects care about their teammates' payoffs and maximizing personal payoffs is not necessarily their optimal strategy (Dhami, 2016). Subjects with these preferences not only seek to maximize their personal welfare, but also care about their opponents' payoffs. When a person's inequity aversion tendency is within a certain range (the inequity aversion factor α is not too small nor too large), the feasibility boundary of the time discount variable δ is expanded to allow a cooperative equilibrium to exist. As a result, the cooperative equilibrium is more sustainable.

The other-regarding nature is two-dimensional in this specific principal-agent setting, as it exists both between workers (horizontal axis) and among the manager and workers (vertical axis). An aversion to other-regarding preference inequity has previously been established by Walster, specifically identified as a form of inequity aversion in every time period t for the manager's utility u_{mt} and workers' payoffs u_{it} where α is the inequality aversion factor:

$$u_{mt} = \pi_t - \alpha(|\pi_t - y_{it}| + |\pi_t - y_{jt}|),$$

$$u_{it} = y_{it} - \alpha(|y_{it} - \pi_t| + |y_{it} - y_{jt}|).$$

$\alpha \in [0,1]$ is assumed to be identical across subjects and time periods for simplicity and it increases as a subject holds a stronger inequity aversion preference. Now, a new set of cumulative utility can be obtained as below [1]:

$$U_m^{'} = \sum_{t=1}^{\infty} \delta^{t-1} u_{mt},$$

$$U_i^{'} = \sum_{t-1}^{\infty} \delta^{t-1} u_{it}.$$

Proposition 2 illustrates that both non-cooperative and cooperative equilibrium still hold when subjects are with other-regarding preferences. Moreover, the range of the time discounted variable δ is wider than the range in the self-regarding preference equilibrium if the inequity aversion factor α is in certain determined range and narrower when surpasses the boundary.

Proposition 2. *a) The strategy (**zero-wage**, **non-coop.**, **non-coop.**) is still a sub-game perfect equilibrium with every subject receiving the identical payoff: zero.*

b) The set of optimal wage w^* for the other-regarding preference equilibrium is non-empty when $\delta \in (\frac{3(1-2\alpha)c(\frac{\beta}{2})-30\alpha\beta}{(1-3\alpha)10\beta+(1-6\alpha)c(\frac{\beta}{2})}, 1]$.

I. If inequity aversion factor $\alpha \in [\frac{c(\frac{\beta}{2})^2+5\beta c(\frac{\beta}{2})}{150\beta^2-6c(\frac{\beta}{2})^2}, \frac{5\beta}{10\beta-c(\frac{\beta}{2})}]$*, the range of the δ is wider than in the self-regarding trigger strategy equilibrium .*

II. If α is in the outside of the range $[\frac{c(\frac{\beta}{2})^2+5\beta c(\frac{\beta}{2})}{150\beta^2-6c(\frac{\beta}{2})^2}, \frac{5\beta}{10\beta-c(\frac{\beta}{2})}]$*, the range of δ is the same or even narrower than the range in the self-regarding equilibrium.*

Proof. a) In every sub-game where the manager gives **zero-wage** and workers choose to exert zero effort demonstrates a Nash Equilibrium, because every subject's payoff is equal and their inequity aversion cost is at its minimum. Subjects' deviations will not only aggrandize their cost but also enlarge the income differences, becoming non-profitable. Therefore, (**zero-wage**, **non-coop.**, **non-coop.**) is a sub-game perfect equilibrium for other-regarding subjects with everyone earning the same income.

[1] The case discussed here is when all subjects are with the same inequity aversion type: α is identical.

b) When the other-regarding manager is playing the trigger strategy, her payoff decreases by the payoff differences between herself and two workers. This number is consistent across all time periods if they continue to play according to the following equilibrium:

$$U_m^{'}(\textbf{positive-wage}, (\textbf{coop.}, \textbf{coop.})) = \frac{1}{1-\delta}(10\beta - 2w^* - 2\alpha|10\beta - 2w^* - (w^* - c(\frac{\beta}{2}))|).$$

If the manager deviates, her payoff will be the same as the self-regarding case because both workers and the manager have zero income:

$$U_m^{'}(\textbf{zero-wage}, (\textbf{coop.}, \textbf{coop.})) = 0.$$

She does not have the incentive to deviate if:

$$U_m^{'}(\textbf{positive-wage}, (\textbf{coop.}, \textbf{coop.})) \geq U_m^{'}(\textbf{zero-wage}, (\textbf{coop.}, \textbf{coop.}))$$

$$10\beta - 2w^* - 2\alpha|10\beta - 2w^* - (w^* - c(\frac{\beta}{2}))| \geq 0.$$

Case 1: If $10\beta - 3w^* + c(\frac{\beta}{2}) > 0$ and $w^* < \frac{10\beta + c(\frac{\beta}{2})}{3}$:

$$10\beta - 2w^* - 2\alpha(10\beta - 2w^* - (w^* - c(\frac{\beta}{2}))) \geq 0$$

$$w^* \leq \frac{5(1-2\alpha)\beta - \alpha c(\frac{\beta}{2})}{1-3\alpha}.$$

To allow the set of w^* to be non-empty, the inequities $\frac{10\beta + c(\frac{\beta}{2})}{3} \geq 0$ and $\frac{5(1-2\alpha)\beta - \alpha c(\frac{\beta}{2})}{1-3\alpha} \geq 0$, must hold. $\frac{10\beta - c(\frac{\beta}{2})}{3} \geq 0$ is always hold by the definition that $\max(c(\frac{\beta}{2})) = 20$ and $10\beta \in (20, 200]$. On the other hand, $\alpha \leq \frac{5\beta}{10\beta - c(\frac{\beta}{2})}$ to allow the inequity $\frac{5(1-2\alpha)\beta - \alpha c(\frac{\beta}{2})}{1-3\alpha} \geq 0$ to exist.

Case 2: When $10\beta - 3w^* + c(\frac{\beta}{2}) \leq 0$ and $w^* \geq \frac{10\beta + c(\frac{\beta}{2})}{3}$:

$$10\beta - 2w^* + 2\alpha(10\beta - 2w^* - (w^* - c(\frac{\beta}{2}))) \geq 0$$

$$w^* \leq \frac{5(1+2\alpha)\beta + \alpha c(\frac{\beta}{2})}{1+3\alpha}.$$

Since $\frac{10\beta + c(\frac{\beta}{2})}{3} \leq \frac{5(1+2\alpha)\beta + \alpha c(\frac{\beta}{2})}{1+3\alpha}$ must be true to allow the set of w^* to be non-empty. This equation is true for any $5\beta \geq c(\frac{\beta}{2})$. This inequality is always true for $\beta \in \mathbb{Z}[3, 20]$. Therefore, the interval of the set of players $w^* \in [\frac{10\beta + c(\frac{\beta}{2})}{3}, \frac{5(1+2\alpha)\beta + \alpha c(\frac{\beta}{2})}{1+3\alpha}]$.

Second, for individual worker i, when she plays **cooperative** strategy, her income is consistent with her coworker j. Therefore, her payoff of playing **cooperative** with inequity aversion preference is:

$$U_i^{'}(\textbf{coop.}, (\textbf{positive-wage}, \textbf{coop.}) = \frac{1}{1-\delta}(w^* - c(\frac{\beta}{2}) - \alpha|10\beta - 2w^* - (w^* - c(\frac{\beta}{2}))|).$$

When she deviates and plays the **non-cooperative** strategy, the combined effort is below the threshold β and the manager earns zero profit. The worker's payoff is then:

$$U_i^{'}(\textbf{non-coop.}, (\textbf{positive-wage}, \textbf{coop.}) = w^* - c(1) - \alpha(|0 - 2w^* - (w^* - c(1))| + |c(\frac{\beta}{2}) - c(1)|).$$

Workers will not deviate if:

$$U_i^{'}(\textbf{coop.e}, (\textbf{positive-wage}, \textbf{coop.}) \geq U_i^{'}(\textbf{non-coop.}, (\textbf{positive-wage}, \textbf{coop.}).$$

Case 1: When $10\beta - 3w^* + c(\frac{\beta}{2}) > 0$ and $w^* < \frac{10\beta + c(\frac{\beta}{2})}{3}$:

$$\frac{1}{1-\delta}(w^* - c(\frac{\beta}{2}) - \alpha(10\beta - 2w^* - (w^* - c(\frac{\beta}{2})))) \geq (1-3\alpha)w^* - \alpha c(\frac{\beta}{2})$$

$$w^* \geq \frac{10\alpha\beta + (1+\delta\alpha)c(\frac{\beta}{2})}{6\alpha + \delta(1-3\alpha)}.$$

To allow the set of the optimal wage choice w^* to be non-empty, $\frac{10\beta + c(\frac{\beta}{2})}{3} \geq \frac{10\alpha\beta+(1+\delta\alpha)c(\frac{\beta}{2})}{6\alpha+\delta(1-3\alpha)}$ must hold. Then $\delta \geq \frac{3(1-2\alpha)c(\frac{\beta}{2})-30\alpha\beta}{(1-3\alpha)10\beta+(1-6\alpha)c(\frac{\beta}{2})}$.

Case 2: When $10\beta - 3w^* + c(\frac{\beta}{2}) \leq 0$ and $w^* \geq \frac{10\beta+c(\frac{\beta}{2})}{3}$:

$$\frac{1}{1-\delta}(w^* - c(\frac{\beta}{2}) + \alpha(10\beta - 2w^* - (w^* - c(\frac{\beta}{2})))) \geq (1-3\alpha)w^* - \alpha c(\frac{\beta}{2})$$

$$w^* \geq \frac{[1-(2-\delta)\alpha]c(\frac{\beta}{2}) - 10\alpha\beta}{\delta(1-3\alpha)}.$$

To allow the set of optimal wage choice to be non-empty: $\frac{10\beta+c(\frac{\beta}{2})}{3} \leq 100$ and $\frac{[1-(2-\delta)\alpha]c(\frac{\beta}{2})-10\alpha\beta}{\delta(1-3\alpha)} \leq 100$ must be true. The first condition is always hold for $\beta \in \mathbb{Z}[3,20]$ and $10\beta + c(\frac{\beta}{2}) - 300 < 0$. The second condition hold if $\delta \geq \frac{(1-2\alpha)c(\frac{\beta}{2})-10\alpha\beta}{(1-3\alpha)100-\alpha c(\frac{\beta}{2})}$. This number is smaller than the upper bound obtained in case 1.

As a result, the set of optimal wage w^* is non-empty for the cooperative equilibrium under the condition $\alpha \in [0, \frac{5\beta}{10\beta - c(\frac{\beta}{2})}]$ and $\delta \in [\frac{3(1-2\alpha)c(\frac{\beta}{2})-30\alpha\beta}{(1-3\alpha)10\beta+(1-6\alpha)c(\frac{\beta}{2})}, 1]$.

When compared to the range of δ in self-regarding cooperative equilibrium, the range of δ is wider than in the other-regarding cooperative equilibrium, if the following condition is satisfied:

$$\frac{c(\frac{\beta}{2})}{5\beta} \geq \frac{3(1-2\alpha)c(\frac{\beta}{2}) - 30\alpha\beta}{(1-3\alpha)10\beta + (1-6\alpha)c(\frac{\beta}{2})}$$

$$150\alpha\beta^2 - c(\frac{\beta}{2})(5\beta + 6\alpha c(\frac{\beta}{2}) - c(\frac{\beta}{2})) \geq 0$$

$$\alpha \geq \frac{c(\frac{\beta}{2})^2 + 5\beta c(\frac{\beta}{2})}{150\beta^2 - 6c(\frac{\beta}{2})^2}.$$

This range of $\alpha \in [\frac{c(\frac{\beta}{2})^2+5\beta c(\frac{\beta}{2})}{150\beta^2-6c(\frac{\beta}{2})^2}, \frac{5\beta}{10\beta-c(\frac{\beta}{2})}]$ is non-empty for $\beta \in \mathbb{Z}[3,20]$, and the range of δ is wider than in the self-regarding case if α is chosen in this certain range. Under the determined inequity aversion factor α, other-regarding subjects are less likely to deviate from the cooperative equilibrium path because they care about others' income and want to keep their teammates' payoffs close to their own payoffs. Otherwise, if α is outside of this certain range, the range of possible δ is the same or even narrower than in the self-regarding equilibrium.

■

The wider range of optimal δ implies that the cooperative equilibrium is more likely to hold when more δ is accessible. It requires subjects to have proper degree of inequity aversion (neither too strong nor too weak). When subjects are too envious of their teammates ($\alpha > \frac{5\beta}{10\beta - c(\frac{\beta}{2})}$), they tend to deviate to a non-cooperative strategy and keep the income difference low. Following this deviation, subjects will earn zero profit. The income difference will also be zero. Envious workers who object to a high-income manager will punish the manager by reducing the firm's revenue through shirking. The same strategy is demonstrated by the envious manager, who will sacrifice her own revenue and pay zero wage to make workers earn zero income. On the other hand, a subject who is guilty about receiving a payoff higher than her teammates will deviate to non-cooperative strategy to narrow the income gap.

Furthermore, the equilibrium with an ignorant subject whose inequity aversion factor is small ($\alpha < \frac{c(\frac{\beta}{2})^2 + 5\beta c(\frac{\beta}{2})}{150\beta^2 - 6c(\frac{\beta}{2})^2}$) will have a similar outcome as the equilibrium with self-regarding subjects. This is because subjects' other-regarding preference is not strong enough. They will continue to focus on maximizing their personal payoffs and pay very little attention to others' income. Therefore, this equilibrium result is not different from the standard case of the self-regarding preference. In other words, the impact of α within subjects' utility function is too small to be significant.

1.3 Experimental Design

Subjects were recruited from UCI's ESSL subjects pool and participated in the experiment online due to restrictions on in-person experiments during the COVID-19 pandemic. When subjects signed up for the session, they received a separate Google Form link to enter their payment information, which was kept separate from the research data. Subjects were also provided with a unique and randomly generated participation ID, which allowed them to log into the session without revealing any of their personal information.

When the session began, subjects received a Heroku link to take part in the online experiment anonymously. They were randomly paired with other two subjects without knowing their demographic information. These matches remained the same during the session and subjects were unable to communicate with each other. They were also not recorded or photographed, as they were not asked to open their camera or join a group chat. The experiment utilized a program written by oTree.

Subjects were provided online instructions in the beginning of each session and during the two experimental stages. For the first stage, the dictator game was conducted within the context of charitable giving. As their "show-up payment," all participants were initially endowed with 700 points, equal to 7 USD. This experimental design is similar to that used by McBride and Ridinger (2020). The participants were then asked to give to one of five charities provided (Appendix A) from their endowment. This donation was made on their behalf without revealing any identifying information. This task aims to test subjects' altruism and other-regarding characteristics within each treatment groups.

Following the dictator game, groups of three participants were formed randomly and the resulting groups were instructed to play the gift exchange game. These groups remained fixed for the entirety of the session so that subjects could form beliefs about their teammates through repetitive interactions. A framework of one principal and two agents was then established between the manager and the workers. Subjects were provided with instructions about their roles and their designated behaviors. The threshold β was common knowledge, as it was communicated to all subjects in the first instructions. After seeing these instructions, subjects were given a quiz to test their understanding. If they answered a certain question incorrectly, explanations of the correct answers were given to verify their understanding of the correct answer.

The manager then determined the wage that she wanted to pay each worker, selected from a range of 0 to 100 points. Each worker within a team was paid the same wage. While each worker can observe her coworker's effort exertion, the manager can only see two workers' sum efforts. This is consistent with the incomplete contract design to eliminate other reward-driven motivations. Individual workers then decide their effort exertions, selecting a level from 1 to 10, which is costly. The cost of this effort is a convex format borrowed from Abeler et al. (2010)'s design, as shown in table 1.1.

A simple gift exchange game was conducted in the control group, identified as the base case. In this group, the managers' payment is determined by the cumulative effort of the workers:

$$\pi_t = 10(e_{it} + e_{jt}) - 2w_t \tag{1.1}$$

The worker's payoff is:

$$y_t = w_t - c(e_i) \tag{1.2}$$

The treatment group introduces a stronger moral hazard motivation, as there is a required minimum effort exertion goal $\beta > 0$ that the team must achieve. If this goal is not reached, the team fails to provide public goods. When this occurs, the manager has no positive return but instead bears a wage cost. If $e_{it} + e_{jt} < \beta$ The manager's payoff then becomes:

$$\pi_t = -2w_t \tag{1.3}$$

Thus, subjects' total payoffs are the sum of what remains of their their 7 dollars "show-up" payment after donation plus their total earning from the gift exchange game. This payoff averages between 10 and 20 USD. Any subjects whose earnings are lower than 7 dollars will be paid 7 dollars.

Because of this, there is no anticipated risk or cost for participants, and there are no benefits other than the monetary payment.

Two sets of β are chosen to be the treatment groups. HT treatment is the case when the production threshold $\beta = 14$ and the LT treatment is $\beta = 6$. A single worker can only feasibly exert a maximum of 10 units of effort; therefore, exerting 14 units of effort can only be accomplished by multiple workers. Even numbers are chosen to allow for equal divisions, as the minimum unit of effort in the design is 1 unit.

The game was conducted for 7 to 10 rounds and the ending was randomly determined, with a random likelihood that the game ends after each round once the number of rounds exceeds 7. The random ending mimics the infinitely repeated game environment and avoids the end-game effect, so that subjects do not know when the game is going to end. This design has been widely used in cooperative and infinitely repeated game experiments (Bó and Fréchette 2009). For each time period, subjects are playing a one shot game: their choices in the last round do not directly affect their payoff in future rounds. This repetition allows subjects to form beliefs about their teammates' reciprocal characteristics. There is a possibility that subjects adjust their behaviors according to who they interact with. Participants' payoffs are considered as their total payoffs in the gift exchange game, as well as what they have kept in the dictator game from their initial endowment.

After finishing the gift exchange game, participants were asked to guess the value of their two teammates' donation amounts from the dictator game. A survey was conducted to explicitly evaluate participants' beliefs regarding both their own and their teammates' reciprocity levels, which was difficult to assess in the context of the one shot game. The survey included a numerical scale assessing how much they agreed with a series of statements about their own generosity and how they cared about fairness in the working environment (shown in Appendix A.2).

1.4 Hypothesis

There are several null hypothesis stated to estimate subjects' behaviors:

1. In the charitable giving dictator game, subjects' donation amount varies. The compositions of subjects with different levels of altruism (revealed by their donation behaviors) are similar across treatment groups.

2. Workers/Managers in the threshold treatment groups follow a similar effort/wage contribution pattern to their contributions in the base case.

3. In threshold treatment groups, the frequency of workers' production failures are similar between HT and LT treatment groups and these failures in production will not drastically alter the manager's wage giving strategy.

4. The ratio of subjects who adopted a non-cooperative strategy are similar across all treatment groups.

5. Workers make their decisions without considering their coworkers' effort contribution nor their teammates' generosity characteristics.

6. Subjects' self-evaluations do not significantly correlate with their contribution strategies.

1.5 Data Analysis

102 subjects were recruited from UCI's ESSL subject pool and took part in the session online through a Heroku server during the COVID-19 pandemic. They were randomly assigned to one treatment (HT:high threshold, LT:low threshold) or the base case. Regardless of assignment, they were formed into 3-member groups: one manager and two workers. Once the session began, they were given 700 points for their initial endowment, which was used to donate to one charity, selected from five charities listed on the web page (100 points were equal to 1 dollar).

Six results are discussed in this section to summarize the findings from the experiment.

Result 1. *Support Hypothesis 1: subjects' donations are spread out to all amount categories, suggesting that subjects are diverse with regard to altruism. However, the compositions of subjects with different generosity levels in each treatment group are similar.*

Subjects' donation statistics in the charitable dictating game are summarized in Table 1.2. The donation task aims to assess subjects' generosity levels and their altruistic practices. The results were heterogeneous and are represented in the table below:

Table 1.2: Subjects' Donation in Each Treatment

Treat.	Sub.	0	1-300	300-500	500-700	Avg.
Base	33	12	14	3	4	175.82
HT	33	7	16	3	7	229.94
LT	36	9	18	6	3	186.61
Sum	102	28	48	12	14	197.46

A two-proportion Z-test was utilized to compare every two treatments' donation results in table 1.2. All tests results were statistically insignificant, implying that subjects' generosity levels are similar within the two treatment groups.

Result 2. *Contradicts Hypothesis 2: HT and LT treatment change workers' initial average effort choice and the threshold makes managers to pay less average wage over time. The trigger strategy described in proposition 1 is more likely to be adopted in HT treatment than in the LT treatment.*

The second task was the gift exchange game. In each round, the manager chose a wage and the two workers exerted costly effort (1 to 10 units) with respect to this received wage. The high threshold (HT) treatment requires at least 14 units of effort in order to successfully produce the final goods. If the final goods fail to be produced—meaning that the combined effort is below 14 units—the manager receives zero revenue from production and still pays the wage cost. The low threshold (LT) treatment sets the threshold at 6 units.

Figure 1.1: Average Wage in Each Period

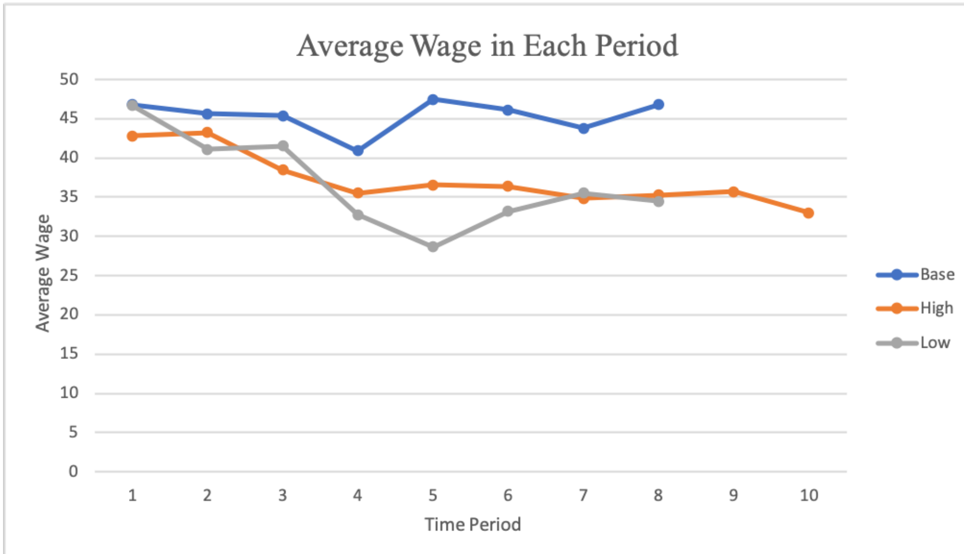
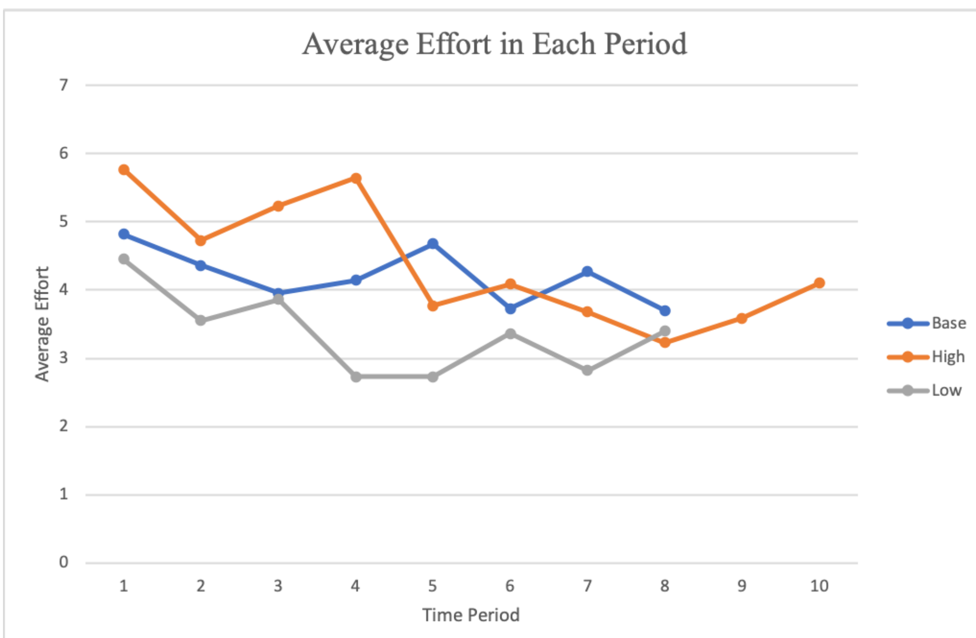


Figure 1.2: Average Effort in Each Period



Subjects' average choices for each treatment are shown in figure 1.1 and figure 1.2, respectively. On average, managers in both treatment groups offered lower wages over time, a tendency not observed in the control group. To test if the binding threshold in the treatment groups had an effect on manager's wage choices, a random effect regression was utilized. The results were statistically significant, suggesting the the added threshold triggers a learning effect. This learning effect is induced by workers' frequent failure to contribute sufficient effort for production, resulting in managers earning negative revenues. In the group where workers are self-regarding and contribute less than sufficient effort, managers are more likely to give low wages after learning the workers' typeswhich is consistent with the trigger strategy described in proposition 1. In other words, managers respond with a self-regarding preferred strategy. Two out of eleven groups' strategies in the HT treatment converge to the self-regarding trigger strategy Nash equilibrium stated in proposition 1. This occurs in the later period of the game, when workers contribute minimum effort and managers give zero wage. This equilibrium was never achieved among groups in the LT treatment and base case. Most of the subjects in the LT treatment and base case play the game with the other-regarding preference across all time periods. Therefore, the trigger strategy is less likely to be adopted when the treatment is low.

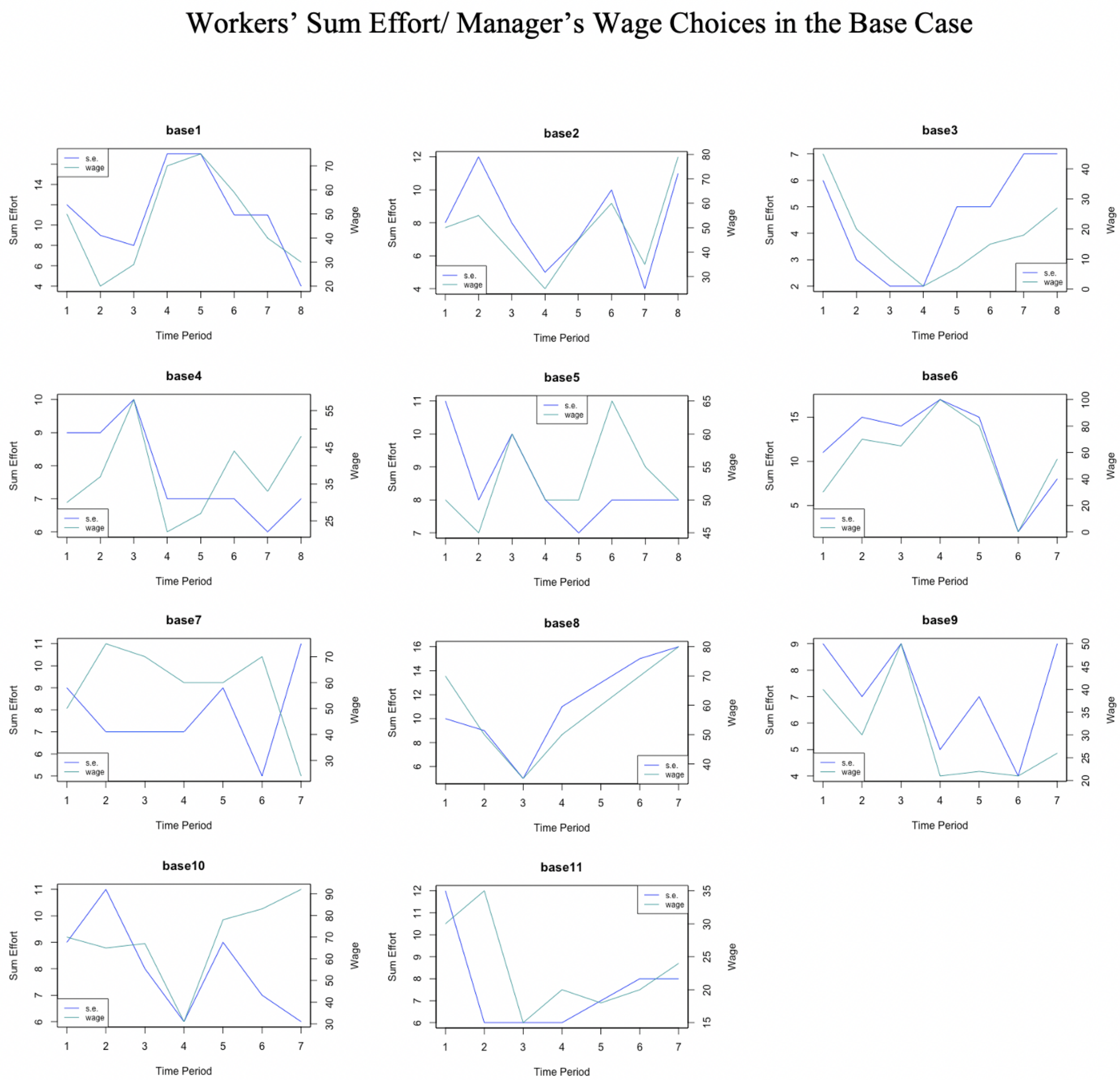
Regarding workers' effort contributions, there is no significant distinction between the three groups, as shown in figure 1.2. It is difficult to distinguish effort-giving patterns across treatment groups with regard to time. However, in the early periods of the game, workers in the HT treatment demonstrate the highest average initial effort, while the LT treatment group demonstrates the lowest average initial effort. One possible explanation for this observation is that the threshold β signals workers to the fair effort that they will need to contribute prior to receiving any information about their teammates. Nevertheless, the period 1's average effort in HT treatment was lower than half of the production threshold yet above the threshold in the LT treatment. This indicates that the high threshold discouraged a proportion of fair-minded workers to act as the threshold required. In the situation where the production threshold is zero (i.e. the base case), the average effort in the initial period is close to 5 units. This is consistent with a general awareness of fairness, since 5 is half of the maximum effort that an worker can choose.

Result 3. *Rejects hypothesis 3: in the HT treatment, the frequencies of production failures were higher than the failure rate in the LT treatment. Such production failures prompt the trigger strategy, in which the manager decreases wage spending in the following period as a tool to punish workers.*

Every individuals' actions in each treatment group are listed in figure 1.3, figure 1.4 and figure 1.5. Subjects' strategies are diverse, but one common strategy is followed by all managers: when workers shirk and the sum effort is reduced respective to the last period, managers always decrease their wage spending for at least one time period. This is a punishment mechanism that all managers demonstrated regardless of their preferences, even though this tendency be maintained until the end of the experiment as described in trigger strategy.

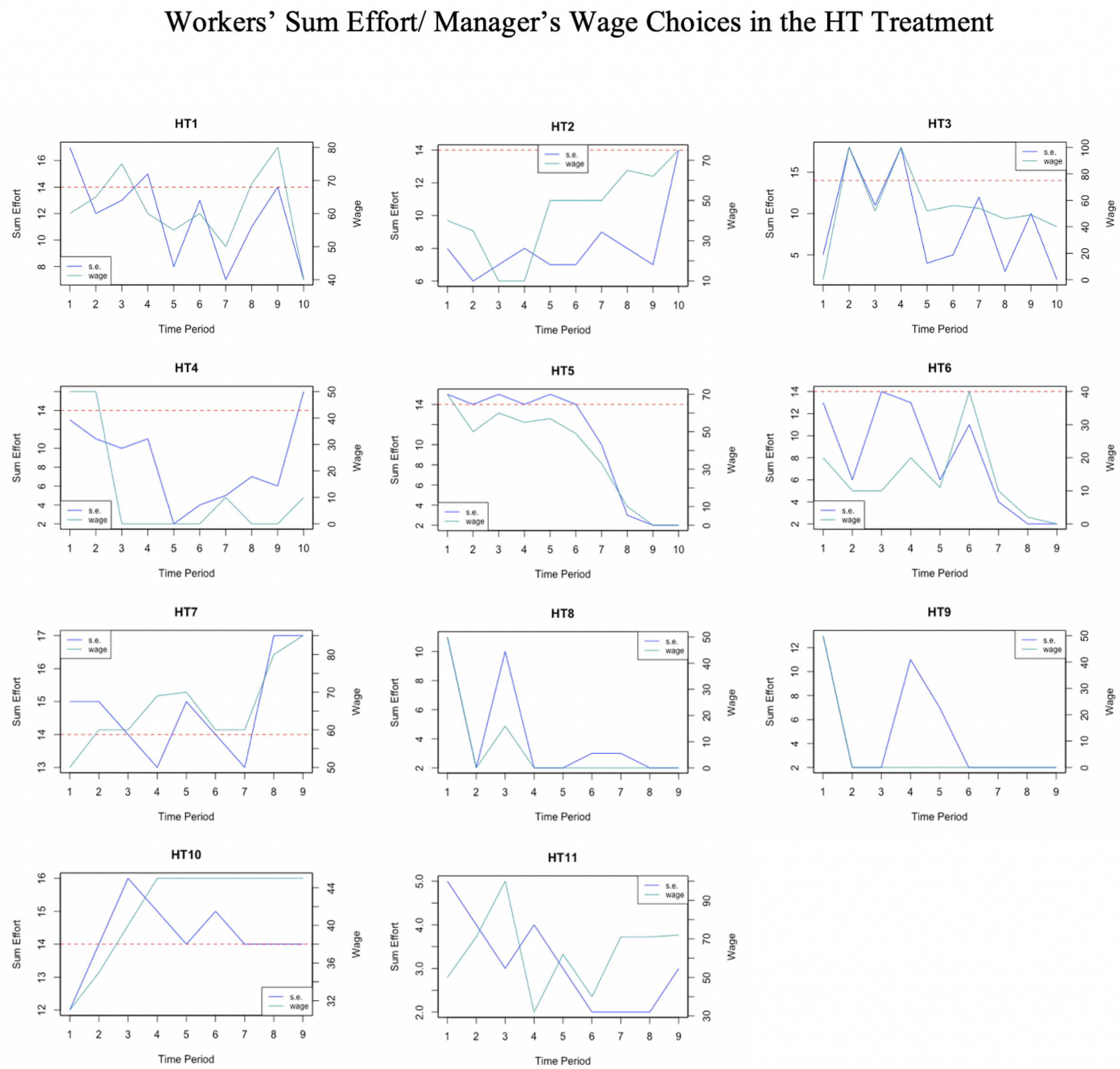
The frequency of production failure is the number of the times that the sum effort curve is under the threshold line β. The HT treatment groups demonstrate a larger accumulative number of production failures than the LT treatment groups, indicating that workers in the HT treatment have a harder time contributing sufficient effort. Such consistent failures in the HT treatment groups leads to a modification in subjects' behaviors which is more dramatic than the resulting modification in the LT treatment, as more subgroups form a self-regarding preferred Nash equilibrium before the end of the experiment. As demonstrated in figure 1.4, subjects in groups HT5, HT6, HT8, and HT9 successfully followed the trigger strategy during the final rounds of the game. Nevertheless, there are not any subgroups in the base case or the LT treatment that successfully form this kind of equilibrium.

Figure 1.3: Workers' Sun Effort/ Manager's Wage Choices in Base Case



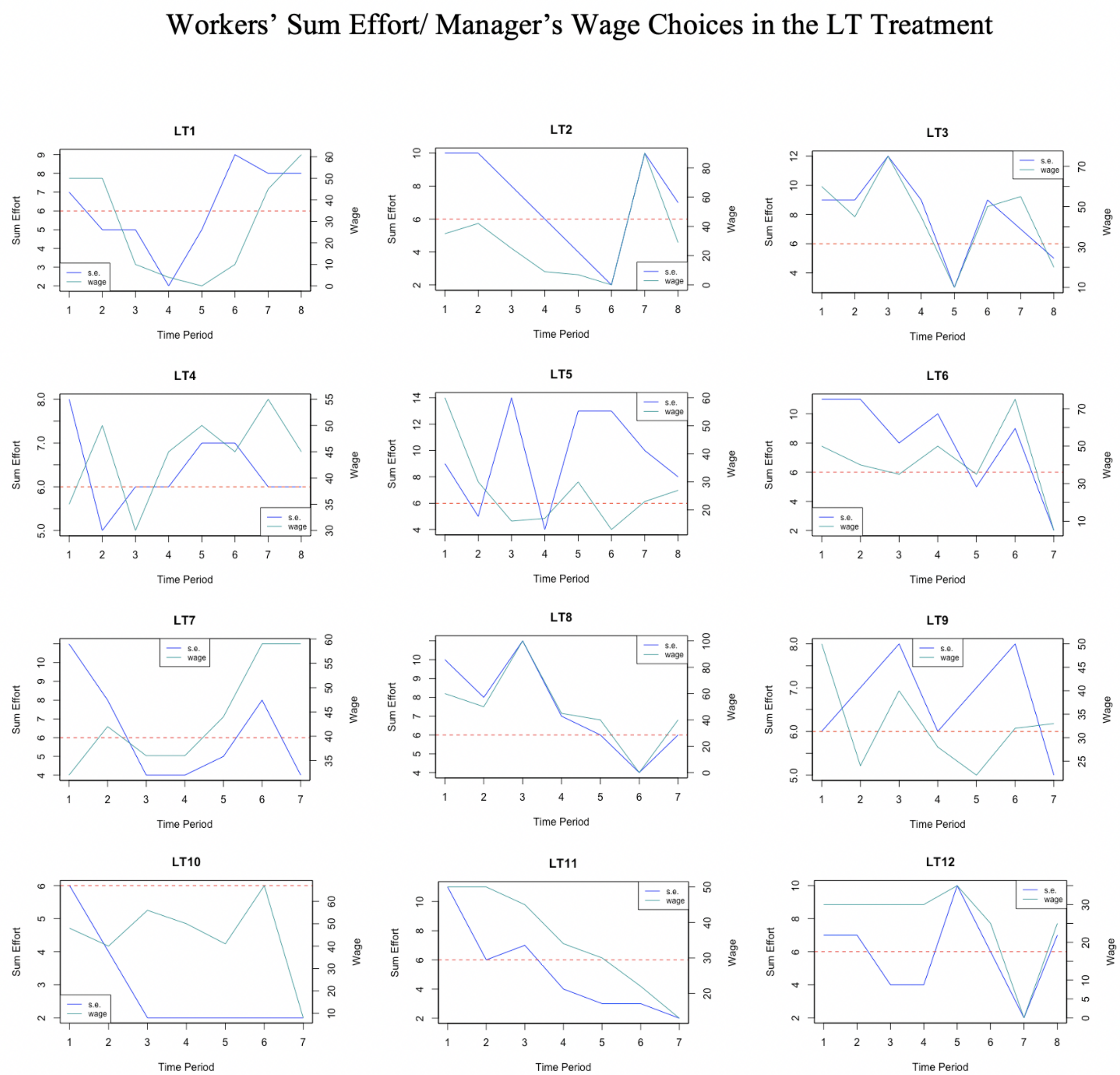
Note: The blue line represents workers' sum effort. The green line is managers' wage choice.

Figure 1.4: Workers' Sun Effort/ Manager's Wage Choices in HT Case



Note: The blue line represents workers' sum effort. The green line is managers' wage choice.

Figure 1.5: Workers' Sun Effort/ Manager's Wage Choices in LT Case



Note: The blue line represents workers' sum effort. The green line is managers' wage choice.

Result 4. *Denies Hypothesis 4: HT treatment group induces a higher proportion of subjects to practice the non-cooperative strategy than in the LT treatment.*

In the charitable giving dictator game, subjects did not show significant differences in characteristics indicative of altruistic behavior across the treatment groups (shown in table 1.2). These results reveal that the composition of subjects with different generosity levels are originally similar, prior to participation in the gift-exchange game. To understand how the treatment altered subjects' behaviors and their internal motivations, subjects were divided into two groups: self-regarding and other-regarding. This was determined according to the strategies they exhibited in the gift exchange game. Managers who had given zero wage, as well as workers who exerted minimum effort in at least one time period, were considered as self-regarding. Such subjects had practiced the non-cooperative strategy at least once. 35 percent of managers and 64 percent of workers practiced self-regarding behaviors during the sessions and were thus counted as self-regarding subjects. The remaining subjects were considered as other-regarding subjects. Among these other-regarding subjects (i.e. subjects who never exhibited non-cooperative behaviors), the frequency of cooperative equilibrium was determined by the treatment. Workers choose to devote at least half of the combined effort 75 percent of time in the base case, as compared to 91 percent of time in the HT treatment, when workers contributed at least the half of the threshold β. Nonetheless, the low production threshold in the LT case encouraged shirking behavior, and other-regarding workers devoted at least half of the binding threshold (β) only 35 percent of time (shown in table 1.3).

Table 1.3: Other-Regarding Workers in Each Treatment

Treatment	Workers	Pure O-R (W)	Percentage (W)
Base	22	13	75.49
HT	22	7	91.11
LT	24	5	35.42
Sum	66	25	71.85

Percentage(W): among the other-regarding workers, the percentage of time that workers perform other-regarding preferred behaviors (i.e., their contributed effort equals to at least half of the sum effort).

For managers' wage choices, as stated in proposition 1, there exists another cooperative equilibrium. In the equilibrium, workers' joint effort is at least equal to the threshold β and the manager pays workers the positive wage w^* at the same time. The wage payment is within the interval of the optimal wage $w^* \in [\frac{c(\frac{\beta}{2})}{\delta}, 5\beta]$. As shown in figure 1.4, subjects in group HT7 and HT10 achieved the cooperative equilibrium by stabilizing their effort and wage choice far above zero, allowing players to earn a positive payoff.

Moreover, when the binding threshold is applied within the treatment groups, different rates of production failures are observed. The HT treatment carries a much higher failure rate (0.711) compared to the LT treatment (0.344). This is expected since the higher threshold requires workers to exert a higher combined effort, which is much more costly than exerting low effort. The high effort cost in the HT treatment provides workers an incentive to deviate from their other-regarding nature and perform non-cooperative behaviors, thereby contributing low effort.

These outcomes have demonstrated that the high threshold drives out subjects' other-regarding incentives and allow them to interact with each other in a manner closer to the non-cooperative strategy described in proposition 1. On the contrary, when the threshold is low, subjects' behaviors are driven away from the non-cooperative equilibrium.

Result 5. *Hypothesis 5 is partially rejected: in both the HT and LT treatment groups, workers make effort contributions according to not only the wage but also their coworkers' effort choice. Their beliefs about their teammates' charitable donations affect their effort choice significantly in all treatment groups.*

The gift exchange game is a two-sided responsive system in which workers make their decisions according to their coworker's efforts and the manager's wage decision. As shown in table 1.4, workers' effort contributions are statistically significant with respect to the wage: as wage increases by 1 point, workers increase their effort contributions by 1 percent across all treatment groups. With respect to their coworkers' actions, the threshold treatments enhance the horizontal interactions within the team, that is, between workers. In the base case, workers' effort contributions are not significantly correlated with their coworkers' actions. However, in the HT and LT treatments, this correlation is statistically significant. This effect is observed especially when the threshold is high: in the HT treatment, every percent increase in their coworkers' effort contribution increases their effort contributions by an average of 30 percent.

The matching of groups during the game is fixed and interactions among teammates are repeated throughout the game. This occurs so that workers form beliefs about their teammates' behavioral patterns, for example if a teammate is: selfish, reciprocal, or generous. One's reciprocity is defined as "responding to actions he perceives to be kind in a kind manner, and to actions he perceives to be hostile in a hostile manner" (Falk and Fischbacher 2005). Workers follow this behavioral rule by exerting higher effort when a higher wage is paid, as well as when her coworker exerts a higher level of effort (as shown in Table 1.4). This behavioral pattern is also consistent with the Fehr-Schmidt form preference described in Proposition 2. At the end of the game, subjects are asked to guess their teammates' donation amount. A universal quantitative criteria to evaluate ones' generosity is not established, since subjects have different opinions about the value of money. Therefore, a relative standard, defined as the difference between the worker's own donation and her guess about her teammates' donations, is applied in the regression. If the subject believes that her teammates are more generous than herself, she tends to estimate that her teammates have donated more than herself. The positive parameters on D_1 and D_2 suggests that the subject believes she is more generous than her coworkers.

Workers' donation guesses reflect their beliefs regarding teammates' fair or reciprocal characteristics. These beliefs direct their effort devotion in the game: in the base and HT treatment, workers tend to shirk when they realize that their coworker is generous with their contributed effort. Yet, this phenomenon does not appear in the LT case. One explanation for this difference is that in the base and HT case, workers initially exert high effort due to the initial signal provided by the threshold, so the manager perceives a sizable sum effort. When workers know that their coworker will keep giving sufficient effort, they have an incentive to decrease their own effort. This is barely noticeable in the sum effort pool, so the worker has a low risk of being punished by the manager.

Result 6. *Partially disavow Hypothesis 6: subjects' self-evaluations of their generosity and their attitude towards fairness shown through the survey significantly correlate with subjects' contribution strategy throughout the game in the HT and base case, but not the LT treatment.*

Subjects form beliefs about their teammates as well as evaluate themselves throughout the sessions. To understand how subjects' self-evaluations guide their choices, they are asked to fill out

Table 1.4: Random effect model of Donation on Effort

	Base	Pr(>lzl)	HT	Pr(>lzl)	LT	Pr(>lzl)
Inter	0.558	4.110e-05*	0.293	0.096	0.513	0.001*
Log(OE)	2.526e-03	0.974	0.306	8.756e-06*	0.162	0.031*
Wage	0.014	3.189e-10*	0.013	2.142e-08*	0.011	3.798 e-06*
D	6.56e-04	0.034*	1.504e-04	0.882	-3.037e-04	0.055*
D_1	4.283e-04	0.763	3.17e-03	0.044*	-1.422e-03	0.030*
D_2	-5.998e-03	0.0018*	-5.19e-03	0.026*	9.497e-04	0.139
D*D_1	7.102e-06	0.361	-6.506e-06	0.064*	NA	NA
D*D_2	7.924e-06	0.334	2.10e-05	0.041*	NA	NA

E : Worker's effort. OE: The other worker's effort contribution in a group. D_1 : The worker's donation minus her guess about her manager's charity donation amount. D_2 : The worker's donation minus her guess regarding the other worker's charity donation. D: The worker's donation to the charity.

a survey at the end of each session to test their beliefs about their personal generosity and reciprocal behavior. This is accomplished by picking a number from a scale of 1 to 7 reflecting how much they agree with each statement (Appendix B). A random effect linear regression was conducted between workers' effort and managers' wage choice as well as their self-evaluations on their own generosity and reciprocity characteristics, specifically corresponding to how much they agree on the statements Q1 and Q2 on the survey (shown on Table 1.5). These questions describe subjects as generous and characterize them as caring about fairness in the working environment. Subjects then select a number on a scale from 1 to 7 to describe their evaluations, with 7 representing the strongest level of agreement and 1 representing the least. In the regression, workers who regard themselves as fair and generous tend to exert higher effort across treatments. In contrast, managers' behaviors are treatment-determined: in the base case, self-regarding and fair managers focus on punishing workers who shirk and tend to offer less wage if they see themselves as fair people. On the contrary, the binding threshold in the HT treatment appears to enhance managers' toleration of workers' shirk behaviors. Correspondingly, they choose to give increased wages if they see themselves as generous.

This finding rationalizes the importance of hiring generous workers in the firm. Workers who regard themselves as generous tend to work hard and their behaviors are a potential positive impact on their coworkers to encourage them to work hard as a team, especially when those workers see themselves as fair workers. This is beneficial for the firm, as it increases productivity.

Table 1.5: Random effect model of Effort/Wage on Survey Question

	Total$_M$	Base$_M$	HT$_M$	LT$_M$	Total$_W$	Base$_W$	HT$_W$	LT$_W$
Inter.	30.99	75.71	-100.88	-0.4	-1.31	-0.35	-2.37	1.08
Pr(>|z|)	0.00*	0.00*	0.08*	0.99	0.00*	0.27	1e-05*	0.56
Payoff	-0.15	-0.29	-0.08	-0.19				
Pr(>|z|)	5e-11*	3e-10*	0.01*	2e-07*				
Log(Eff.)	16.96	14.88	18.73	15.32				
Pr(>|z|)	2e-16*	9 e-11*	5e-08*	3e-05*				
Log(OE)					0.23	0.08	0.31	0.16
Pr(>|z|)					1e-08*	0.3	1e-06*	0.03*
Wage					0.01	0.01	0.01	0.01
Pr(>|z|)					<2e-16*	1e-09*	4e-09*	9e-06*
Q1	-0.92	-6.27	31.14	0.57	0.36	0.09	0.63	-0.26
Pr(>|z|)	0.54	0.00*	0.02*	0.93	0.00*	0.08*	3e-07*	0.49
Q2	-2.74	-10.29	16.26	3.48	0.27	0.11	0.40	-0.10
Pr(>|z|)	0.08*	0.00*	0.11	0.51	0.00*	0.03*	0.04*	0.73
Q1*Q2			-4.85	-0.42	-0.06		-0.11	0.05
Pr(>|z|)			0.05*	0.71	0.00*		0.00*	0.46

1.6 Conclusion

In the principle agent framework, the binding threshold production environment drives out subjects' other-regarding incentives. In the HT and LT treatment, there are more subjects—both managers and workers—who choose the non-cooperative strategy throughout the session compared to subjects in the base case. This occurs even though those subjects show no distinct differences in the charitable donation task. Furthermore, the threshold setting increases the risk of production failure. Managers therefore learn to play the non-cooperative strategy over time, and some groups converge to the non-cooperative equilibrium especially when the threshold is high. In other words, this kind of binding goal setting scheme is not optimal to motivate workers to work hard and improve the firm's revenue margin. Workers do not earn a share in the production revenue and completing the firm's production goal does not change their pre-determined wage. Therefore, a new profit-sharing contract which allows workers to earn a share in production revenue may help increase workers' enthusiasm to contribute sufficient effort toward production goals.

Apart from the subjective conditions set by the treatments, subjects' beliefs direct their moves in the game. Workers have the incentive to shirk if they believe their coworkers are generous with their effort exertion. The production threshold works together with workers' beliefs in determining their effort contribution: a low threshold alleviates workers' obligations and they continue to shirk if they regard their managers as generous in wage giving. Conversely, a belief that the threshold is high encourages workers to work hard, since the high threshold induces managers to pay a relatively high wage and workers work harder since they are paid more. Their self-evaluations also have an effect on their strategies. Managers who regard themselves as generous tend to give higher wages and generous-minded workers exert more effort in the HT treatment.

This finding identifies the importance of considering workers' tendencies toward generous behavior in the hiring process: working with generous workers who always regard themselves as contributors and care less about their personal losses will help the team build a positive working culture. This will improve the team's overall working efficiency. This becomes important especially when the firm's production goal is challenging, as workers who behave in a generous way will become a role model to encourage coworkers to work hard.

The binding threshold communicates two sets of information to subjects: an unbinding goal signal and a binding threshold which directly impacts managers' payoffs. In order to decompose those two effects, another set of goal-setting treatments should be tested in the future study, namely, the non-binding production thresholds in the game. Moreover, adding a profit-share scheme to workers' payoffs will allow the thresholds gift exchange game to have similar features as the threshold public goods game. The comparison of the results yielded by these two games will improve understanding of contract design between a principal and agents, specifically under the gift exchange game context. This form of the game has not yet been studied and is worthy of further exploration.

Chapter 2

Effort and the Timing of Payments in a Threshold Gift Exchange Game

Abstract

This study considers whether changing the timing of payments in different versions of a gift exchange game can improve subjects' production. The theoretical model proposed by this study predicts that the payment order does not alter subjects' behavior. However, the experimental results demonstrate that changing the payment order does significantly increase workers' effort contribution, as well as reduce managers' wage payment in the threshold gift exchange game and the non-threshold gift exchange game. A higher proportion of subjects reach a cooperative equilibrium in the payment-after-production treatment. I define the payment made after the production as a bonus payment, while payment before production is respectively designated as a wage payment. Adding a non-zero threshold to the gift exchange game does not alter subjects' behavior in the wage treatment, but the threshold increases managers' average wage payment in the bonus treatment.

JEL Classification Code: C92, D23, J30, L23, M52

2.1 Introduction

For firms that produce manufactured goods, production thresholds are a natural part of the production process. If a threshold is binding, then lower-than-threshold effort will cause a production failure. For example, a car cannot be successfully sold if any part of the car is missing. The threshold gift exchange game is a game that deals with the principal-agent relationship within firms, yet the threshold production case has only been studied by Zhao 2020. In the most basic version of the gift-exchange game, studied by Fehr et al. 1997, Charness 2004, and Gachter and Falk 2002, etc., the manager decides a certain wage for workers, who in turn determine the effort they will contribute to help generate outputs for the manager. In the threshold version of the gift exchange game conducted by Zhao (2020), the workers only generate output if they put in sufficient effort. This experiment demonstrated that simple goal setting is not an effective motivating tool to improve workers' productivity. How to overcome the production failure and improve working efficiency is therefore a realistic issue that many firms face.

One possible way to overcome production failure is to use bonuses rather than wages. A bonus is a motivating tool that is currently utilized in firms. End-of-year bonuses and stock sharing are devices that managers utilize to encourage well-performing workers. For example, in 2020, a typical wage for Ford Motor Company's assembly line worker is 21 dollar per hour with a 3625-dollar annual bonus. In the same year, another automaker, General Motor Cooperation (GM), paid an assembly line worker an average of 17 dollars per hour, with a 9000-dollar bonus. The annual income of an individual worker who works 8 hours per day and 200 days per year is similar in these two firms, yet GM pays a higher bonus with a smaller share of pre-determined wage compared to Ford. On the other hand, some firms cancel their bonus plans to pay higher wages. The famous retailer Walmart has just decided to end the quarterly bonuses for store associates, which have been paid to employees for decades, and instead raise the hourly wages. Whether Ford and GM or Walmart's decision is optimal for the firm's production is unclear since the ability of the bonus to improve production efficiency not been examined either theoretically or experimentally. For reasons of simplicity, this project only considers the two extreme cases in which workers are paid only through wages or only through a bonus.

This project theoretically and experimentally examines whether the bonus payment can help firms improve production within the threshold production setting. Specifically, I change the payment structure from wages to a bonus payment in the repetitive, one-to-one gift exchange game model. In addition, I examine workers' effort contribution and managers' payment strategies in the laboratory experiment. Following Brandts and Cooper (2006)'s design, the worker is paid either by a bonus or a wage but never a combination of both payment methods. The difference between the wage and the bonus payment is then considered the payment timing.

I first examine a game-theoretic model of the threshold gift exchange game. I find that the range of cooperative equilibria is equivalent between wage and bonus conditions when subjects' payoffs are not time discounted. The theory thus does not identify any difference in behavior across the two payment types. However, under the same time discount setting, experimental results demonstrate that changing the payment order from before to after the production significantly increases workers' effort contributions in each time period. However, managers are able to pay less on average under each effort level. Moreover, a positive production threshold does not change subjects' behavior in the wage treatment yet causes managers to pay more in the bonus treatment. In the game, generous workers tend to work harder while managers who care about fairness in the working environment distribute an increased wage or bonus. Female managers also pay higher wages on average. One possible explanation for these observations is that the bonus payment shifts workers' role in the game from the gift receiver to the gift provider. As a result, the reward and punishment mechanism in the game may vary. Subjects' behavior in the bonus treatment is therefore different from those in the wage treatment.

This paper contributes to discussions of principal-agent behaviors in two ways. The first contribution is the theoretical finding that the ranges of cooperative equilibria payment with bonuses and wages are the same when payoffs are not time discounted. The second contribution is that the experimental results demonstrate that the bonus payment improves production efficiency in the threshold production setting.

Section 2 compares this paper to Brandts and Cooper (2006) and Healy (2007)'s work to demonstrate the similarities and differences. The formal model is developed in Section 3 and the experiment is described in Section 4. The hypotheses drawn from this model are described in Section 5 and the corresponding analysis of experimental results is included in the following section (Section 6). A brief summary and possible directions for future work appear in Section 7.

2.2 Literature Review

The bonus payment was previously experimentally tested within the principal-agent framework established by Brandts and Cooper (2006). In their game, paying the bonus increased the laziest workers' effort contributions within the group. Similar to the threshold gift exchange game, workers do not share company's revenue, so successful production results do not improve their payoffs. If a profit-sharing scheme is also introduced into the threshold gift game through the bonus payment, workers may be more motivated to work hard.

In contrast to the gift exchange game, the laziest worker's contribution determines the group revenue in Brandts and Cooper (2006)'s game. The laziest worker is defined as the worker who gives the least effort. Obviously, this framework does not fit all real-life situations, yet studying the bonus payment in the gift exchange game will broaden the discussion. Additionally, only workers' behavior is studied in Brandts and Cooper (2006)'s game. To complete the puzzle, managers' payment behavior and the interactive strategies between both sides are examined in this paper.

This paper also builds upon Healy (2007)'s work, which studied the gift exchange game to test the formation of reputations in a repeated labor market. He mimics the labor market, in which each worker matches with one firm. In Healy's design, he assumed that workers have two types: reciprocal and selfish. Firms are rational. They pay a high wage to reciprocal workers and a low wage to selfish workers, since reciprocal workers contribute high effort and selfish workers contribute low effort.

Although this paper also utilizes a gift exchange game with one-to-one matching, it differs from Healy's work in several aspects. First, Healy's matching between subjects in the game is random but not fixed over time. As a result, the firm cannot punish the the worker's deviation behaviors. For players, the game in every time period is considered a one shot, since they are likely to play with a new opponent every time. In this paper, the matching is fixed through the game. Therefore, workers who give low effort will be punished by the manager in the next time period. As a result, the game is repeated for subjects, who make decisions to maximize their gross payoff over time. Healy's random matching design is realistic since workers may not work for the same company forever and can leave, if they would like to do so. However, fixed matching in this paper is also realistic in the sense that most workers do not leave a firm right immediately. Workers tend to change their jobs after several months or years spent working on the same firm. In a word, our design studies subjects' repeated interaction while Healy's design checks one shot encounter.

Second, Healy restricts the timing of the wage payment, designating that it must be made prior to production, while the bonus case is added in this paper. The bonus case allows the manager to pay workers after production ends in each time period. Healy made this restriction to rationalize the reputation effect. Since the firm has never worked with the worker before and she pays the wage prior to learning the worker's real type, she has to form a belief about the worker's type through the worker's former public record. Nevertheless, in this new model, the firm can learn a worker's real type through repeated interactions with the same worker. In this newly invented bonus case, managers only pay after observing workers' effort contribution. Here, workers cannot earn a positive payoff if they do not contribute any effort.

Finally, subjects' action space in Healy's model is 2 by 2. There are only 2 choices available to subjects: high or low. Managers can only choose to pay high or low wage and workers can choose to contribute high or low effort. This restriction on the action space causes the game to be another form of the prisoners' dilemma game since only a non-cooperative Nash equilibrium exists in his model. This strategy is dominant, while the cooperative strategy is more beneficial to both players in the game. According to this design, the worker and the manager's strategies can reach the equilibrium only if they are paid equally.

The limited action spaces cannot fulfill the purpose of this work. In order to understand subjects' interactive behavior in different treatments, a larger range of choices should be provided. In this case, they are given a certain amount of freedom to adjust their behaviors according to the setting. As a result, subjects can also form a cooperative equilibrium and the non-cooperative equilibrium is no longer dominant. In this study, workers can choose any effort level from 1 to 10. Managers can choose any payment number from 0 to 100 units. This relaxed action space gives the firm power to divide the revenue between herself and the worker unequally. Moreover, this newly invented model also includes a threshold. A lower than threshold effort contribution causes production failure and therefore zero production revenue. The threshold allows more than one Nash equilibrium to exist within the game. The cooperative equilibrium is also a Nash equilibrium in which workers give higher than threshold effort and the manager pays a high wage. The proof for the Nash equilibrium is shown on part 3.

After including the relaxed action space and the threshold in the model, subjects can achieve Nash equilibrium with higher than zero contribution and an uneven division of production revenue. The changes made to this model enable it to evaluate the questions that this paper aims to answer.

2.3 Basic Model

In a threshold gift exchange game with a successful contract between one manager and one worker, the payoff of the manager π_t is:

$$\pi_t = \begin{cases} 10e_{it} - w_t, & e_{it} \geq \beta, \\ -w_t, & e_{it} < \beta. \end{cases}$$

Every individual worker i's payoff is:

$$y_{it} = w_t - c(e_{it}).$$

The manager first decides on the wage $w_t \in [0, 100]$ paid to workers at time period t. Following observation of this wage, the worker decides the effort exertion e_{it}. This effort exertion will directly affect the manager's revenue. When a threshold for successful production $\beta \geq 0$ is required, the manager risks production failure and earns non-positive revenue if the effort is below the threshold β. The standard gift exchange game is a special case of the threshold gift exchange game with $\beta = 0$.

The worker i receives the wage at a certain time point even when production failure occurs at that time point. The effort cost function is an increasing and convex function borrowed from Abeler et al. (2010), as shown in Table 2.1. When the effort level increases, the cost of each unit of effort starts to increase in a nonlinear pattern.

Table 2.1: The Cost of Effort Function

e_{it}	1	2	3	4	5	6	7	8	9	10
$c(e_{it})$	0	1	2	4	6	8	10	13	16	20

In this standard one-shot game, a worker's strategy is a function of the manager's wage choice $e_i(w_t) = \mathbb{Z}[1, 10] \times [0, 100]$. The action space for effort is 0 to 10 units and the wage space is 0 to 100 points. However, in an infinitely repeated game, subjects' cumulative payoffs are discounted at each time period by the time discount factor $\delta \in [0, 1]$. The manager acts to maximize the sum of single-period payoffs across all time periods. The manager's utility function is:

$$U_m = \sum_{t=1}^{\infty} \delta^{t-1} \pi_t.$$

The individual worker i selects her effort $e^*_{it} \in \mathbb{Z}[1, 10]$ units in each time period to maximize her utility:

$$U_i = \sum_{t=1}^{\infty} \delta^{t-1} y_{it}.$$

This payment after production scheme exists in real life, as many firms offer a bonus payment as a part of the compensation they give to workers. It is unclear if giving bonuses to workers is beneficial for the firm. This is the reason I want to explore the payment after production scheme in the context of the threshold gift exchange game.

In the scheme, managers do not make decisions regarding basic wage payments for the sake of simplicity. The basic wage that is paid to workers is the exogenous minimum wage, which is set up to be zero points at each time period. Instead, after production results are revealed, the manager will decide how much bonus the worker receives. This allows the bonus payment to serve as another form of wage, which is received after the production rather than before production. This change reverses the provider of gift exchange from the worker to the firm. The worker knows that this bonus will be given following her work but does not know how much will be paid until the the production outcome is realized. This bonus b_t will be realized if production is successful. Therefore, the manager no longer makes the first move but instead makes the decision when the worker finishes her contribution. The worker must believe that the manager will pay them enough once they contribute the effort. Otherwise, the worker would not contribute any effort. As a result, the manger's payoff at each time period t π_t becomes:

$$\pi_t = \begin{cases} 10e_{it} - b_t, & e_{it} \geq \beta, \\ 0, & e_{it} < \beta. \end{cases}$$

Every individual worker i's payoff is:

$$y_{it} = \begin{cases} -c(e_{it}) + b_t, & e_{it} \geq \beta, \\ -c(e_{it}), & e_{it} < \beta. \end{cases}$$

This newly invented model introduces key features that differ from the original threshold gift exchange game. First, a worker's payoff is no longer secure. She is unable to receive any positive income if the production fails. Second, at each time period, the manager responds after the worker makes their contribution. The manager has the power to reward workers' effort contribution but is not able to motivate them to contribute. This model also introduces a profit sharing scheme. The manager chooses to divide revenue between herself and the worker. She no longer assumes the risk of earning a negative payoff, which is a possible scenario in the original game if the manager pays a very high wage to the worker.

There are two sets of salient strategies when the game is repeated infinitely. One is the non-cooperative strategy and the other is the cooperative trigger strategy:

Workers:

- **non-cooperative** (**non-coop.**): always exerts the minimum effort $e_{it} = 1$ in every time period t under all situations and earns zero bonus.
- **cooperative** (**coop.**): choose $e_{it} = \beta$ in period t=1; and then continue to select $e_{it} = \beta$ if receives bonus $b_t \geq b^*$ in all former time period t-1. Otherwise, the worker chooses $e_{it} = 1$.

Manager:

- **zero-bonus**: shares zero bonus to the worker no matter the production is successful or not.
- **positive-bonus**: If production is successful, the manager selects $b_1 = b^*$ in period t=1, and then continues to select $b_t = b^*$ if the worker always chooses $e_{it'} \geq \beta$ in each time period $t^{'} < t$. Otherwise, the manager gives zero bonus.

Proposition 1. *a) In the infinitely repeated game, the strategy profile (**zero-bonus**, **non-coop.**) is a sub-game perfect equilibrium.*

*b) Under a given $\beta \in \mathbb{Z}[2, 10]$, and the time discount factor $\delta \in [\frac{c(\beta)}{10\beta}, 1]$, there exists a non-empty set of optimal bonuses $b^* \in [c(\beta), 10\beta\delta]$ allowing the strategy profile (**positive-bonus**, **coop.**) to be another sub-game perfect equilibrium.*

Proof. a) In every single sub-game of this infinitely repeated game, the strategy (**zero-bonus**, **non-coop.**) becomes a Nash-Equilibrium. The manager lacks the incentive to share the production profit with workers because it reduces her own payoff. Her choice of profit sharing does not motivate workers to work hard at the next time period t+1. In order to maximize the payoff, the optimal strategy for the manager is to give zero bonus. By anticipating this result through backward induction, the best response for the worker is to exert minimum effort, as exerting extra effort is costly. Contributing effort does not increase her payoff. Therefore, the strategy (**zero-bonus**, **non-coop.**) is the sub-game perfect equilibrium in every single sub-game. As a result, it is the sub-game perfect equilibrium for the entire game.

b) In the cooperative strategy, the manager's utility without deviation is:

$$U_m(\textbf{positive-bonus}, \textbf{coop.}) = \frac{1}{1-\delta}(10\beta - b^*).$$

If the manager wants to deviate, the ideal choice is to deviate in the first time period. Otherwise, the payoff she receives from deviating decreases as time passes. Besides, the sequential nature of the game implies that the manager's deviation will trigger workers' deviating response for the following time periods $e_{it} = 1$. Therefore, her utility is:

$$U_m(\textbf{zero-bonus}, \textbf{coop.}) = 10\beta.$$

The manager will not deviate and continue to give $b_t = b^*$ if:

$$U_m(\textbf{positive-bonus}, \textbf{coop.}) \geq U_m(\textbf{zero-bonus}, \textbf{coop.})$$

$$\frac{1}{1-\delta}(10\beta - b^*) \geq 10\beta$$

$$b^* \leq 10\beta\delta.$$

This result is feasible for any $\delta \geq 0$ and $\beta \geq 0$, which is always true.

For individual worker i, her utility function under the cooperative strategy set is:

$$U_i(\textbf{coop.}, \textbf{positive-bonus}) = \frac{1}{1-\delta}(b^* - c(\beta)).$$

On the other hand, if the worker i deviates, her optimal choice is to deviate at the first time period due to the time discounting. Because she is the first to decide, she will receive zero bonus starting at time period t:

$$U_i(\textbf{non-coop.}, \textbf{positive-bonus}) = 0.$$

The worker i will keep playing $e_i = \beta$ in each time period if:

$$U_i(\textbf{coop.}, \textbf{positive-bonus}) \geq U_i(\textbf{non-coop.}, \textbf{positive-bonus})$$

$$\frac{1}{1-\delta}(b^* - c(\beta)) \geq 0$$

$$b^* \geq c(\beta).$$

Therefore, the discount factor δ satisfies $\delta \in [\frac{c(\beta)}{10\beta}, 1]$ such that the set of $b^* \in [c(\beta), 10\beta\delta]$ is non-empty.

■

Under the cooperative equilibrium, there are three focal situations in which the production revenue can be divided. Firstly, the non-empty range of b^* is determined to allow for the existence of a cooperative equilibrium. The lower bound $b^* = c(\beta)$ is the minimum bonus that the worker is willing to receive in order to play within a cooperative equilibrium. In this case, the manager takes all the profit for herself and the worker earns 0 payment. Workers want to receive a higher bonus when the effort cost increases. If the bonus is below the lower bound, it is not enough to cover the workers' effort cost.

On the other hand, the upper bound $b^* = 10\beta\delta$ is the highest amount that the manager is willing to pay to maintain a cooperative equilibrium. The worker takes all revenue and the manager earns 0 profit in this case. Her revenue increases with the time discounted threshold $10\beta\delta$, so that she is able to pay a higher wage with a larger δ.

Finally, the perfect equilibrium bonus that allows the manager and the worker to share the profit equally under the cooperative equilibrium is the number b^* that allows the payoff of the worker to equal to the payoff of the manager across all time periods:

$$U_i(\textbf{coop.}, \textbf{positive-bonus}) = U_m(\textbf{positive-bonus}, \textbf{coop.})$$

$$\frac{1}{1-\delta}(b^* - c(\beta)) = \frac{1}{1-\delta}(10\beta - b^*)$$

$$b^* = 5\beta - \frac{c(\beta)}{2}$$

This number is within the optimal bonus range and allows the cooperative equilibrium to exist.

In the wage payment case, this cooperative range that allows a cooperative equilibrium to exist is $w^* \in [\frac{c(\beta)}{\delta}, 10\beta]$. Therefore, if subjects are patient, meaning that the time discount variable is close to 1, the range of payment choices to allow the cooperative strategy to exist is the same. The change in the payoff structure does not induce considerable difference in the manager's action space, allowing the cooperative equilibrium to exist unless subjects are very impatient. This implies that the timing of the payment should not significantly influence subjects' behaviors.

However, if subjects are highly impatient and the time discount variable is far from 1, the ranges of cooperative equilibrium in the two are no longer the same. The difference between these two cooperative range is that the range of the optimal bonus is discounted by the time discount variable δ. This difference is caused by the sequential nature of this game. The order of the move determines the deviation payoff that the player can receive by playing a non-cooperative strategy. The detailed payoffs that players receive by playing cooperative and non-cooperative strategies are listed in Table 2.2. In the bonus case, the manager moves second, so she can receive the production revenue without being punished in the first time period.

Table 2.2: Subjects' Payoffs for Playing Two Strategies

Managers	Coop.	Non
Bonus	$\frac{1}{1-\delta}(10\beta - b^*)$	10β
Wage	$\frac{1}{1-\delta}(10\beta - w^*)$	0
Workers	**Coop.**	**Non**
Bonus	$\frac{1}{1-\delta}(b^* - c(\beta))$	0
Wage	$\frac{1}{1-\delta}(w^* - c(\beta))$	w^*

1.Coop.: Cooperative Strategy 2. Non: Non-cooperative Strtaegy

Since the time discount variable can also change subjects' behavior within in the model, the time discount variable in subjects' payoffs is set to be 1 in the experiment in order to understand the effect of the bonus in subjects' behaviors. As the result, this paper will only discuss the situation where the time discount variable equals to 1. The theoretical prediction is that paying a bonus instead of paying a wage does not change subjects' behaviors.

There are more than one equilibria that can be reached by the worker as long as the worker's effort contribution is larger than β. The effort choice that corresponds to the general cooperative trigger strategy e_{it} can be any number $\in [\beta, 10]$. These effort levels can help the firm generate positive revenue when subjects interact with each other cooperatively. The reason for choosing $e_{it} = \beta$ in the proof is for the sake of simplicity. The proof for $e_{it} \in [\beta, 10]$ is the same as $e_{it} = \beta$ except the final range of the bonus becomes $b^* \in [c(e_{it}), 10e_{it}\delta]$, where $e_{it} \in [\beta, 10]$. Especially in the base case with threshold $\beta = 0$, the range of the optimal payment b^* and e_{it} is expanded to the whole action space. Then, cooperative equilibrium exist in almost every single effort and payment level.

This paper focuses on the above equilibrium for reasons of simplicity. Moreover, since other equilibria have similar features as the cooperative equilibrium, the proofs are similar. Except for the existence of a non-cooperative sub-game perfect equilibrium for this infinitely repeated game, the first proposition aims to show that a cooperative trigger strategy equilibrium also exists under a certain determined time discount factor δ.

2.4 Experimental Design

Subjects were recruited from UCI's ESSL subjects' pool. For simplicity, there are two subjects randomly assigned to be in one group and one of them is assigned as the manager while the other is assigned as the worker. This matching is fixed throughout the game. Every subject is given 7 dollars, which is equal to 1400 points, as her initial endowment. This initial endowment is given to allow the possible loss that subjects may encounter during the game. If the subject ends up with an endowment less than 7 dollars, she still receives 7 dollars as her "show-up" payment.

In order to test subjects' responses to different payment timings and thresholdthis experiment involves a 2 by 2 design where the treatments are defined as the following: wage without threshold (WN), wage with threshold (WT), bonus without threshold (BN), and bonus with threshold (BT). The detailed numbers of participants in each treatment are listed in Table 2.3. Whether the manger pays the wage or the bonus is determined by the setting. Managers in the wage cases (WN and WT) are required to make decisions about the wage payment before workers act. They pay 0 bonus to workers. On the other hand, the bonus is the only payment given to workers in the bonus cases (BN and BT) where managers pay 0 minimum wage and decide the bonus payment after production in that certain time period. Since the maximum effort that a worker can contribute is 10 units, the maximum revenue for the firm at each time period is 100 points. Thus, the manager can choose a payment to the worker, determined to be either a bonus or wage, from 0 to 100 points. The minimum unit that a manager can choose is 1 point.

Table 2.3: Number of Subjects in 4 Treatment Cases

Treatments	Wage	Bonus
Non-Thres.	26 (WN)	38 (BN)
Thres.	26 (WT)	42 (BT)

1.Thres.: threshold 2. The treatment's name is listed in the bracket.

On the other hand, each individual worker determines her effort exertion, selecting a level from 1 to 10, which is costly. The minimum unit that a worker can choose is 1 unit. The cost of the effort is a convex format borrowed from Abeler et al. (2010)'s design, as shown in Table 2.1. The production threshold is set to be 5 units of effort in cases with thresholds (WT and BT) and 0 in cases without thresholds (WN and BN). The 5 units threshold for effort is half of the largest effort that can be devoted by the worker. This is consistent with the salient common impression regarding fair effort contribution shown in Zhao's previous (2020) experiment. In the basic gift exchange game without the production threshold, the average effort contribution was 5 units in the initial time period when subjects did not have any information about their teammates.

The game was conducted for 15 to 20 rounds and the ending was randomly determined, with a 50 percent chance that the game ended after each round once the number of rounds exceeded 15. Subjects are informed of this structure before the beginning of the game. This setting is to mimic workers' experiences in the firm. In real life, workers stay in the same firm for some time periods and then end up leaving the firm or pursuing retirement. This ending time is random since workers do not know when they will leave the firm in the very beginning, but have the sense that they will end up leaving the firm in the future.

Since the time discount variable in the game is set to be 1, subjects were paid the aggregate payoffs that they have earned throughout the game without time discounting. These payoffs are realized within each time periods. Managers' payment and workers' effort choices were recorded in each period to track subjects' activities. This payment information is kept private, known to the subject herself without being revealed to anyone else. At the end of the session, a survey was conducted to explicitly evaluate participants' beliefs regarding both their own and their teammates' social preferences. Specifically, the survey included a numerical scale assessing how much they agreed with a series of statements about their own generosity and how much they cared about fairness in the working environment (shown in Appendix B.1), which is difficult to assess in the context of the game.

2.5 Hypotheses

Now, let us consider the effect of changing the payment order in the threshold gift exchange game. When the time discount variable is equal to 1, the model predicts that subjects play in a cooperative equilibrium within the same payment giving range for both the bonus and wage case. Therefore, we have:

Hypotheses 1. *Managers in the wage treatment and bonus treatment pay the same wage to workers.*

Then, by responding the consistent payment strategy, workers should behave the same in both cases:

Hypotheses 2. *Controlling for the threshold, workers in the bonus treatment should exert the same level of effort as those in the wage treatment.*

Moreover, according to Zhao's former study, adding a threshold to the simple gift exchange game fails to motivate more subjects to play cooperatively, especially when the threshold is high. Then, the threshold in the game should only act as a reference and allow cooperative players to coordinate through this reference point, but their behaviors do not change due to the threshold. It means that selfish players in the non-threshold gift exchange game will still play selfishly in the threshold gift exchange game. The fourth hypothesis is that:

Hypotheses 3. *Controlling for the payment method, subjects behave the same in the threshold treatment as those in the non-threshold treatment.*

In conclusion, as stated above, those two treatments should not motivate subjects to play cooperatively. The interaction effects caused by these two treatments on subjects' behaviors should be minimal:

Hypotheses 4. *The ratio of subjects which give a zero wage/bonus or exert the minimum effort will be the same across all treatment groups.*

As stated in the model, there are various profit sharing strategies that the manager can choose in the cooperative equilibrium as long as both players earn at least 0 profits. In the experiment, subjects will adopt various profit sharing strategies. If we assume that subjects' behaviors are consistent across treatments, I would predict that:

Hypotheses 5. *Subjects' total payoffs are the same across treatments.*

Even though the model predicts that subjects' behavior is the same in the bonus and the wage cases, there are several reasons that subjects may behave differently in the bonus and the wage cases. First, since there is a wide range of choices that allow for cooperation, subjects may face a hard time find the mutual satisfying wage/bonus and effort levels, especially in the non-threshold cases where the equilibrium range is wider than in the threshold cases. Furthermore, changing the payment order from before to after the production cause changes to subjects' identity. In the bonus case, workers are no longer gift receivers. They become gift givers. Gift givers always give more in order to be paid back compare to the amount that they contribute when they are gift-receivers.

2.6 Data Analysis

134 recruited subjects participated in the experiment online through the Heroku server, including 54 males and 90 females. Their years in school and majors were varied. The game lasted 15 rounds

for the WT, BN, and BT treatments and 19 rounds for the WN treatment. Within each treatment, the length of the game was the same for all two-person groups. Detailed interactive histories for each treatment group are listed in Figure 2.1 to Figure 2.4.The major experimental findings are listed below. Subjects' behaviors vary significantly across treatments. The key patterns of these variations will be identified in the following results.

Result 1. *Contrary to Hypothesis 1, managers' wage-giving patterns are different in the wage and bonus treatments. On average, a higher wage is given in the wage treatment compared to the bonus treatment.*

The average wage-giving over time differs across treatments (shown in Figure 2.5 and Table 2.4). Managers in group BT gave the higher average wage compared to the BN.

However, when comparing wage differences between WN and BN, as well as between BT and WT, the average wage variation patterns are unclear. The pattern of variations within WN and BN's average wage are similar and the average wage lines intersect with each other.

Thus, the first step of the analysis is to test if there are systematical distinctions of payment-giving across these treatment groups. The ANOVA test was employed to check if those managers who pay workers in those treatments are from the same population. If those managers are from the same population group, their payment strategies should be consistent with each other. In other words, if the ANOVA test result is significant and rejects the null hypothesis, the treatments are demonstrated to effectively influence managers' payment strategy.

In this situation, managers in various treatments are considered as coming from population groups characterized by distinct payment giving strategies. As a result, the regression shows a significant result with a p-value equal to to 0.0046, meaning that treatments effectively influence managers' payment strategies. This finding thoroughly rejects hypotheses 1.

Before diving into the regression, we should understand that the causes of this wage contribution difference are not singular. Since the wage payment is a direct response to the effort contribution,

Figure 2.1: Effort and Wage Contribution On WN

Note: The blue bar represents worker's effort. The red line is managers' wage choice.

Figure 2.2: Effort and Wage Contribution On WT

Note: The blue bar represents worker's effort. The red line is managers' wage choice.

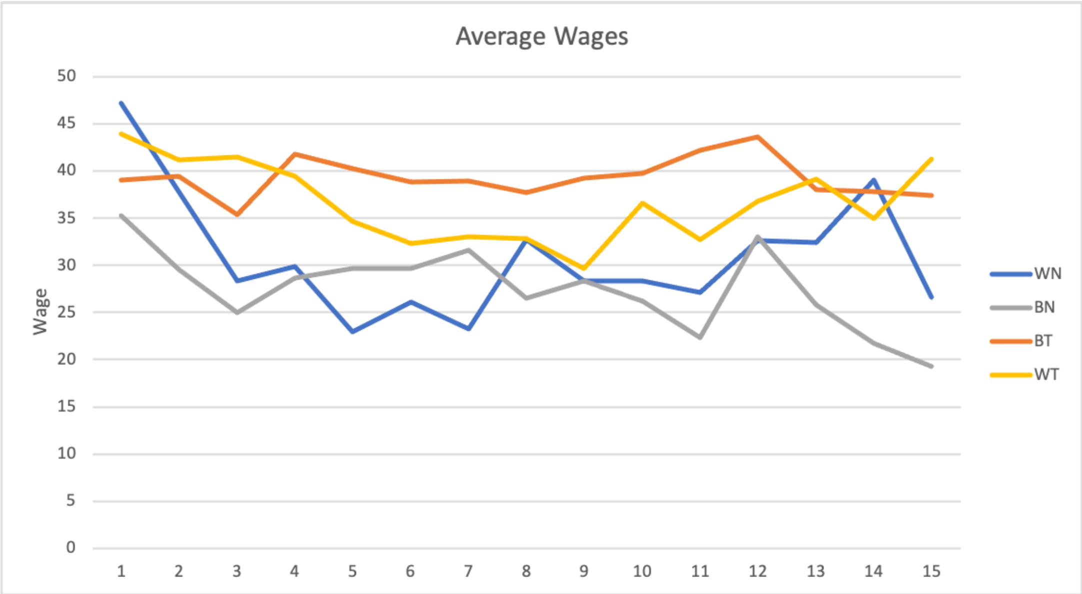
Figure 2.3: Effort and Wage Contribution On BN

Effort and Wage Contribution On BN

Figure 2.4: Effort and Wage Contribution On BT

Note: The blue bar represents worker's effort. The red line is managers' wage choice.

Figure 2.5: Aveage Wage



Note: This graph includes managers' average payment in each treatment. BT is the highest.

Table 2.4: Average Wages Overtime

Time	WN	WT	BN	BT
1	47.15	43.92	35.32	39
2	37.85	41.15	29.58	39.48
3	28.31	41.46	25	35.38
4	29.92	39.46	28.63	41.76
5	23	34.62	29.63	40.29
6	26.07	32.31	29.68	38.81
7	23.23	33	31.58	38.9
8	32.69	32.85	26.53	37.71
9	28.31	29.69	28.32	39.24
10	28.31	36.62	26.21	39.71
11	27.08	32.77	22.32	42.19
12	32.62	36.77	33	43.67
13	32.46	39.15	25.84	38
14	39.08	35	21.74	37.86
15	26.61	41.23	19.32	37.38
16	24.31			
17	29.54			
18	22			
19	29.38			

joint consideration of the wage and effort distribution is inevitable. To explore the payment order effect in depth, the influence of the effort must be further controlled.

At this step, it is unclear which treatment is responsible for changes in managers' behavior. To answer this question, more in-depth analysis is necessary. The fixed effect regression was run to test treatment effects, including effort as a control variable. The time effect, subjects' personal preferences on fairness, and their demographic characteristics are also controlled within the regression. In the regression, the wage distribution in the WN case is set to be the base case, and the wage payment in the other three treatments is used as a variable to compare with the base case. If the p-value of the treatment variables WT, BN or BT is significant, then this particular treatment has impacted managers' wage/bonus choices significantly.

The regression shows that the p-values for BN and BT are less than 5 percent (Table 2.5), meaning that the payment order has altered managers' strategies. The negative estimates imply that when the payment order changes, managers pay less to workers in average. Therefore, paying a bonus rather than a wage helps managers redistribute higher revenue to themselves without discouraging workers.

Table 2.5: Fixed Effects Regression of Variables' Effects on Wage

	Est.	Pr(>t)	Est	Pr(>t)	Est.	Pr(>t)	Est.	Pr(>t)
Effort	7	<2e-16*	6.79	<2e-16	6.33	<2e-16*	6.29	<2e-16*
WT	0.98	0.48	0.58	0.67	1.87	0.17	2.17	0.11
BN	-16.07	<2e-16*	-14.8	<2e-16*	-15.15	<2e-16*	-15.14	<2e-16*
BT	-10.04	1e-14*	-9.29	5e-13*	-9.14	3e-13*	-9.31	3e-13*
Q1			-0.47	0.2	-0.13	0.73	-0.21	0.6
Q2			1.83	8e-13*	1.71	3e-10*	1.74	2e-10*
Q3					-2.2	3e-06*	-2.28	1e-06*
Q4					2.27	<2e-16*	2.39	<2e-16*
Female							2.9	0.00*
Age							-0.21	0.43
Year							0.62	0.13
Major							-0.22	0.06

1.est.: estimation. The error in the regression is clustered at the session. 2. The significant level for p-value in this regression is 0.01.

Result 2. *Contrary to Hypotheses 2, workers' effort contributions are significantly different between the wage and bonus treatments when controlling for the threshold. A higher average effort level is contributed by workers in the bonus treatment compared to those in the wage treatment.*

The effort contribution differences across treatments are obvious (shown in Figure 2.6 and Table 2.6). The BT treatment has the highest average effort across all time periods while the BN treatment is second highest.

Now, the effect of changing the payment timing on effort was decomposed by running the two-sample t-test across treatment groups. The two-sample t-test was applied to check if workers in two groups were from the same population group. A significant result implies that those two groups have different effort contribution patterns. The results are shown in Table 2.7. The p-values of the WN-BN comparison and the WT-BT comparison are each less than $2.2 * 10^{(-16)}$, which is statistically significant. Therefore, paying the wage after the production significantly increased workers' average effort contribution, which rejects the hypotheses.

However, this regression does not control for indirect effects. The shift of payment order can indirectly impact the effort contribution by changing managers' payment strategy. In order to control for this indirect impact, another set of fixed effect analyses was made to test the treatment effect on effort contribution (shown in Table 2.8). The p-value for WT is insignificant, implying that adding the threshold itself fails to motivate workers, but changing the payment order from before to after the production has successfully improved the effort contribution by an average of 2 units (compared to the wage case, as the p-values for BN and BT are significant).

In conclusion, according to the regression, when the wage is paid after the effort contribution, workers give higher effort on average compared to the other case. One possible explanation for this phenomenon is that a certain number of workers mistakenly treat this game as a one-time game. As a result, their optimal strategy is to contribute high effort in the bonus treatment case. If they give low effort, they will be punished and never have the chance to deviate since the game is a "one-shot."

Table 2.6: Average Effort Over time

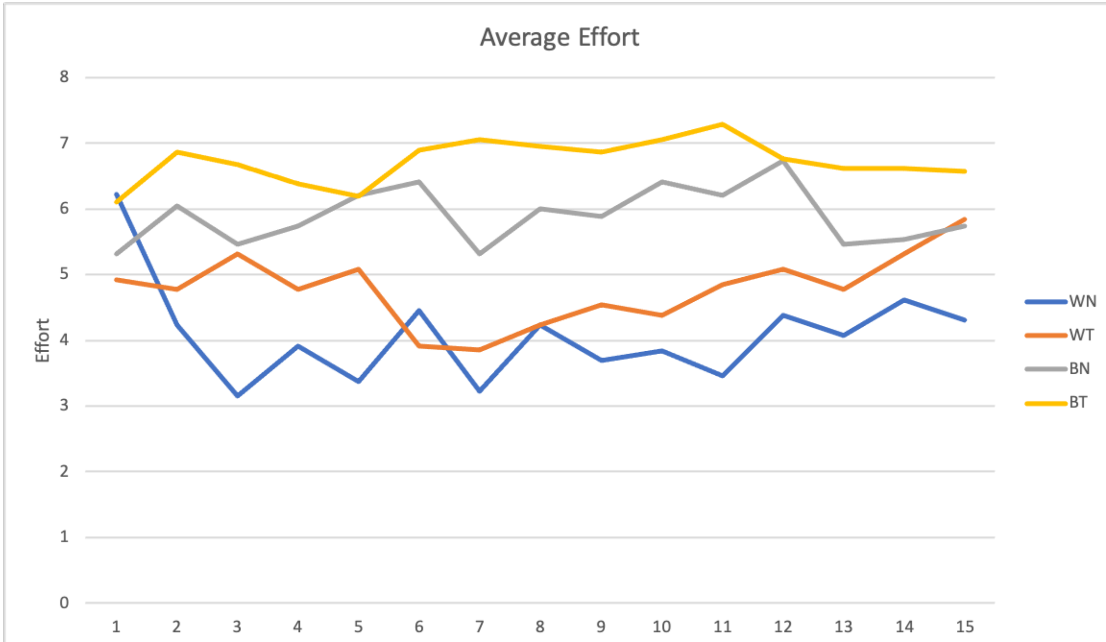
Time	WN	WT	WT Perc.	BN	BT	BT Perc.
1	6.23	4.92	69.23	5.32	6.1	95.24
2	4.23	4.77	61.54	6.05	6.86	100
3	3.15	5.31	61.54	5.47	6.67	90.48
4	3.92	4.77	53.85	5.74	6.38	95.24
5	3.38	5.08	69.23	6.21	6.19	90.48
6	4.46	3.92	38.46	6.42	6.9	95.24
7	3.23	3.85	30.77	5.32	7.05	95.24
8	4.23	4.23	38.46	6	6.95	90.48
9	3.69	4.54	53.85	5.89	6.86	90.48
10	3.84	4.38	46.15	6.42	7.05	95.24
11	3.46	4.85	53.85	6.21	7.29	95.24
12	4.38	5.08	53.8	6.74	6.76	95.24
13	4.08	4.77	46.15	5.47	6.62	90.48
14	4.62	5.31	61.54	5.53	6.62	90.48
15	4.31	5.85	61.54	5.74	6.57	90.48
16	3.08					
17	4.69					
18	3.23					
19	4.23					

1.WT (BT) Perc.: Percentage of groups in WT (BT) treatment that successfully achieve production. Successful production means that the worker in this group has contributed at least 5 units of effort.

Table 2.7: P-value for Two Sample T-test (Effort Differences Across Treatments

	WT	BN	BT
WN	0.0004*	<2.2e-16*	<2.2e-16*
WT		3.75e-08*	<2.2e-16*
BN			1.039e-07*

Figure 2.6: Average Effort



Note: This graph represents workers' average effort in each treatment. BT is the highest and WN is the lowest.

Table 2.8: Fixed Effects Regression of Variables' Effects on Effort

	Est.	Pr(>t)	Est.	Pr(>t)	Est.	Pr(>t)	Est.	Pr(>t)
Wage(Bonus)	0.075	<2e-16*	0.073	<2.2e-16*	0.073	<2.2e-16*	0.072	<2.2e-16*
WT	0.26	0.07	0.23	0.1	0.22	0.13	0.24	0.1
BN	2.07	<2e-16*	2.01	<2.2e-16*	1.97	<2.2e-16*	2.02	<2.2e-16*
BT	2.01	<2e-16*	1.97	<2.2e-16*	1.94	<2.2e-16*	1.98	<2.2e-16*
Q1			0.16	2.35e-05*	0.14	0.0004*	0.14	0.001*
Q2			-0.002	0.95	-0.02	0.52	-0.019	0.51
Q3					0.02	0.69	0.02	0.7
Q4					0.06	0.02	0.06	0.01
Female							-0.08	0.43
Age							-0.03	0.38
Year							-0.0002	0.99
Major							0.01	0.34

1. est.: estimation. The error in the regression is clustered at the session. 2. The significant level in this and the former regression is 0.01.

Result 3. *Partially consistent with Hypotheses 3, workers' behaviors are not significantly impacted by the threshold. However, managers on average give higher bonuses when there is a threshold compared to when there is no threshold.*

When controlling for the payment order, the presence of a threshold makes little difference with regard to the rate of non-cooperative behavior in the WN and WT treatment. This result is further confirmed by result 2. Players who have decided to play selfishly in the non-threshold gift exchange game are not motivated to play cooperative strategies in the threshold game. According to the regression results in Table 2.3 and Table 2.6, the p-values for WT in both regressions are insignificant, so that adding the threshold does not significantly change subjects' strategies when payment is made before the production.

This is consistent with Zhao's former experiment conducted in a two worker-one manager gift exchange game framework, as a too high (7 unit) or a too low (3 unit) effort threshold does not motivate workers to work harder. Especially when the threshold is high, this drives a higher proportion of subjects to enact a non-cooperative strategy compared to the case without the threshold. This experiment uses a middle range (5 unit) effort threshold, which is half of the maximum accessible effort. This insignificant finding completes the argument that adding a threshold, no matter at what level, neither helps to increase the effort contribution nor significantly changes managers' payment patterns.

However, when combining a threshold with a bonus payment, the fixed effect regression provides different estimates for BT and BN when considering bonus giving, even though this difference is only noticeable from the managers' side. On Table 2.5, the estimate for BN is -16.07 while the estimate for BT is -10.04. These two variables are both statistically significant.

In order to control for the payment order, another set of fixed effect regressions is run to compare the payment and effort differences in those two bonus groups. In the regression, the BN treatment is utilized as the base to compare with the bonus/effort in treatment BT. The results of this regression are shown in table 2.9. These results are consistent with the former comparison made in Table 2.7. In the bonus cases, the threshold only has the significant effect of changing managers' behaviors.

Table 2.9: Fixed Effects Regression of the treatment on Bonus/Effort

Effort			Bonus		
	Est.	Pr(>t)		Est.	Pr(>t)
Bonus	0.07	<2e-16*	Effort	5.47	<2.2e-16*
BT	0.01	0.91	BT	7.28	4.748e-11*

The significant level in this regression is 0.01. The left two columns are the results of regressing BT's effort on BN's effort. The right two columns are results of regressing BT's bonus on BN's bonus. The base case is BN.

From the numbers given above, we can tell that the respective effects of payment order change and the threshold on managers' payment giving operate in different directions. Paying after production induces managers to pay less on average. On the other hand, the positive estimates on BT (shown on Table 2.7) means that adding a threshold to the bonus treatment alleviates this decrease in bonus giving.

Result 4. *Contrary to the Hypothesis 4, the ratios of cooperation are different across treatments. Within each treatment, individual behavioral differences are correlated with personal subjective preferences regarding generosity and fairness.*

As stated in result 1, shifting the payment order changes workers' behaviors drastically. Moreover, workers are not only contributing higher effort when they get paid after the production (compared to when paid beforehand), but also are more likely to play with cooperative effort contribution strategies in the bonus treatment case. In Table 2.4, comparing the percentage of successful production, the BT has a much higher success rate than the WT treatment in every time period. This means that a higher percentage of groups in the BT treatment achieved cooperative equilibrium.

When considering the interaction history presented in Figure 2.1 to Figure 2.4, especially the WT treatment, workers in group 2, 8, 9, 12 and 13 keep playing lower-than-threshold effort for most of the time periods (Figure 2.1). On the other hand, there was only one group (group 11) in which the worker and the manager converged to the non-cooperative equilibrium strategy in the BT treatment (Figure 2.3). If we compare the groups in WN and BN (Figure 2.3 and Figure 2.2), we can find similar results: 5 out of 13 WN groups (group 1, 3, 5, 10, 12) converge to play a non-cooperative equilibrium compared to 4 out of 19 groups (group 6, 8, 15, 18) in the BN treatment. When comparing BN with BT, the non-cooperative ratio is also distinguishable (shown in Figure 2.3 and Figure 2.4).

Further, the threshold in the bonus payment case motivated more players to converge into cooperative equilibrium compared to subjects in the non-threshold treatment. Once they reach the equilibrium, subjects maintain that particular equilibrium. Equilibrium effort levels vary across groups but all remain above a threshold effort level of 5.

Besides the across-treatment differences, individual behavioral differences exist within treatment groups. Subjects' personalities and subjective preferences may play a role in their behaviors. Therefore, I analyzed the possible correlation between their contribution behaviors and their self-reflected answers to survey questions. Subjects' self-evaluation regarding fairness and generosity is reflected in the end-of-game survey questions Q1, Q2 and Q3. The specific questions are stated in Appendix B.1. Subjects are asked to slide the scale bar from level 1 to level 7 to answer how much they agree with the statement. Level 1 refers to disagreement and higher values represents higher levels of agreement.

Q1 states that "you are a generous person". Subjects choose a high level on the scale if they believe that they are generous. The significant linear regression result on Table 2.4 implies that workers who believe that they are generous tend to exert higher levels of effort. However, the insignificant results for the fairness concerns questions stated in Q2 and Q3 reveal that workers who work harder exhibit higher self-reported generosity but not concerns for fairness. Generous workers work more but workers who care about fairness do not work more. This is due to their belief that they have already fulfilled managers' requirements.

Generally speaking, there is a distinction between generosity and fairness. Generosity means that a person has done more than she needs to do while fairness means that a person has done exactly what she needs to do. The former analysis agrees with the statement that workers believe that they regularly contribute sufficient effort.

Nevertheless, generosity characteristics do not motivate managers, as managers are more motivated by fairness concerns. Q2 is a statement about how much a person values fairness. The positive estimate for variable Q2 shows that managers who choose a high level for this question distribute higher payments to workers on average. This result is illustrated in Table 2.3.

Q3 asks the managers to evaluate if they think that they have paid workers sufficient wage/bonus. The regression generates a significant result when the manager's payment is regressed on the variable Q3. This means that managers who believe that they have given enough payment tend to give less wage or bonus. When subjects are assigned to be managers, they can never be generous despite their self-identification as generous because they represent more than themselves. They have to keep the company alive and profitable. This makes sense in real-life since companies rarely overpay their employees.

When regarding others' behaviors, the survey question Q4 comments on teammates' behaviors. Subjects who agree with this question believe that their teammate has done what she should do, including paying enough wage or contributing enough effort. Managers are willing to increase their wage payment when they find that workers have worked hard enough. This is consistent with the estimate of Q2. Managers care about fairness and they reward the worker who plays fairly. In their mind, only hard-working workers deserve high payment.

This study provides a new finding with regard to demographic characteristics. Gender plays a significant role in subjects' strategy for playing the game. In the regression, female is a dummy variable with a value equal to 1 if the subject is a female. Otherwise, the value is 0. In the regression, female managers give higher wages on average. Workers' gender, year in school and age do not influence their effort contribution strategy.

Result 5. *Contrary to Hypothesis 5, subjects' payoffs are significantly different across all treatment groups. Managers in the BN treatment have the highest payoffs among all managers in the game, while workers in the WN treatment earn the most among workers in the experiment.*

As stated in previous results, mangers' payment giving strategies are significantly impacted by treatments. According to Table 2.5, managers pay the least payment in the BN treatment but pay the most in the WT treatment. However, managers' payoffs are not only impacted by their payment choices but also determined by workers' respective effort contribution. In Table 2.8, workers' effort contribution is the highest in the BN treatment yet lowest in the WN treatment. By combining those two pieces of information, we can conclude that managers in the BN treatment earn the most profit among those 4 cases. Nevertheless, since the effort and payment differences in WN and WT are statistically insignificant, it is unclear which treatment case produces managers with the lowest payoff.

Further, in order to study the treatment effect on subjects' payoffs, a fixed effect regression is applied on subjects' final payoffs. The results of the regression are shown in Table 2.10. In the regression, managers' payment choices in each time period and workers' effort contributions are two controlled elements, since subjects' payoffs are significantly correlated with those two elements. In addition, time effects, subjects' subjective preferences, and demographic characteristics are also controlled in the regression.

The base case in the regression is the subjects' payoff in the WN treatment. The regression shows that after controlling for wage and effort level, mangers in the BN case earn the most on average, yet workers earn the least compared to the other three cases. This proves that managers in BN distribute the highest revenue to themselves compared to managers in the other three cases. Changing the payment order from before to after production helps a firm to generate higher revenue. It gives managers a second mover advantage in the game. In this case, workers earn the least. On the contrary, managers in the WT treatment earn, on average, 132.35 units less than managers in

Table 2.10: Fixed Effects Regression of the treatment on Payoffs

Mana.			Work.		
	Est.	Pr(>t)		Est.	Pr(>t)
Wage	-4.61	<2.2e-16*		6.42	<2.2e-16*
Effort	37.12	<2.2e-16*		4.05	0.14
WT	-131.35	<2.2e-16*		-44.58	0.02
BN	173.16	<2.2e-16*		-153.79	3.52e-16*
BT	151.54	<2.2e-16*		-118.52	1.65e-11*
Q1	6.77	0.13		2.37	0.67
Q2	-3.79	0.29		8.79	2.99e-07*
Q3	-22.85	1.67e-05*		-54.65	2.41e-14*
Q4	19.53	4.13e-10*		36.78	<2.2e-16*
Female	64.71	1.62e-09*		52.36	8.98e-05*
Age	-4.97	0.008*		-17.97	4.03e-05*
Year	24.67	9.63e-7*		20.46	0.0025*
Major	-5.15	0.0002*		-9.75	2.78e-09*

1. Mana.: manager. Work.: worker. 2. The significant level in this regression is 0.01. 3. The left two columns show the results of regressing managers' payoffs on covariates. The right two columns show the results of regressing workers' payoffs on covariates. 4. The base case is WN.

the base case. This is because those managers pay higher wages than the base case, even though workers do not increase their effort contribution in return.

A possible source of confusion is that workers in the positive-threshold treatment do not earn more than the base case. This is caused by the higher rate of production failure in the threshold treatment. Since workers' low contributions cause managers' low revenue in the WT treatment (shown on Figure 2.2), managers punish workers by giving them zero wage. This punishment may offset the high wage that workers receive in previous time periods when they utilize a cooperative strategy.

Even though adding the threshold decreases managers' profits, changing the payment order to the bonus effectively alleviates the loss brought on by the threshold. In Table 2.10, the BT's estimates for managers' payoff is positive and is only slightly lower than the BN case. This result strongly supports adding a bonus payment to workers' contracts, especially in firms that utilize a positive threshold feature in their production process.

2.7 Behavioral Explanations

One possible explanation for managers' high payoff in the bonus treatment is that they are gift receivers in the bonus treatment yet gift givers in the wage treatment. As gift receivers, managers are less reciprocal compared to workers. When workers are gift receivers, they receive wages as the gift rather than contributing effort to win a bonus in the bonus treatment.

Many previous gift exchange experiments define the wage-effort relation by using the linear form (Fehr et al. 1998, Charness 2004):

$$e_{it} = \alpha + \nu * w_t$$

Since the manager is the gift receiver in the bonus case, we can redefine the relationship as:

$$b_t = \gamma + \xi * e_{it}$$

This ν is a measure of workers' reciprocity level and the ξ is the measure of managers' reciprocity level when acting as gift receivers. A positive ν found in Fehr et al. 1998 and Charness 2004's study proves the existence of reciprocal motivation, as workers who are paid more increase their effort contribution .

After running the Tobit regression, the value of ν is found to be 0.093 for WN, and 0.08 for WT. The value of ξ is 5.09 for BN and 7.86 for BT. Since 1 unit of effort contribution gives the manager 10 units of revenue, the estimate of ν is interpreted as follows: when the manager increases the wage by 1 more unit of currency, the worker gives 0.93 units of currency back to the manager in the WN treatment and 0.8 units in the WT treatment. Nonetheless, when the worker gives the manager 1 unit of revenue in the bonus case (which is equivalent to 0.1 units of the effort contribution), the manager only pays 0.509 and 0.786 units back to the worker in the form of a bonus. In sum, these numbers prove the hypothesis that workers are more generous when they are gift receivers compared to managers in the same position. Furthermore, the reciprocity measure for gift receivers within these four treatments are less than 1 for 1. This explains why gift receivers obtain higher revenue than gift givers in each treatment, as they keep some portion of the gift that they receive rather than return the gift in its entirety.

Another possible explanation for managers' high payoffs in the bonus treatment is that subjects are adverse to risk. Correspondingly, their utility functions are no longer simple aggregate expected payoffs. The following concave utility function satisfies subjects' risk-averse preferences:

$$U'_m > 0 \qquad \& \qquad U''_m < 0$$

$$U'_i > 0 \qquad \& \qquad U''_i < 0$$

As stated in the model, the division of the profit is the decision of the manager. The optimal payments which allow for the existence of a cooperative equilibrium fall within a defined range. If the manager chooses to pay the lower bound of the optimal payment, the worker earns zero. As the manager pays more, the manager's share of the total profit shrinks. It is reasonable to infer that when subjects are playing cooperatively, they are less likely to deviate if they can receive a bigger share of the profit, compared to the case where they gain a smaller share of the total profit.

If the worker deviates in the wage treatment, the manager who plays the cooperative strategy losses the wage payment made in the first time period. As a risk-averse agent, the risk of losing the wage payment is considered more painful than earning less or paying the worker more to maintain their cooperation. On the contrary, the manager losses nothing if the worker deviates in the bonus treatment. It becomes a less risky game for the manager since she makes her payment after the worker in each time period. Therefore, even though the expected total profit for both treatments is the same if the worker exerts the same effort, the manager pays a higher payoff to the worker in the wage treatment compared to the bonus treatment. This occurs at every level of the effort contribution. Applying the same logic, if the worker is risk-averse, the bonus treatment is riskier than the wage treatment. As a result, the worker will exert higher effort in the bonus treatment not only to allow the manager to earn more, but also to encourage her use of the cooperative strategy and to avoid the potential loss caused by the manager's deviation. This explanation is consistent with Luzuriaga and Kunze (2018)'s finding in their gift exchange game experiment. They found that risk-averse workers exert higher effort levels when there is more uncertainty in their payment structure. Obviously, the bonus treatment induces a higher uncertainty within the worker's payment compared to the wage treatment, as the worker sees the manager's decision before she makes her own decision.

Subjects' risk-averse nature can also explain why managers pay more in the threshold treatment than in the non-threshold treatment. Because production failure is painful for managers, they will earn zero revenue when the production failure occurs, while workers are not directly affected. They will be affected only if they are punished by managers for playing non-cooperatively. As a result, managers pay more on average in the BT case to encourage workers to work harder and avoid production failure, while the difference in workers' effort contribution is minimal.

2.8 Conclusion

The threshold gift exchange model predicts that a rational subject will perform consistently regardless of whether payment is paid before or after production, assuming no time discounting on payoffs. However, the experimental results have shown that the payment order drastically impacts subjects' decision making. For managers, giving a payment after production make them the gift receiver, allowing them to pay a lower wage at each level of effort contribution. Workers in the bonus treatment tend to work much harder and contribute a higher level of effort at every level of income that they receive since they are gift givers. As a result, the ratio of subjects that commit to playing a non-cooperative equilibrium decreases in the bonus treatment compared to the same ratio in the wage treatment. This result can be explained by the fact that gift receivers are less reciprocal in the bonus treatment compared to the wage treatment. Therefore, paying bonuses is an effective and cost-free strategy that a firm can take to improve production efficiency and lower human resource costs.

Another finding is that the threshold treatment does not improve production in the gift exchange game. This is consistent with Zhao (2020)'s study which proves that the threshold increases non-cooperative play in the game, especially when the threshold is high. Therefore, the non-zero threshold becomes a potential risk which may cause production failure. Risk-averse managers in the threshold treatment pay a higher average payment to encourage workers and avoid the risk of production failure. The threshold-nature firm therefore faces a potential higher labor cost than other firms.

Finally, when considering subjective characteristics, this experiment finds that fair-minded managers pay more to workers and that generous workers work harder. Human resource managers can look into candidates' characteristics when searching for good workers for their firms. Moreover, gender plays a role in modifying managers' behavior, as female managers tend to pay more wage or bonus to workers in the game compared to male managers. These characteristics matter in subjects' decision making but are not yet embedded in the model. The study of subjects' other-regarding features deserves additional exploration, especially as this can be built into the gift exchange game model. This newly invented model will improve understanding of how subjects' subjective preferences impact their behaviors.

As mentioned in the introduction, different firms pay workers different combinations of wages and bonuses. Nevertheless, which combination is the most efficient for the firm remains a mystery. Future studies may focus on testing which combinations of the bonus and the wage is the most optimal to improve firms' production.

Chapter 3

Competition and Forecast Accuracy:Theory and Experimental Evidence

Abstract

The performance rankings of financial agents affect their funding inflow. However, it is unclear how agents' price prediction is affected by knowing their own rankings. In the learning to forecast experiment (LtFE) designed to study agents' price prediction, the ranking information misleads agents, causing them to be less cautious about changes to the market. Ranked agents take longer to predict convergence to the fundamental market price compared to unranked agents. One potential explanation for this is that ranking information is misleading in a volatile market. High ranking agents' predictions are not necessarily close to the fundamental market price when the market condition changes, yet they are reluctant to change their predictions due to their high rankings. Low ranking agents will follow the predictions of high ranking agents. Agents' rankings are not stable and change in each time period. Therefore, all agents' predictions are driving away from the fundamental market price. One potential explanation for this is that ranked agents take a longer time to find the optimal heuristic price prediction rule.

3.1 Motivation

In the world of economics, no man is an island. A significant feature of living in an economic world is our interdependence. Participants include investors, suppliers, consumers, and social planners. Interactions within and among these groups keep the economy moving. The most basic kind of relationship between these participants is competition. For example, in product markets, rival producers compete with each other to gain more market shares (Stopford et al. 1991).

Similarly, in financial product markets, agents who predict product prices compete with each other. However, their behavior is not well understood by researchers. A financial database website called Audit Analytics publishes an annual market share report for transfer agents in order to rank the performance of the top 5 transfer agent firms. This knowledge intensifies competition among agents, because the top-performing agents can attract more investors to hire them and use their services (Kopányi et al. 2019). The positive relationship between performance and the fund inflow has been previously confirmed by many studies. Researchers (Ippolito, 1992; Goetzmann and Peles, 1997; Fant and O'Neal, 2000; Del Guercio and Tkac, 2002; Jun et al. 2014) previously demonstrated that "the past top-performing funds attract disproportionately large inflows in subsequent periods." For example, Morning Star Inc. rates mutual funds with a rating system of 1 to 5 stars. The ratings of top-performing agents are typically 4 or 5 stars, compared to others rated as 3 stars or less. Individual investors use this rating as a primary indicator for their decision making. Del Guercio and Tkac 2008 studied over 10,000 star rating changes and found that an upgrade from 4 to 5 stars on mutual funds' rating has a large effect on money inflow in the six months following the new rating, resulting in 32 million dollars of abnormal flow, or a 25 percent increase above normal. Moreover, Chun and Larrick (2021) have shown that consumers pay a disproportionate amount of attention to the top ranked option in the market. They conclude that "those at the top of the hierarchy maintain a disproportionate level of popularity in the market" (Chun and Larrick 2021). Therefore, receiving a top ranking is important for agents, allowing them to maintain their revenue and maintain a high position in the market.

However, how the ranking system affects agents' performance, specifically their prediction behaviors, has not been well studied. The status of the financial market changes over time due to expected or unexpected shocks. It is difficult to study the isolated effect of competition in this kind of financial market, as agents' sum interactions go beyond competition. They share information with each other and they also learn from each other. A controlled laboratory experiment is therefore a good tool to test the effect of the ranking system within a dynamic financial market. The learning to forecast experiment (LtFE), founded by Marimom and Sunder (1993) and Marimom et al. (1993) and developed by many other researchers (Bao and Duffy 2016, Bao et al. 2013, and Heemeijer et al. 2009, ect.) is a well-developed laboratory experiment for studying agents' price prediction behavior within the financial market. In the experiment, participants are assigned the role of professional forecasters and given the assignment to forecast the economic variable, defined as the price in this project. The realized trading price linearly depends on the arithmetic average of subjects' predictions and subjects are rewarded by the accuracy of their predictions.

This project studies how agents' prediction behaviors change when they are given ranking information as well as ranking payment, specifically in a context which intensifies competition within the positive feedback learning to forecast (LtF) framework with the unexpected external shocks developed by Heemeijer et al. (2009) and Bao et al.(2012). This experiment implements two treatments, namely the ranking information treatment and the ranking-determined payoffs treatment. In the ranking information treatment, participants are given their performance rankings according to their prediction accuracy in each time period. In the ranking payment treatment, subjects not only see their ranking in the market, but are also paid according to their ranking in each time period. The financial market is highly volatile and the steady state market price changes several times due to external shocks. These external shocks change the supply and demand of a financial good, causing the price of the good to change. Subjects' prediction behavior and prediction performances are recorded and analyzed.

The experimental results show that ranking information and ranking payment treatment slows down all agents' attempts to find the fundamental values of the market good. There is a higher frequency of mis-pricing mistakes made by agents when they are given ranking information within the game, and this effect applies to all agents who see their ranking information. Therefore, ranking information misleads all agents in the market to misunderstand the market conditions, as well as negatively impacts their selection of suitable heuristic strategies no matter their ranking. Accordingly, agents should understand and carefully utilize the ranking device alongside additional market information to help improve their performance. The results of this experiment helps fill gaps in understanding the effect of ranking system on agents' price prediction behavior.

The high-rank type and low-rank type agents' constant behavioral differences cannot be distinguished in this study, since agents' predictions are close to each other in the same market. In a certain time period, high-ranking agents regard their high rankings as a sign of making correct predictions, so they tend to keep their original predictions until they are no longer ranked highly. Low-rank agents immediately change their predictions to be closer to the realized market price when they are ranked low. As a result, the high-ranking and low-ranking agents' predictions become similar to each other in the next time period. Moreover, no players are consistently high-ranking, so we only study the overall effect of ranking information. We are unable to identify how the high-rank type agents are different from low-rank type agents since they perform similarly in the same market and agents' ranking type is indistinguishable.

3.2 Literature Review

In the field of charitable giving, competition arises through the ranking system, which has been demonstrated to affect subjects' donation behaviors in the dictator game, as tested by Duffy and Kornienko (2010). In their experiments, subjects on average gave the most from their endowment to their paired opponents when they were ranked according to the amount they gave. This is in comparison to the control group, in which the ranking information is not given. Furthermore, they gave the least on average when they were given rankings according to the endowment that they keep for themselves. Therefore, subjects do react to the ranking information and they change their behaviors accordingly.

Kopányi et al. (2019) did an LtFE experiment to test the effect of competition in the financial market. They intensified competition by giving the predictions of top performing players more weight to determine the market price. This structure can potentially bring these high-ranking players more monetary payoffs, since their predictions are closer to the market price. However, when the market is unstable, top performing agents are not necessarily predicting the price accurately. The unstable market gives low-ability agents the chance to also rank high. As a result, when those agents are given a larger numeric weight on the market price formation mechanism, the market price is farther away from the fundamental values when compared to the standard LtFE. It is therefore reasonable to see a mixed result on Kopányi et al. (2019)'s work. However, in real life, the impact of a single predictor's behavior is limited within the market due to enormous amounts of market participants. Furthermore, the competition's effects on participants' payoffs are more general and more visible than the effects on market price. In this project I therefore chose to modify the payoff structure rather than the market price mechanism in order to study the competition in the market.

Kopányi et al. (2019) found that subjects in unstable markets have a higher level of mispricing when competition is intensified. Nevertheless, they did not control for market conditions, i.e., making the market stable or unstable. The market condition in each of their groups is consistent and they claim that the market is unstable when the realized market price remains turbulent over time. In order to reassess their conclusion, I added market shocks to make the market condition unstable to check if the resulting competition worsens subjects' prediction accuracy.

As for the effect of ranking information, former research has shown that the anticipation of social ranking affects subjects' performance (De Botton 2004; Wilkinson and Picket 2010), as well as that gender differences exist in subjects' responses to competition. Schram et al. (2019)

found that men tried harder to win the game when there are performance rankings, compared to when there is no performance ranking. On the contrary, women tended to work less when there was a performance ranking. Barankay (2012) did a field experiment in a furniture company and found that the performance ranking among salesmen increases sales by 10 percent in 3 years, but that this treatment effect is only significant for men. Therefore, in this new experiment, the gender differences on performance will be considered as a side issue within the ranking information treatment.

3.3 Basic Model and Experimental Design

According to Heemeijer et al. (2009)'s design, the price adjustment rule is a simple linear relationship where the market price at the time period t is a simple linear function of the average prediction price: $\bar{p_t}^e = \frac{1}{n}\sum_{h=1}^{n} p_{h,t}^e$:

$$p_t = f(\bar{p_t}^e).$$

If the agents believe that the asset price will go up in the next time period, investors tend to increase their investment in the asset market at the current time period because they will earn some revenue by selling the asset at a higher price level. As a result, the demand for the asset during this time period increases while supply decreases, so that the asset price increases in this time period. This situation fits the case where the market asset price and the agents' price expectation follow a positive feedback rule. Therefore, I will only consider the positive feedback price adjustment rule. In cases with the positive feedback, the price adjustment rule according to Bao et al. (2012)'s design is:

$$p_t = p_t^* + \frac{1}{1+r}(\bar{p_t}^e - p_t^*) + \epsilon_t, \epsilon_t \sim N(0, 0.09)$$

where r is the risk free interest rate in the financial asset market. Consistent with previous research, the interest rate r is set to be 5 percent. The slope of this function becomes $\frac{20}{21}$. Since the slope is close to 1, the convergence on subjects' prediction is relatively slow compared to when the slope is smaller. As a result, the differences in subjects' behavior for each treatment is more observable due to the slow convergence rate. ϵ_t is small demand/supply shock in the market.

The (time varying) rational expected fundamental value in both treatments is given by p_t^*, which is:

$$p_t^* = \begin{cases} 56, & 1 \leq t \leq 20, \\ 41, & 21 \leq t \leq 43, \\ 62, & 44 \leq t \leq 65, . \end{cases}$$

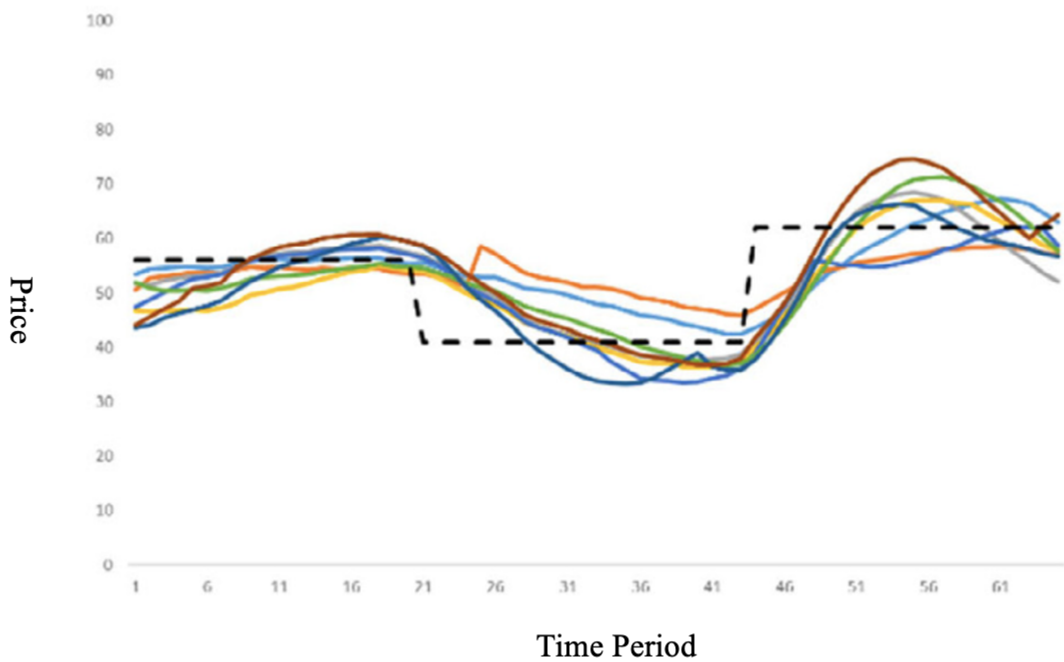
The dynamic of the price in the positive feedback LtFE found by Bao et al.(2012) is shown in Figure 3.1. This volatility is observed to effect the market price in the positive feedback price mechanism with shocks. Therefore, it takes agents a certain time period to predict values close to the steady state market price. This market formation mechanism is unknown to players in the experiment. They are notified that there are large shocks in the market which will change the market conditions, and that changes in market condition will cause changes in the market price. However, they are not given any information on when and how those shocks will occur.

Subjects were recruited from UCI's ESSL subject pool. Markets were made from 6 randomly selected subjects. Their assignment was to predict the market price for a total of 65 time periods. At the beginning of each time period, they began by making a prediction about the market price. The market price was then realized according to the aggregate subjects' prediction. Finally, their monetary payoff in that time period was realized.

Agents' payoffs are solely determined by the correctness of their predictions, where individual agent h's monetary payoff at the time period t is based on the absolute error of her predictions:

$$E_h = \frac{1300}{1 + |p_t - p_{h,t}^e|},$$

Figure 3.1: Price Dynamic/ Agents' Price Prediction in Bao et al.



Note: The colored lines are the realized market price in each experimental group, as measured at each time period.
The dotted line represents the fundamental market price at each time period.
The realized market prices are close to the fundamental market price but rarely converge.

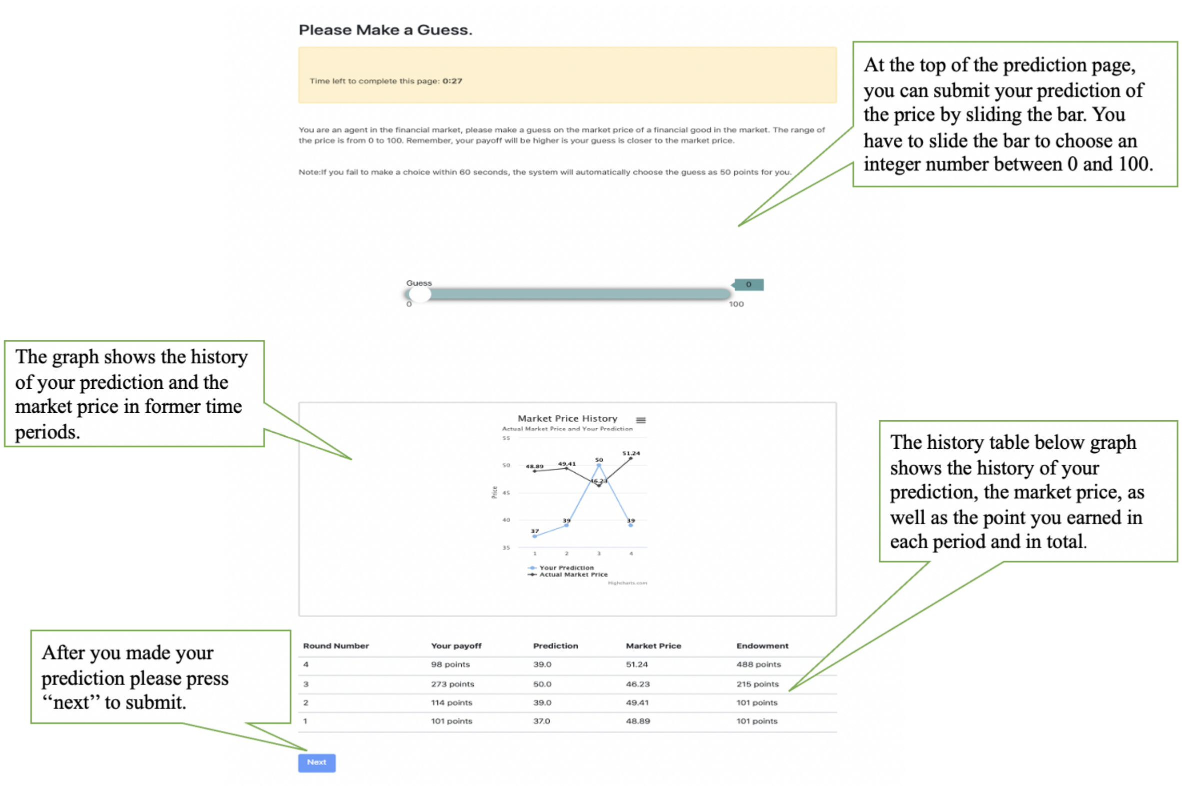
where 1300 points is equal to 0.5 dollar. This payoff function is hyperbolic and its distribution is close to the normal distribution. Former studies use the payoff function $1300 - \frac{1300}{49}(p_t - p^e_{h,t})^2$, which is truncated on its' distribution. The truncation distribution obscures the differences in subjects' predictions and payoffs while this newly proposed payoff function helps to avoid the issue of truncation. Subjects were aware of the market price, their own prediction, and their own payoffs in each time period.

The rank condition utilized in this experiment was formerly used by Andreoni 1995 in his public goods game to intensify competition among group members. In his experiment, this ranking payment increases earning differences among group members, which eliminates cooperative behavior in the group. As a result, subjects are willing to work harder to receive a higher payoff. Therefore, the ranking payoff system intensifies the competition in Andreoni's (1995) work.

Two treatments and one base treatment were implemented in the experiment. In the base treatment, subjects played the standard LtFE. Ranking highly increases both subjects' social standing and monetary payoffs. These two effects can be separated by two different treatments, namely ranking information and ranking payment. In the ranking information treatment, subjects' earnings are solely determined by their prediction accuracy, which is indirectly related to their ranking. As a result, subjects with different rankings can earn similar payoffs if their predictions are similar. Ranking information therefore provides subjects with a merely psychological reward. On the other hand, in the ranking payment treatment, subjects are paid according to their ranking. In this case, subjects with different rankings will earn distinguishable payoffs, meaning that top-ranking players are given a large portion of the market earnings. This design stresses the the effect of ranking in subjects' monetary earning and this ranking information brings not only psychological rewards but also monetary rewards. By redistributing the aggregate market earning in the market by ranking, subjects are motivated to predict the price accurately since they are paid according to the ranking. Simultaneously, prediction accuracy becomes a confounding factor. Subjects in the game do not have the incentive to make extreme predictions since they are ranked low if they make extreme predictions. This payment structure effectively avoids cutthroat competition within the market.

In the ranking information treatment (RI), subjects also played the standard LtFE as subjects in the base treatment. They were given their performance rankings according to their prediction accuracy at that time period. Other players' predictions and rankings were unknown to them. Nevertheless, subjects in the ranking payment treatment (R) were paid according to their relative ranking to each other in the market, with payments decreasing as ranking decrease, i.e., the person with the highest ranking earned the most. Subjects who tied were randomly ranked and still paid according to their ranking. These subjects were paid according to the percentage of the aggregate earning of the whole market at that certain time period. The specific distribution of this aggregate earning is shown in Table 3.1. The payoff differences between two adjacent rankings is 5 percent, except for the difference between ranking 1 and ranking 2, which is 6 percent. However this

Figure 3.2: Experiment Explanation



distinction is minimal. The purpose of this distribution is to keep the aggregate earnings in the ranking treatment comparable with other treatments. The earning differences between adjacent rankings are kept almost identical.

Table 3.1: The Ranking Payment

Rank	1	2	3	4	5	6
Percentage	30	24	19	14	9	4

The prediction page for the experiment is provided in Figure 3.2. There is a sliding bar, enabling subjects to choose a number between 0 and 100. Below the sliding bar, there is a dynamic line chart showing subjects' predictions with the realized market price in each time period. A history table showing subjects' performance and payoffs is also provided below the graph. The specific instructions used in the experiment are included in Appendix C.1.

At the end of the game, subjects were given a reflective cognitive test to evaluate their cognitive abilities. This test was first proposed by Frederick (2005) and is utilized broadly within the field of experimental Economics. Besides cognitive ability, price prediction also requires coordination abilities. Subjects must consider other players' behaviors in order to make reasonable predictions. Therefore, the beauty contest game will be given to the subjects to test their coordination abilities. These two test results were added together and used as an indicator of subjects' price prediction expertise.

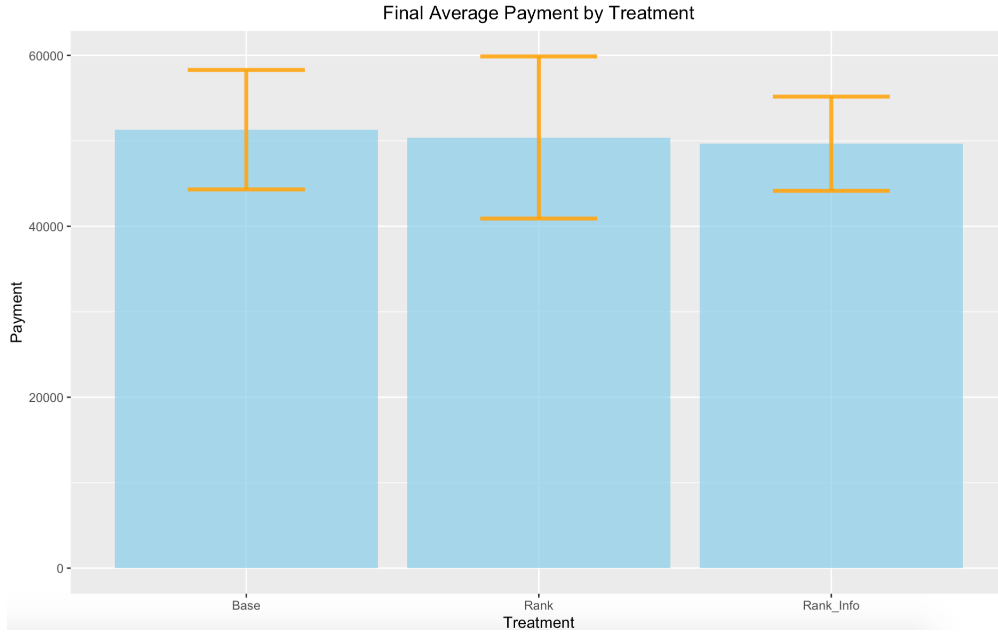
3.4 Preliminary Result

96 recruited subjects participated in the experiment online through the Heroku server, including 25 males and 71 females. Their years in school and majors are varied. There are 5 groups in the base and RI treatment, and 6 groups in the R treatment. Within each group, 6 subjects are randomly selected to be in the same market. The game lasts 65 rounds. Subjects' behaviors vary significantly across treatments. The key patterns of these variations will be identified in the following results.

Subjects are paid by their aggregate earnings across all time periods and the detailed earning results for each treatment are shown in Figure 3.3. While the base case generates the highest average payoffs, the rank information and the rank payment treatments generate the lowest average payoffs. The standard deviation of payoff distribution is the largest in the rank treatment, due to the payoff redistribution by ranking.

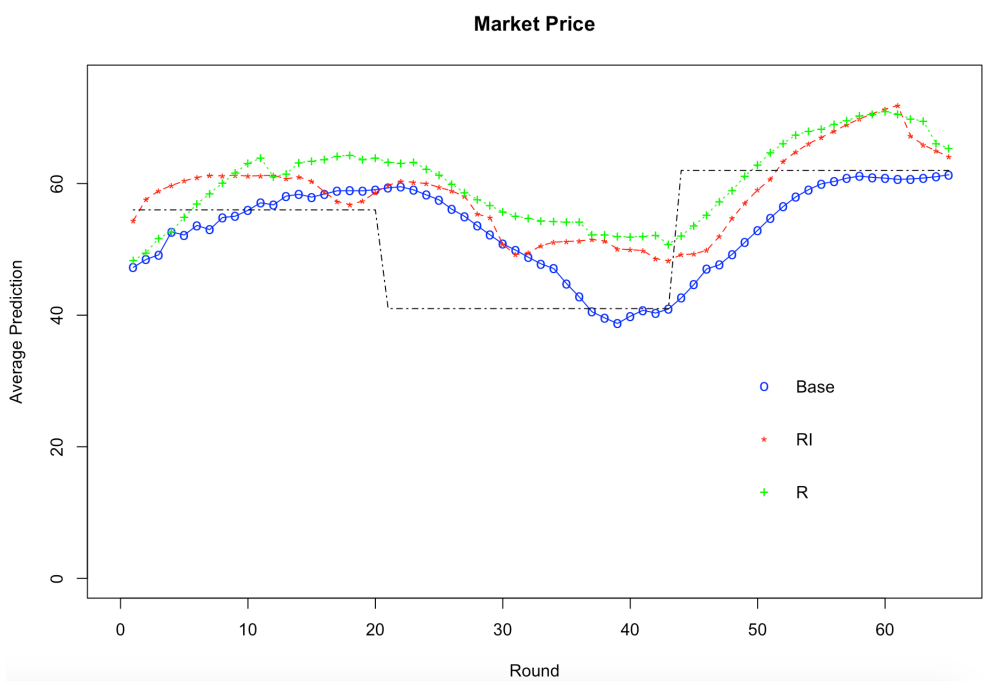
The market price across treatment groups is shown in Figure 3.4. The market price in the base case is presented by the blue line in the graph. The resulting pattern is consistent with Bao et al. (2012)'s finding in Figure 3.1, in which there is under-pricing as the fundamental value decreases and over-pricing as the fundamental value increases. In the RI and R treatments, there is a consistent over-pricing across all time periods. Subjects in two treatments (RI and R) take a longer time to change their predictions compared to subjects in the base case. The fixed effect regression result,

Figure 3.3: Final Average Payment by Treatment



Note: The blue bars are average payment received by agents in each treatment.
The orange line represents the standard error.
The average earning is the highest in the base treatment.

Figure 3.4: Market Price Across Treatment



Note: The black dotted line is the fundamental market price.
The average realized market prices in the base group is the closest to the fundamental market price over time.

which regresses subjects' predictions per treatment indicator, is significant for both treatments. Accordingly, the ranking information and the ranking payment do change subjects' prediction behaviors in the market over time. Subjects' characteristics, including gender, major, and age do not exhibit any significant effect toward their predictions.

In this work, we do not study behavioral differences between high-rank type and low-rank type agents since it is impossible to identify consistently high-ranking agents. All agents have been ranked as number 1 or number 2 for several time periods. According to Appendix table C13 and C14, the agents who win most number 1 rankings in the first 20 time periods typically are not ranked as number 1 for any following time periods. Nevertheless, the overall distinctions among agents in the ranking treatment groups and the base groups are significant. The main finding regarding subjects' prediction behaviors is that:

Result 1. *Subjects' predictions never converge to the fundamental value in the ranking payment treatment. A few subjects' predictions converge to the fundamental value in the ranking information treatment, yet more than half of the subjects' predictions converge to the fundamental value in the base treatment.*

According to Figure 3.4, the average market prices in three treatments all move around the fundamental value but rarely converge to it over time. Within the first 20 periods, we designate agents who gain the most number 1 rankings in each group as the high-ranking agent and the one with the most number 6 rankings as the low-ranking agents. Then, we recorded the time period in which their predictions fall into the fundamental market price interval on period 21-43, which is a range close to 41. In table 3.2, the first column [31,51] is the interval with 41 as the median and the length is 20. The second interval [36, 46] has the length 10 and the last interval [40, 42] has the length 2. When agents' predictions fall into the the interval [40,42], their predictions are very close to the fundamental value.

In order to study group level and individual level market price and prediction convergence rates, a series of Wilcoxon Singed Rank tests are utilized to compare each set of predictions with the

Table 3.2: Wilcoxon Singed Rank Test: Market Prices (Predictions) vs. Fundamental Values

Base				RI				R			
Grp	Indi.	Grp	Indi.	Grp	Indi.	Grp	Indi.	Grp	Indi.	Grp	Indi.
	0.00		0.95		5E-7		0.00		5E-9		0.06
G1:	0.00	**G4:**	0.90	G1:	2E-6	G4:	0.01	G1:	3E-9	**G4:**	0.04
	0.00		0.81		8E-8		0.00		1E-8		0.1
	0.01		0.99		9E-9		0.00		1E-7		0.07
0.00	0.01	**0.98**	0.89	1E-08	2E-8	0.00	0.00	1E-09	2E-8	**0.05**	0.06
	0.00		0.92		3E-8		0.01		4E-10		0.83
	8E-5		0.13		2E-5		0.23		1E-7		7E-5
G2:	0.00	**G5:**	0.37	G2:	8E-6	**G5:**	0.25	G2:	2E-9	G5:	2E-5
	0.00		0.05		6E-6		0.6		3E-9		9E-6
	0.00		0.11		0.01		0.3		3E-9		2E-6
8E-5	0.00	**0.1**	0.02	1E-5	1E-5	**0.28**	0.63	1.2E-9	2E-8	3E-6	3E-6
	4E-5		0.07		2E-6		0.27		4E-10		2E-5
	0.17				6E-12				3E-6		1E-8
G3:	0.16			G3:	2E-11			G3:	3E-6	G6:	4E-8
	0.25				9E-11				1E-6		5E-9
	0.23				1E-11				1E-6		7E-8
0.22	0.18			1E-11	2E-10			3E-7	3E-07	3E-9	6E-9
	0.35				6E-11				9E-7		4E-9

fundamental value. The null hypothesis is that the median of the market price in each group is equal to the fundamental value if none of the following hypotheses are rejected: (1) the market price is 56 in periods 1–20; (2) the market price is 41 in periods 21–43; or (3) the market price is 62 in periods 44–65 at a level of 5 percent. The p-value of the Wilcoxon Signed Rank test is used to compare the market price in each group to the fundamental value, as well as to compare the the individual predictions with the fundamental value, as shown in Table 3.2. The groups with a p-value larger than 0.05 are labeled in bold text. 3 out of 5 groups do not reject the null hypothesis in the base treatment, indicating that those groups have market prices which converge to the fundamental values. However, only 1 out of 5 groups' p-value has a p-value larger than 0 in the RI treatment. In the R treatment, only 1 group has a p-value close to 0.05, but 2 individuals in this group make predictions far away from the fundamental value. Therefore, the majority of subjects' predictions in the R treatment never converge to the fundamental value.

Beyond the convergence rate, agents in the treatment groups are more reluctant, on average, to change their predictions:

Result 2. *Subjects in the ranking treatment groups tend to be more reluctant to change their predictions when market condition changes compared to subjects in the base treatment.*

Group level predictions are shown in Figure 3.5-Figure 3.7. In each graph, the red line represents the fundamental value of the product in each time period. Subjects' predictions in base treatment group 1 and 3 change drastically in response to the shock. In each group, over-pricing lasts for several periods right after the shock, which drives the fundamental value down in time period 20. There is also an under-pricing effect that lasts for several time periods after another shock drives up the fundamental value in time period 43. By comparison, in the two ranking treatments, especially in the rank payment treatment, the length of over-pricing lasts much longer compared to the base treatment groups. This implies that subjects are more reluctant to change their predictions when the market condition changes.

This reluctance is also captured by table 3.3. This table considers the agents who gain the most number 1 rankings in the first 20 periods as high-ranking agents and those who gain the most number 6 rankings as low-ranking agents. Then, it records the number of the time period when their predictions fall into the certain interval. Those intervals' width are 20, 10 and 2, but they all contain the fundamental market price of period 21-43 as the median. When their predictions fall into a narrower interval, these predictions are closer to the fundamental market price. In each base group, 4 out of 5 groups have predictions fall into the second interval [36, 46]. On the other hand, only 2 out of 5 and 2 out of 6 groups in the RI and R treatment have similar predictions. Therefore, more agents in the base treatment are making predictions closer to the fundamental value compared to agents in those two ranking treatments.

Another finding from the table supports our claim that this study is not able to compare the high-rank type agents with low-rank type agents. If we compare the high-ranking agent with low-ranking agents' predictions within the same group, the distinctions are minimal. The time

Table 3.3: The Time Period that Player's Prediction Within Certain Range (From Period 21-43)

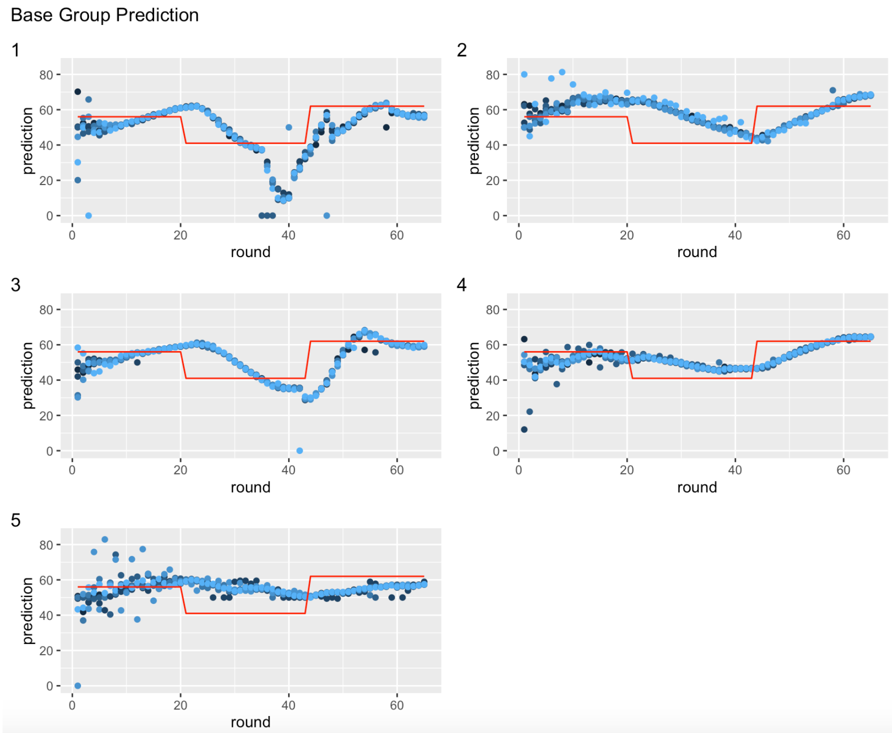
		High-Rank				Low-Rank			
Treat.	Group	ID	[31,51]	[36,46]	[40,42]	ID	[31,51]	[36,46]	[40,42]
Base	1	1	28	29	31	2	28	30	32
	2	10	36	41	N	12	39	42	N
	3	13	30	33	34	18	30	33	35
	4	24	27	36	N	21	29	37	N
	5	25	41	N	N	29	N	N	N
RI	6	32	43	N	N	34	N	N	N
	7	41	N	N	N	42	33	N	N
	8	43	N	N	N	47	38	N	N
	9	49	32	32	32	53	31	40	41
	10	59	35	35	35	57	35	35	35
R	11	61	30	38	N	62	38	N	N
	12	72	N	N	N	71	N	N	N
	13	77	38	N	N	74	39	N	N
	14	83	39	N	N	84	37	N	N
	15	89	32	32	32	90	32	32	35
	16	91	N	N	N	94	N	N	N

[31,51] is the range of fundamental value 41 +10 and -10. [36,46] is the range of fundamental value 41 +5 and -5. [40,42] is the range of fundamental value 41 +1 and -1. N means that that player's prediction never reach that certain interval. High-Rank player is the player who ranked 1 most within the group. Low-Rank player is the player who ranked 6 most within the group.

[]

period when high-ranking and low-ranking agents' predictions fall into the same interval are close or even equivalent to each other. The low-ranking agents at the first 20 time periods do not perform significantly different from the high-ranking agents. Moreover, there are no consistently high-ranking agents, as seen in Appendix table C13 and C14. The high-ranking agents change when the fundamental market price changes and the high-ranking agents in the first 20 rounds can rank as low as number 6 in later time periods. Using this set of experiments, we cannot distinguish high-ranking agents' behavior from low-ranking agents. The specific difference between ranking types (high-type and low-type) is beyond the scope of this study. We instead focus on understanding the overall effect of ranking information for general agents.

Figure 3.5: Base Group Price Prediction



Note: The read line is the fundamental market price.
The dots are agents' price predictions at each time period in group 1-5.
Same for Figure 3.6 and Figure 3.7.

Figure 3.6: Rank Information Group Price Prediction

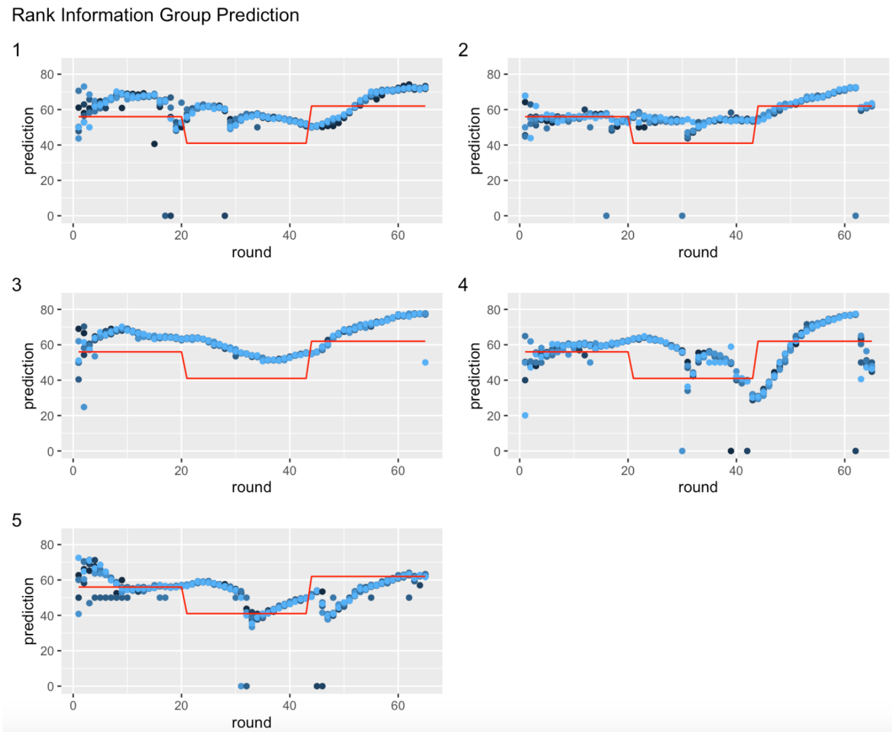
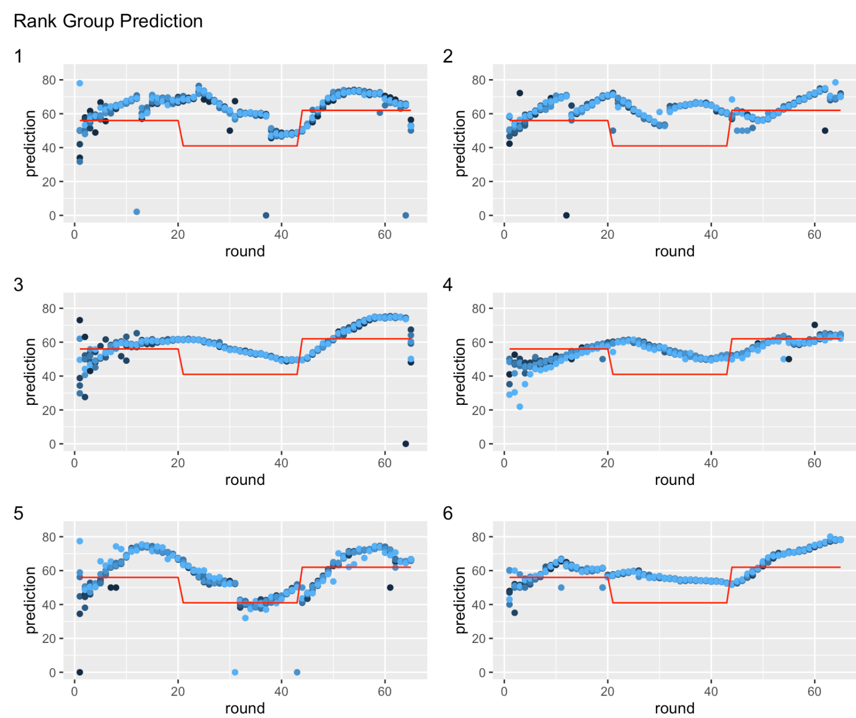


Figure 3.7: Rank Group Price Prediction



Even though we cannot distinguish the differences between high-ranking and low-ranking agents, we can still study individual behaviors within each treatment. Visible heterogeneity is found among subjects, as demonstrated in their rankings in each time period. To understand how individuals react to their ranking changes, a sets of fixed effect regressions were conducted. Ranking was set as the independent variable while controlling for time as well as individual and group fixed effects. There are two dependent variables in this regression: one is the prediction differences between two adjacent periods, which are labeled as Diff. in the table. This variable represents the extent of changes on certain individual's predictions between two adjacent time periods. The other dependent variable is the distance (labeled as Dis. in the table) between the prediction and the fundamental value. This difference shows if subjects' predictions are accurate to the fundamental value, which implies subjects' ability to make predictions. The regression result is given in Table 3.4.

The p-values are larger than 0.05 for all regressions when distance is set as the dependent variable. This means that ranking high or low does not help minimize the prediction distance from the fundamental values. It also demonstrates that subjects are not making better predictions when they are ranked high. The variable ranking 6 is the only statistically significant variable. The positive estimator implies that subjects' predictions are farther away from the fundamental value when they rank low. Besides, the significant results for ranking 5 and 6 in both treatments demonstrates that:

Result 3. *In both treatments, subjects are more likely to make larger changes on their predictions when they ranked low (5 or 6) compared to when they are ranked higher.*

For every individual, when subjects' ranking are low, they are more likely to make predictions different from what they have predicted at the last time period. This is because the ranking information signals that their predictions are far from the market price relative to others' predictions. These two sets of regression agree with Kopányi et al.(2019)'s finding that low-ranking subjects' predictions are closer to the fundamental value when the market condition is unstable. As a result,

Table 3.4: Ranking vs. Difference and Distance

	RI		R	
Rank	Diff.	Dis.	Diff.	Dis.
2	-0.01	-0.05	0.16	0.06
	(0.98)	(0.93)	(0.89)	(0.91)
3	0.51	0.58	0.29	0.11
	(0.44)	(0.30)	(0.80)	(0.84)
4	0.72	0.27	0.73	0.41
	(0.27)	(0.62)	(0.53)	(0.45)
5	1.51*	0.29	1.18	0.56
	(0.02)	(0.60)	(0.32)	(0.31)
6	2.1*	0.01	2.59*	2.73*
	(0.00)	(0.97)	(0.04)	(1.6E-6)

Diff.: Difference between predictions in two adjacent time periods.Dis.:Distance between subjects' predictions and the fundamental values.

when low-ranking subjects change their predictions, their predictions become farther away from the fundamental value.

The phenomenon that agents maintain their predictions when they rank high and change their predictions when they rank low can also explain the similar predictions made by high-ranking and low-ranking agents in the same group (Table 3.3). When agents are in the same market, they all make adjustments on predictions according to the realized market price. Agents with high-rankings keep their predictions close to the last time period's market price since their high rankings inform then that they are making profitable predictions. On the other hand, low-ranking agents change their predictions drastically, as seen in Table 3.4. They adjust their predictions to be closer to the last time period's market price, since the ranking signals that their former predictions were incorrect. As a result every agents' predictions are close to each other in the next round, since they all try to predict the price according the realized market price in the last time period.

Regarding how subjects' individual ability affects their predictions, the finding is that:

Result 4. *Subjects' cognitive ability and coordination ability do not significantly affect their predictions in all treatments.*

To understand potential individual heterogeneity in subjects' prediction behaviors, cognitive and coordination abilities may serve as potential indicators of subjects' ability to make predictions close to the market price. Subjects were given a cognitive ability test containing three questions. They earned one point for each correct answer. The maximum score is 3 and the least score is 0. Furthermore, the coordination score is set as the absolute difference between their answer and the theoretical optimal choice of 0 on the beauty contest game. The result of the fixed effect regression is insignificant at a level of 5 percent when regressing the average changes in predictions in all periods on the cognitive ability score, coordination score, SAT score and GPA. Similarly, in ranking treatments, the p-value is insignificant when regressing the prediction changes on those ability indexes after controlling for the average rankings.

Taking cognitive ability as the independent variable, the mean distance between the prediction and the fundamental value is the only dependent variable that generates a significant result in a fixed effect regression. The estimate is 0.35, which indicates that subjects with high cognitive ability are making predictions farther away from the fundamental value. This can be explained by the turbulent nature of the market. Because the market is unstable, subjects with high cognitive ability more easily figure out the pattern of the market price, and correspondingly make predictions close to the market price while the market price is far away from the fundamental values. Therefore, subjects with high cognitive ability may have tried harder to make predictions yet may not perform well in the market. Moreover, this significance disappears after controlling for the treatment effects. The results therefore suggest that the ranking information is a much stronger signal in guiding subjects' behaviors compared to their own beliefs and intellectual abilities within an unstable market. This might also be the reason that subjects' prediction differences are not significantly correlated with their abilities, since the ranking information plays a much more powerful role in their learning process.

3.5 Heuristic Explanations

To understand subjects' individual price prediction patterns, Bao et al. (2012) proposed several models. Again, we do not compare agents' intra-group differences with regard to heuristic rule adoption, as their predictions are similar even though their ranks are drastically different. We instead focus on understanding agents' aggregate behavioral distinctions across treatments.

3.5.1 Simple Linear Prediction Rules

The simplest prediction rule is a linear prediction rule in which subjects make predictions on the current market price based on the previous market prices and previous predictions up to three time periods:

$$p^e_{h,t} = c + \sum_{i=1}^{3} o_i p_{t-i} + \sum_{i=1}^{3} s_i p^e_{h,t-i} + v_i$$

The linear regression result is heterogeneous (shown in appendix table C1-table C3). In the table, the variables which significantly affect the current price prediction are different across individuals within each treatment group. 29 out of 30 subjects in the control group have at least one significant coefficient and this number is 28 out of 30 in the RI treatment and 4 out of 36 in the R treatment.

The last two columns are the results of a Chow test on the break point to test the stability of the model between the time before and time after the shock. The break point is chosen at rounds 21 and 44 in order to divide the game into three time periods. The null hypothesis for $Chow_1$ and $Chow_2$ is that the econometric model stays the same between the time before and after the break point 1 (round 21) and break point 2 (round 44). The ratio of players whose test result is significant is different across treatments (shown in table 3.5). Subjects in the RI treatment were most reluctant to change their prediction patterns. This ratio is similar in the base treatment and the R treatment, while the R treatment has a lower significance rate.

Table 3.5: Significance of the Chow Test

	Base	RI	R
P1 vs. P2	7/30	14/30	12/36
P2 vs. P2	22/30	13/30	26/36
Total	24/30	19/30	28/36

3.5.2 Simple Heuristic Rules

To eliminate the heterogeneity shown in the linear predictions, this study proposes another set of heuristic rules. The estimation result is shown in appendix table C4-C6. Two rules are tested. The first is a trend following rule:

$$p^e_{h,t} = p_{t-1} + \gamma(p_{t-1} - p_{t-2})$$

This γ can be either positive or negative. The positive γ represents a trend following rule, in which subjects increase their predictions as they notice increases in market price in the previous time period. On the other hand, a negative γ shows a contrarian rule, in which they predict the market price to be lower although it increased in the last time period. Since this is a positive feedback price market, consistent with Bao et al. 2012's finding, most of subjects in all treatments have a positive γ within [0.16, 1.7]. 18 out of 30 agents have statistically significant γ in the base treatment and only 3 among them have negative γ. 17 out of 30 agents have statistically significant γ and this number is 22 out of 36 in the RI treatment.

The second rule is the adaptive rule:

$$p^e_{h,t} = p^e_{t-1} + \omega(p_{t-1} - p^e_{t-1})$$

The adaptive rule could explain subjects' price prediction to some extent, since the estimate ω is significant for every individual participant. However, the wide range of the residual standard error of this model (from 0.6 to 10) implies that the adaptive rule is not generally a perfect fit for every individual. It fits some agents' behavior better than others. Moreover, the model-fit regressions show indistinguishable results on subjects' adaptive rules across treatments. Therefore, further analysis is necessary to explain the behavioral differences between the base treatment and the ranking treatments (RI and R).

3.5.3 Heuristic Switching Models (HSMs)

Since those simple linear models and heuristic models fail to explain the treatment effect, another set of Heuristic Switching models, proposed by Anufriev and Hommes (2012), is utilized to disentangle the treatment effect and explain subjects' patterns of price prediction. In the model, subjects switch their heuristic prediction rules among four potential rules, which consist in two trend following rules (positive and negative), the adaptive rule, and and the adjustment rule. Details of each rule are as follows:

The adaptive expectation rule (ADA): $p^e_{t+1,1} = p^e_t + 0.85(p_t - p^e_{t,1})$.

The contrarian rule (CTRs) is the trend following rule with negative coefficient: $p^e_{t+1,2} = p_t - 0.3(p_t - p_{t-1})$.

The trend extrapolating (TRE) rule is the positive feedback trend following rule: $p^e_{t+1,3} = p_t + 0.9(p_t - p_{t-1})$

The last rule is an anchoring and adjustment heuristic (A&A): $p^e_{t+1,4} = 0.5(p^{av}_t + p_t) + (p_t - p_{t-1})$.

The first term in the last equation p^{av}_t is the mean of all former prices in the sample. I have also compared the MSE of model fit using the optimal coefficients median found in my experimental data with the coefficients Bao et al. (2012) used. The difference is minimal. Therefore, to make the results more comparable, I used the exact same value that they have used.

Agents in the market switch their heuristic rules according to the utility function, which is mainly composed by the squared prediction error. It is the difference between the prediction using heuristic rule h, where $h \in \{1, 2, 3, 4\}$, and the realized market price:

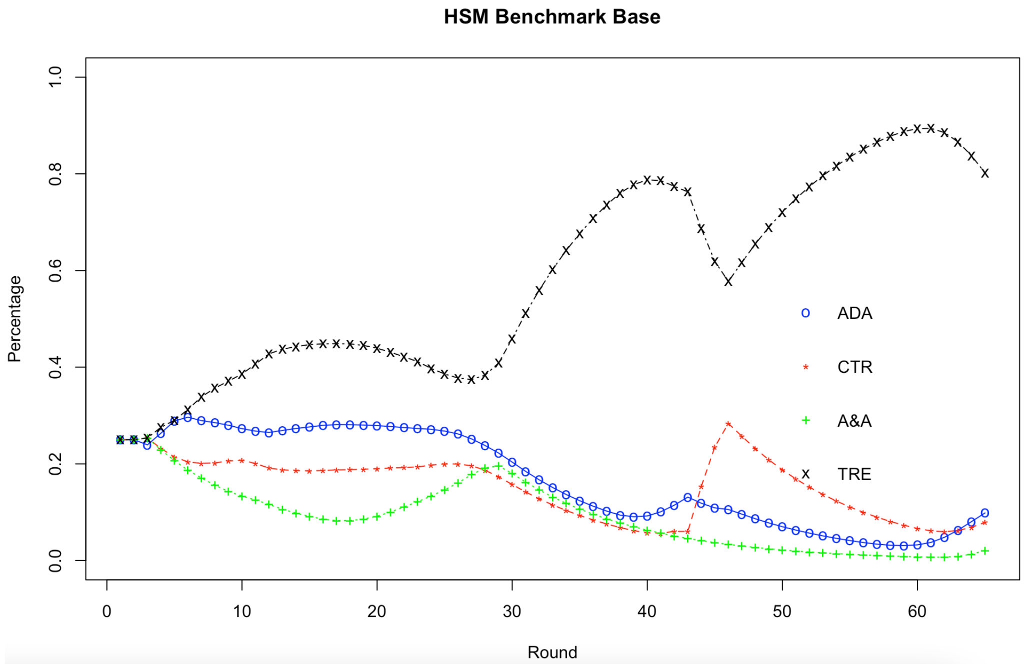
$$U_{t,h} = -(p_t - p^e_{t,h})^2 + \eta U_{t-1,h}.$$

$\eta \in [0,1]$ measures the degree a subject worries about her past performances. A larger η implies that subjects seriously consider past errors. A smaller η represents the opposite. A population level distribution of subjects using those four heuristic rules is modeled by Hommes et al. (2005) and Diks and van der Weide (2005) using a discrete choice model with asynchronous updating:

$$n_{t,h} = \delta n_{t-1,h} + (1-\delta)\frac{exp(\beta U_{t-1,h})}{\sum_{i=1}^{4} exp(\beta U_{t-1,i})}.$$

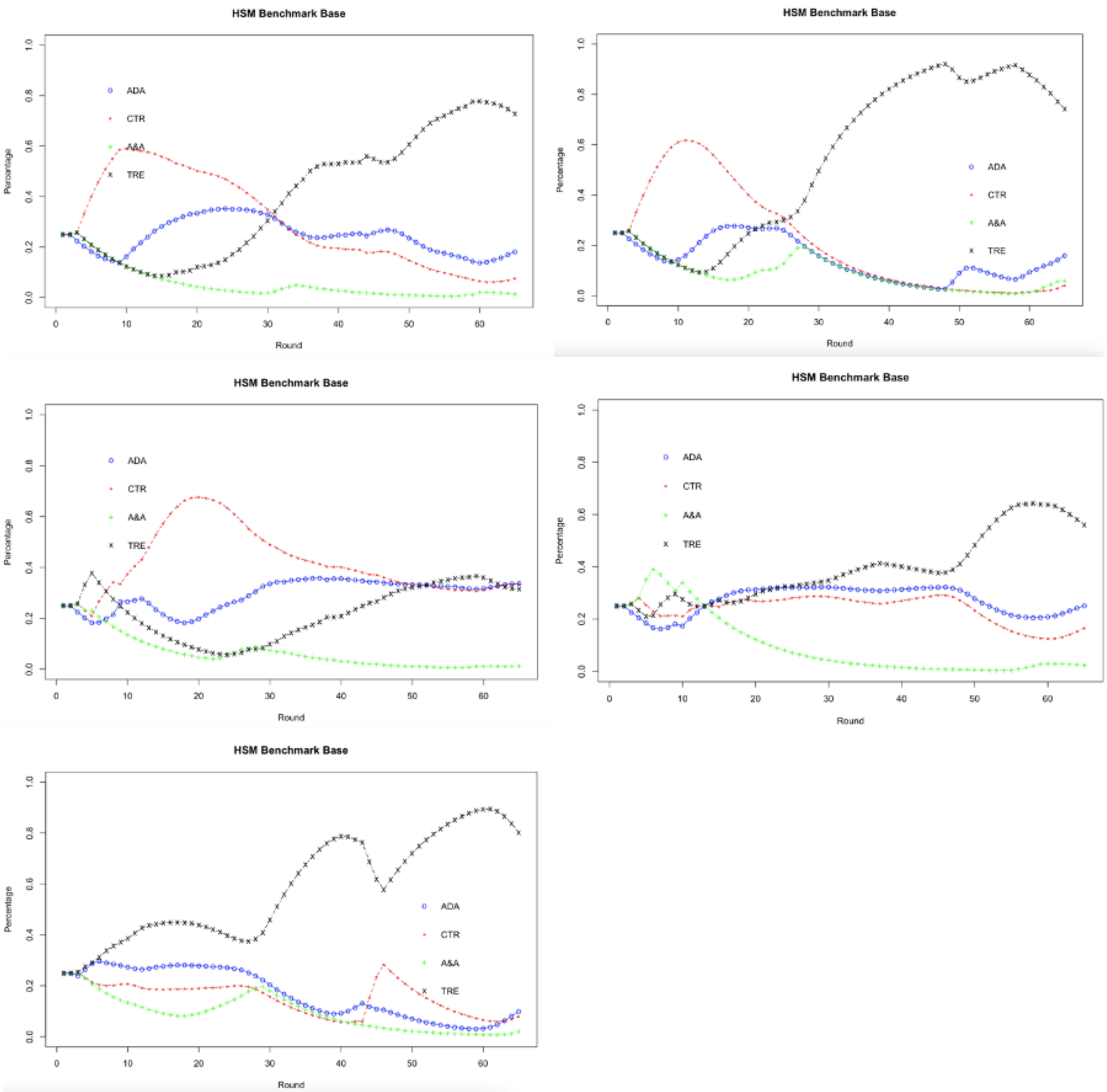
$\delta \in [0,1]$ measures the likelihood of subjects sticking to their original heuristic, so $(1-\delta)$ represents the portion of subjects who update their heuristic. Moreover, $\beta > 0$ is the sensitivity measure of subjects' rate of updating. A smaller β means that the subjects put more equal weight on those four rules. Subjects with a greater β switch their prediction strategy to the most optimal heuristic strategy more rapidly compared to others with lower β. The benchmark value applied by Bao et al. (2012) and Anufriev and Hommes (2012) is $\beta = 0.4, \eta = 0.7, \delta = 0.9$ with the initial distribution $[n_{1,1}, n_{1,2}, n_{1,3}, n_{1,4}] = [0.25, 0.25, 0.25, 0.25]$. A simulation of subjects' predictions one time period ahead is conducted at the group level to simulate the population-level distribution of the heuristic switching in regard to time. One typical heuristic distribution for the base group is shown in figure 3.8. This simulation matches Bao et al. (2012)'s simulation of the positive feedback LTFE. As time goes by, TRE dominates over the three other rules. When a shock occurs, there is a drop in the ratio of subjects who utilize TRE rules to predict price. The simulations of all five base treatment groups are shown in figure 3.9. Besides group 3, where the ratio of subjects who adopt ADA, CTR, and TRE are similar, another 4 groups adopt TRE as the dominant strategy, especially at the later period of the game. Moreover, there is a small amount of turbulence in the ratio of TRE at the time when the shock happens. Nevertheless, the overall tendency is that the ratio of TRE increases and the ratio of other heuristic rules decreases.

Figure 3.8: HSM Benchmark in a typical Base Group



Note: Those four lines represent the portions of agents take each HSM. ADA is the dominant in later periods.

Figure 3.9: HSM Benchmark in Base Groups



Note: Those four lines represent the ratio of agents in the population who take one of the four HSM rules.
ADA is the dominant in later periods in all groups.
The HSM composition fluctuates more frequently on RI (figure 3.10)
and R treatment (figure 3.11).

When comparing the simulation results for the RI and R treatments (shown in Figure 3.10 and 3.11), A stronger turbulence in heuristic rules switching is evident. Even though TRE remains the dominant rule, other rules surpass the TRE once TRE becomes the dominant strategy. However, in the base treatment, once the TRE become dominant, it remains the dominant strategy. This may be because a higher proportion of subjects in the RI and R treatments are more reluctant to change. They do not switch their strategies until later time periods.

Figure 3.10: HSM Benchmark in Rank Information Groups

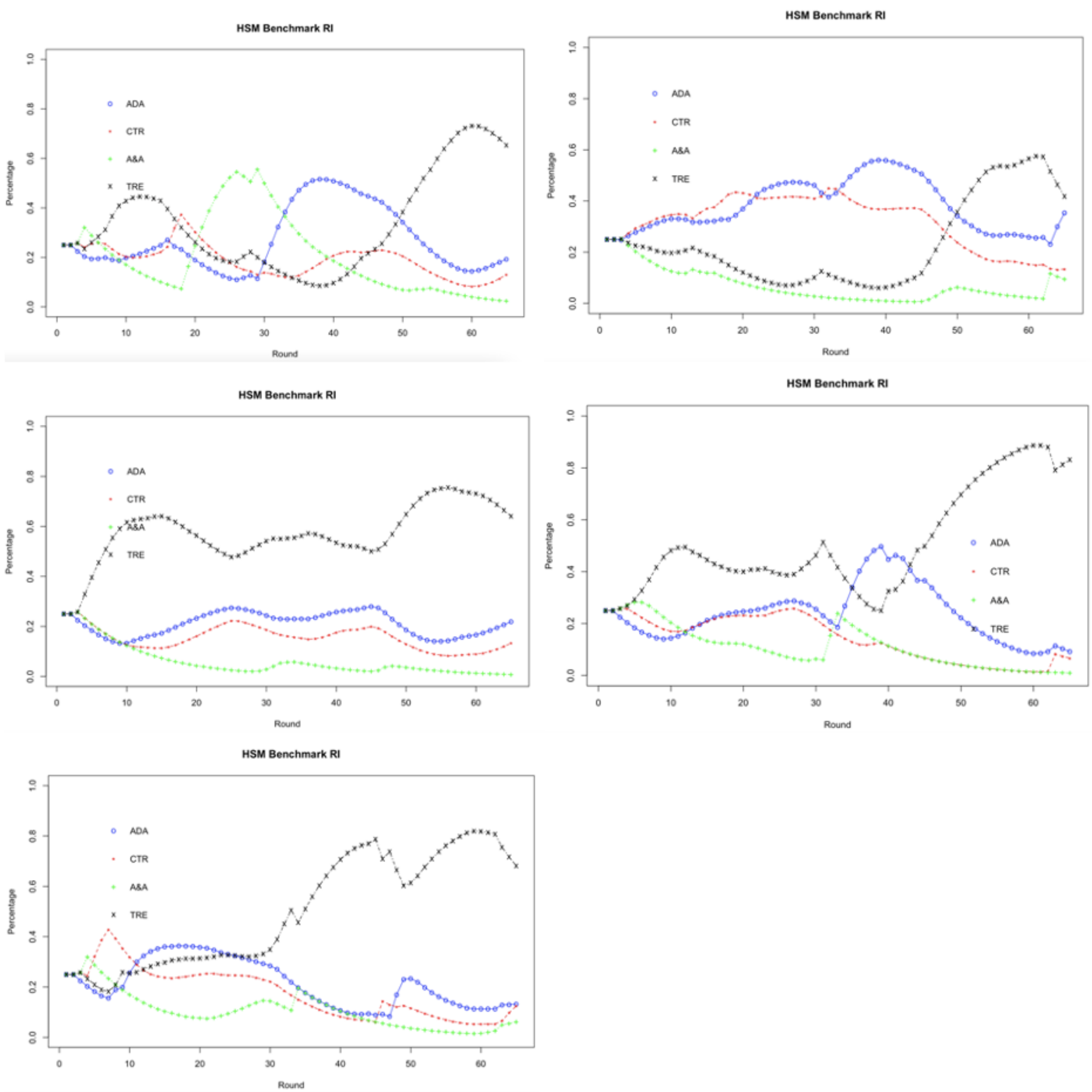
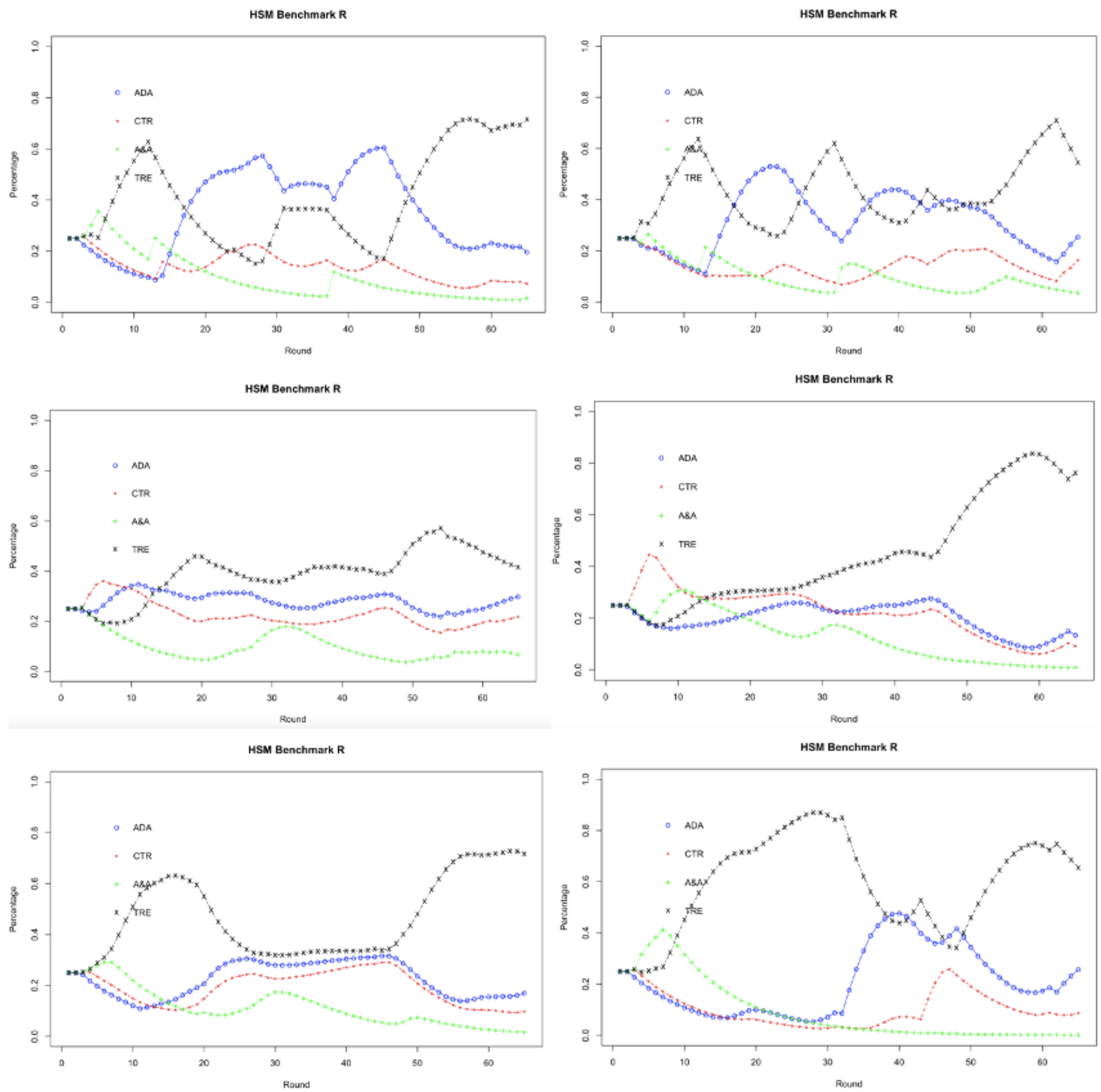


Figure 3.11: HSM Benchmark in Rank Groups



In order to assess this theory, I used the grid search method to find the most optimal parameters β, η and δ to fit individual behaviors at the group level. The result of the model fit is in Table C10-C12. I fit the experimental data with these four simple heuristic models (A&A, ADA, CTR, and TRE), rational expectation (RE fundamental), naive, and three HSMs. The rational expectation (RE fundamental) reflects the fundamental values of the market price and the naive model is the last-time-period prediction. Generally speaking, the HSM Group model is the best fit for the individual behavior coefficients found through the grid search method.

The average of the HSM coefficients by treatment are listed in table 3.6. The distinctions between treatment coefficients implies that the inertia to change in the two treatments is formed through different channels. In the R treatment, when comparing the coefficients in R with the base treatment, η is the least in the R treatment, which measures subjects' consideration of past errors. A small η implies that subjects only care about the current situation and take little consideration of past errors compared to subjects in base treatment. This payoff redistribution by ranking makes subjects care less about past tendencies. In conclusion, ranking payment misleads subjects to ignore the past trend since the ranking payment redistribution encourages them to maximize the current time period's payoffs. As long as they rank high in a certain time period, they lose incentive to change their heuristic strategies. As a result, ADA becomes the dominant rule for some time periods in the R treatment since ADA is the only rule takes into account the one-period ahead error.

On the other hand, in the RI treatment, stagnation is caused by insensitivity to the optimal heuristic path. The β is the smallest in the RI treatment when compared with the base treatment. This means that subjects do not know which heuristic strategy performs the best, so they value those four heuristic rules equally. This is caused by misleading ranking information. Especially when the market is unstable, most subjects have been ranked high for at least several time periods due to the unstable market conditions. They believe that they have found the optimal heuristic when they rank highly, so they lose the sense of seeking the optimal strategy due to this ranking information. Therefore, switching to the optimal heuristic takes a longer time compared to the base treatment.

According to result 3, subjects make significant changes to their predictions only when their rankings are the lowest. The other 5 players in the market do not make these large changes to their predictions. Both ranking information and the ranking payment give players incorrect signals about their heuristic strategy. These ranking histories facilitate the false illusion that their prediction heuristic is accurate. They are ranked high not because they have switched to the optimal heuristic rules but because they accidentally match the unstable market prices for several time periods. As a result, they are reluctant to change their heuristic, even when their predictions drift away from the

Table 3.6: Average Coefficients

	β	η	δ
Base	3.6	0.4	0.5
RI	1.9	0.3	0.5
R	3.9	0.1	0.6

realized market price due to updated market conditions. Since 5 out of 6 subjects in the market are not adjusting their predictions in a flexible manner, the realized market prices fail to converge to the fundamental value. Moreover, the market prices in the ranking treatment are less volatile than the realized market prices in the base treatment groups. Subjects in the base group do not see the ranking information and correspondingly do not form false beliefs about the market condition. They are more flexible, adjusting their predictions according to the conditions of the market.

3.6 Conclusion

In this experiment, competition impedes agents' ability to adjust their predictions as they approach the fundamental market price. They continuously over-price the product when performance rankings are given. Over-pricing is more significant in the ranking payment treatment. Agents who ranked high and made unnecessary prediction changes when they ranked low are often reluctant to make adjustments according to the market conditions. This is the main cause of the overpricing.

Due to unstable market conditions, agents are not necessarily making predictions close to fundamental values even when they are ranked high. Agents adjust their predictions according to the realized market price no matter if they rank high or low, as their predictions are similar as long as they are in the same market. Besides this, rankings are highly volatile and no one can maintain a high ranking throughout the game. Therefore, we are unable to distinguish high-rank type agents from low-rank type in this experiment. Nevertheless, agents behave significantly different when they are given ranking information compared to when they do not have rankings. In a market with ranking information, the market prices in ranking treatments rarely converge to the fundamental value. On the other hand, in the base treatment which lacks this ranking information, more than half of the realized market prices converge to the fundamental value.

Players' prediction accuracy is not significantly impacted by their cognitive and coordination ability. A possible explanation for this is that the turbulent market conditions are too difficult to understand, even by high ability players. The only significant result demonstrates that subjects with high cognitive ability make predictions farther away from the fundamental values compared to players with low cognitive ability. This finding can again be explained by the unstable market conditions. High ability players may be good at understanding the rule of market price so they make predictions closer to the market price. However, unstable market conditions make the market price far from the fundamental market price. Therefore, in some time periods, when subjects' predictions are close to the market price, they are actually making predictions far from the fundamental values.

Individual price prediction behavior can be understood by the heuristic switching model. Subjects' tendency to stagnate instead of shifting to a better-performing heuristic rule can be explained by the fact that the ranking information obscures the optimal heuristic rule. For the ranking payment treatment, the ranking payment drives participants' attention away from the the former trend and makes a higher proportion of subjects unwilling to change their heuristic strategies.

Ranking institutions such as trading managers and hedge funds according to their performance is a common phenomenon. Those companies take their rankings very seriously. They use it as a indicator to rate their performances in the industry. However, this work demonstrates that in the field of finance, when products have a fundamental value, these performance rankings may be misleading. The turbulent nature of the market indicates that top performers in the market are not necessarily the ones who are making the right decisions according to market prices. Therefore, participants in the market should be more careful when interpreting their past performances, especially when they notice apparent signals of market condition mobilization. Similarly, for investors who are following the suggestions made by those agents, they should also be more skeptical about those agents' choices even they were top-performers in the past.

Besides competition through the ranking mechanism, agents in the market also cooperate with each other through information sharing and other forms of communication. These collaborations may have an effect on subjects' beliefs and strategies when participating in the market. However, how this information sharing affects agents' prediction performance is unclear and warrants further study.

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Appendix A

Appendix 1: Repeated Threshold Gift Exchange Game: An Experimental Evidence

A.1 Chart of charities

Name of the charity	Description
Wounded Warrior Project	The mission of Wounded Warrior Project is to honor and empower wounded warriors. Our purpose is: to raise awareness and enlist the public's aid for the needs of severely injured service men and women; to help severely injured service members aid and assist each other; and to provide unique, direct programs and services to meet the needs of severely injured service members.

Patient Advocate Foundation	The mission of the Patient Advocate Foundation (PAF) is to provide effective mediation and arbitration services to patients to remove obstacles to healthcare including medical debt crisis, insurance access issues and employment issues for patients with chronic, debilitating and life-threatening illnesses. PAF is a national organization which provides professional case management services to Americans with chronic, life threatening and debilitating illnesses. PAF case managers serve as active liaisons between the patient and their insurer, employer and/or creditors to resolve insurance, job retention and/or debt crisis matters as they relate to their diagnosis also assisted by doctors and healthcare attorneys. PAF seeks to safeguard patients through effective mediation assuring access to care, maintenance of employment and preservation of their financial stability.
American Red Cross	Since its founding in 1881 by visionary leader Clara Barton, the American Red Cross has been the nation's premier emergency response organization. We bring shelter, food and comfort to those affected by disasters, large and small. We collect lifesaving donated blood and supply it to patients in need. We provide support to our men and women in military bases around the world, and to the families they leave behind. We train communities in CPR, first aid and other skills that save lives. And we assist our neighbors abroad with critical disaster response, preparedness and disease prevention efforts. We are able to do all this by mobilizing the power of volunteers and the generosity of donors.

World Wildlife Fund	Founded in 1961, World Wildlife Fund's (WWF) mission is the conservation of nature. Using the best available scientific knowledge and advancing that knowledge where we can, we work to preserve the diversity and abundance of life on Earth and the health of ecological systems by: protecting natural areas and wild populations of plants and animals, including endangered species; promoting sustainable approaches to the use of renewable natural resources; and promoting more efficient use of resources and energy and the maximum reduction of pollution. We are committed to reversing the degradation of our planet's natural environment and to building a future in which human needs are met in harmony with nature. We recognize the critical relevance of human numbers, poverty and consumption patterns to meeting these goals.
Save the Children	Save the Children invests in childhood - every day, in times of crisis and for our future. In the United States and around the world, we are dedicated to ensuring every child has the best chance for success. Our pioneering programs give children a healthy start, the opportunity to learn and protection from harm. Our advocacy efforts provide a voice for children who cannot speak for themselves. As the leading expert on children, we inspire and achieve lasting impact for millions of the world's most vulnerable girls and boys. By transforming children's lives now, we change the course of their future and ours.

A.2 Survey After the Experiment

Age: (e.g., 18)

Gender: female male Other

Major: (e.g., economics)

Now, please slide the bar for the following questions to show how much do you agree with the following statements. 1 represents strongly disagree, 7 represents strongly agree, and each level in the middle is in between those levels.

Manager :

- Q1. Generally Speaking, you would say that you are a generous person.
- Q2. Generally speaking, you care about fairness in the working environment and will act according to what you believe is fair.
- Q3. In this specific firm setting, I have paid workers the wage that they deserve.
- Q4. In this specific firm setting, those two workers have worked hard enough. The workers have exert enough effort which matches the wage that they receive.
- Q5. I have paid workers enough wage according to how much that they have worked.

Worker :

- Q1. Generally Speaking, you would say that you are a generous person.
- Q2. Generally speaking, you care about fairness in the working environment and will act according to what you believe is fair.
- Q3. In this specific firm setting, I have done enough work according to the wage that I have received.
- Q4. In this specific firm setting, the manager has paid me the wage that I deserve.
- Q5. In this specific firm setting, my coworker has contributed enough effort.

Appendix B

Appendix 2: Effort and the Timing of Payments in a Threshold Gift Exchange Game

B.1 Survey After the Experiment

Age: (e.g., 18)

Gender: female male Other

Major: (e.g., economics)

Now, please slide the bar for the following questions to show how much do you agree with the following statements. 1 represents strongly disagree, 7 represents strongly agree, and each level in the middle is in between those levels.

Manager :

- Q1. Generally Speaking, you would say that you are a generous person.

- Q2. Generally speaking, you care about fairness in the working environment and will act according to what you believe is fair.
- Q3. In this specific firm setting, I have paid the worker the wage/bonus that she deserves.
- Q4. In this specific firm setting, the worker has worked hard enough. The worker have exert enough effort which matches the wage/bonus that they receive.

Worker :

- Q1. Generally Speaking, you would say that you are a generous person.
- Q2. Generally speaking, you care about fairness in the working environment and will act according to what you believe is fair.
- Q3. In this specific firm setting, I have done enough work according to the wage/bonus that I have received.
- Q4. In this specific firm setting, the manager has paid me the wage/bonus that I deserve.

Appendix C

Appendix 3: Competition and Forecast Accuracy:Theory and Experimental Evidence

C.1 Experiment Instruction

In this experiment, you will be randomly paired with five other players. You are advisor of a trading company and those five other players are in the same market with you. They are advisors of different trading companies.

There is one task on the session. In the task, you will make choices to earn some payoffs. In the task, every 1,300 points counts as 0.5 dollar. If you are ready, please click the next button. Once you click the button, you cannot go back.

Work as an Advisor

In this experiment you participate in a market. Your role in the market is an advisor of a trading company who is active on a market for a certain financial product. In each time period the trading company needs to decide how many units of the product he will buy, intending to sell them again the next period. To take an optimal decision, the company asks you to make a prediction of the market price of the product during 65 successive time periods.

Let's learn how will you get paid. In each round, you will predict the market price, which is a real number between 0 and 100. Your earnings during the experiment will depend on the accuracy of your predictions. The smaller your prediction error is, the greater earnings you will get at the end of the experiment. Afterwards, you will get paid according to the accuracy of your predictions in all rounds. Your payoff function is as follow: 1300/ (1+|Your Prediction -Market Price |).

Therefore, if your prediction is closer to the market price, the absolute value of the difference between those two numbers will be smaller, then your payoff will be larger. Note: Every 1,300 points count as 0.5 dollars.

About the Market The price of the financial product will be determined by the law of supply and demand. Supply and demand on the market are determined by the trading companies (you are advising one of them) of the product. Higher price predictions make a trading company demand a larger quantity and vice versa. A high price prediction also makes the trading company less willing to sell the product in this period, which decreases the supply and vice versa. The exact manner by which the market price is determined is unknown to you, but you will see on your screen the evolution of the actual price over time and you can learn from this information to improve your forecasts.

There are several large trading companies active on this market and each of them is advised by a participant of this experiment. Total supply and demand are largely determined by the sum of the individual supplies and demands of these companies. The rule for determining the market price is subject to change in demand and supply but the market price will always depend on the average prediction of you and the other 5 market participants. There are two kinds of exogenous shocks which may affect the total supply and demand: (1) in each period, there may be small random fluctuations in the supply caused by transportation delay or other reasons. (2) In some periods, there may large persistent changes in the demand caused by demand from other international markets or other reasons.

Let's get ready for the quiz! This section is quiz section, the results of the quiz will not influence your final payoff. It only helps you to understand the rules and payment structure of the experiment.

Before we start, let's preview the prediction page. During the experiment your prediction page will look like this after the first time period, please read instructions in the graph carefully. At the top of the prediction page, you can submit your prediction of the price. You have to slide the bar to choose a number between 0 and 100. After you made your prediction please press "next" to submit. You might need to wait for other participants in the same market before continuing to the next period. The market price for the next period will be calculated once all the members in the same market have submitted their predictions. Then you continue with the prediction in the next period for the price in the period after the next period, and so on. The graph below the sliding bar shows the history of your prediction and the market price. The history table below graph shows the history of your prediction, the market price, as well as the point you earned in each period and in total. The more recent information is put closer to the top. You can use your mouse and the stroller to trace the information in older past. The graph and the table will be updated in the beginning of each new period. Please notice that the price and prediction information in the above graph and table is just for illustration. The data are generated randomly. So, it does not have any implication on what will really happen in our experiment. If you are ready to make predictions, click next button.

C.2 Additional Tables

C.3 Subjects' Rankings in Different Peiriods

multirow

Table C1: Simple Linear Prediction Rules Base Group

ID	C	p^e_{-1}	p^e_{-2}	p^e_{-3}	p_{-1}	p_{-2}	p_{-3}	R^2	RSE	AC	C_1	C_2
1	2.36	0	0	0.15	1.17	0	-0.6	0.98	2.1	Y	N	Y
2	2.96	0	0	0	1.55	0	-0.45	1	0.95	Y	N	Y
3	0	0.54	0	-0.35	1.52	0	0	0.9	5.47	Y	Y	Y
4	0	0	0	-0.12	1.59	-0.69	0	0.99	1.25	Y	N	Y
5	0	0	0	0	1.23	0	0	0.65	8.73	Y	N	Y
6	0	-0.1	0.09	-0.06	1.94	-0.78	0	1	0.63	Y	N	Y
7	0	0.33	0	0	1.12	-0.39	0	0.99	0.68	Y	N	Y
8	0	0.32	0.22	0	1.07	0	-0.55	0.98	1	Y	N	N
9	0	0	0.3	0	1.22	0.09	-0.69	1	0.5	Y	Y	Y
10	0	0	0	0	1.26	0	0	0.96	1.51	Y	Y	N
11	0	0	0	0	0.94	0	0	0.97	1.29	Y	Y	Y
12	0	-0.4	0.76	0	4.4	-6.6	2.95	0.73	5.39	Y	N	N
13	0	0	-0.27	0	1.61	0	0	0.98	1.45	Y	N	Y
14	3.1	0	0	0	1.46	0	0	0.98	1.53	Y	N	Y
15	1.01	0.56	0	-0.22	1.44	-1.02	0.33	1	0.37	Y	N	Y
16	1.1	0.27	0	0	1.45	-0.6	0	1	0.56	Y	N	Y
17	0	0.41	0	0	1.17	0	-0.29	1	0.5	Y	N	Y
18	-11.75	0	0	0	3.42	0	0	0.86	4.71	Y	N	Y
19	0	0	0	0.23	1.1	0	0	1	0.9	Y	N	Y
20	0	0.4	-0.25	0	1.01	0	0	0.99	0.56	Y	N	Y
21	0	0	-0.34	0	0	0	0	0.79	2.92	Y	N	N
22	0	0	0	0	1.68	-0.82	0	0.97	1.05	Y	Y	N
23	0	0	0.26	-0.18	1.16	-0.48	0	0.99	0.57	Y	N	Y
24	0	0	0	0.18	1.77	0	-0.35	0.99	0.47	Y	N	Y
25	0	0	-0.43	0.17	0.71	0	0.3	0.89	0.9	Y	Y	Y
26	0	0.36	0	0	0	0	0	0.56	2.91	Y	Y	N
27	0	0	0	0	0.83	0.81	0	0.47	3.52	Y	N	Y
28	13.04	0	0	0	1.25	0	0	0.77	1.41	Y	N	N
29	0	0	0	0	0	0	0	0.24	6.75	N	N	N
30	0	0.21	0	-0.37	0.38	0.6	0	0.86	1	Y	N	N

Estimation of $p^e_{h,t} = c + \sum_{i=1}^{3} o_i p_{t-i} + \sum_{i=1}^{3} s_i p^e_{h,t-i} + v_i$ in Base Treatment. The first column shows the participant's ID. The second to eighth columns show the estimated coefficients, all estimates with p-value larger than 5 percent are dropped. The RSE is the residual standard error. The AC is the overall significance of the model. The last two columns are the significance of the Chow test. C_1 is the Chow test comparison between the predictions before and after the time period 20 and C_2 is the the Chow test comparison between the predictions before and after the time period 43. Y means that the null hypothesis is rejected. N means that the null hypothesis is not rejected.

Table C2: Simple Linear Prediction Rules Rank Informaiton Group

ID	C	p^e_{-1}	p^e_{-2}	p^e_{-3}	p_{-1}	p_{-2}	p_{-3}	R^2	RSE	AC	C_1	C_2
31	0	0	0	0.15	0.75	0	0	0.7428	4.09	Y	Y	N
32	0	-0.51	0	0	4.26	-2.54	0	0.56	9.07	Y	N	N
33	0	0	0	0	0	1.67	-1.11	0.45	8.24	Y	N	N
34	0	0	0.3	0.18	0.87	0	0	0.94	1.75	Y	N	N
35	0	0	0.13	0	1.12	0	-0.26	0.99	0.74	Y	N	N
36	0	0	0	0	1.13	0	-0.25	0.99	0.91	Y	N	N
37	0	0.42	0	0	1.03	-0.46	0	0.96	1.32	Y	N	N
38	0	0	0	0	1.08	0	0	0.98	0.83	Y	N	N
39	0	0	0	0	1.06	0	0	0.98	1.01	Y	Y	N
40	0	0	0	0	1.26	0	0	0.97	1.51	Y	N	N
41	0	0	0	0	0	0	0	0.1	13.83	N	N	N
42	0	0.27	0	0	0.57	0	0	0.93	1.65	Y	Y	N
43	0	0	0	0.13	1.93	-0.81	0	1	0.56	Y	Y	N
44	0	-0.27	0	-0.21	1.75	0	0	1	0.49	Y	Y	Y
45	0	0	0.13	0	1.48	-0.65	0	1	0.52	Y	N	N
46	0	0	0	-0.17	1.86	-0.66	0	1	0.43	Y	Y	Y
47	0	0	0.2	0	1.29	0	0	0.99	0.97	Y	N	Y
48	0	0	0	0	2.58	0	0	0.82	3.47	Y	Y	Y
49	0	0	0	0	1.37	0	0	0.74	6.98	Y	Y	Y
50	0	0	0	0	0	0	0	0.46	11.43	Y	Y	Y
51	0	0	0	0	1.58	-0.55	0	0.98	1.72	Y	Y	Y
52	0	0	0	0	1.62	0	0	0.98	1.62	Y	N	Y
53	0	0	-0.46	0	1.3	0	0	0.63	8.78	Y	Y	N
54	0	0.3	0	0	2.15	-1.96	0.6	0.96	2.5	Y	N	Y
55	4.56	0	0	0	0.73	0.63	0	0.97	1.4	Y	Y	Y
56	0	0.76	-0.41	0	0	0	0	0.62	7.7	Y	Y	Y
57	0	0	0	0	3.2	-3.46	1.01	0.69	5.4	Y	N	N
58	6.6	0	0	0	0.8	0	0	0.91	2.12	Y	N	Y
59	0	0	0	0	2.18	0	0	0.57	6.93	Y	Y	Y
60	0	0	0.25	0	1.22	-0.42	0	0.99	0.94	Y	Y	Y

Estimation of $p^e_{h,t} = c + \sum_{i=1}^{3} o_i p_{t-i} + \sum_{i=1}^{3} s_i p^e_{h,t-i} + v_i$ in RI Treatment.

Table C3: Simple Linear Prediction Rules Rank Group

ID	C	p^e_{-1}	p^e_{-2}	p^e_{-3}	p_{-1}	p_{-2}	p_{-3}	R^2	RSE	AC	C_1	C_2
61	0	-0.47	0	0	1.1	0	0	0.9108	2.47	Y	N	Y
62	3.03	0.47	0	-0.14	0.95	-0.38	0	0.98	1.03	Y	N	Y
63	0	0	0	0	2.07	-2.66	1.48	0.47	9.87	Y	N	Y
64	0	0	0	0	1.11	0	0	0.42	8.94	Y	N	Y
65	0	0	0	0	0	0	0	0.38	8.96	Y	N	Y
66	4.02	0	0	0	1.16	-0.36	0	0.98	1.04	Y	N	Y
67	0	0	0	0	0	0	0	0.11	9.63	N	N	N
68	0	0.52	0	0	0.96	0	0	0.96	1.1	Y	Y	N
69	0	0.33	0	0	1.28	-0.58	0	0.96	1.16	Y	Y	Y
70	0	0	0	0	1.38	0	0	0.75	3.03	Y	Y	Y
71	0	0.65	0	0	1.16	-0.79	0	0.89	2.03	Y	Y	Y
72	0	0	0	0	0	0	0	0.25	6.2	Y	Y	N
73	0	0	0	0	0	0	0	0.31	9.41	Y	N	Y
74	0	0.7	0	-0.25	0.66	0	0	0.96	1.51	Y	N	Y
75	0	0	0	0.21	1.41	0	-0.56	0.98	1.19	Y	Y	Y
76	0	0.34	-0.25	0.23	0.85	0.67	-0.84	1	0.49	Y	N	Y
77	-1.52	0	0	0	1.25	0.56	-0.42	1	0.57	Y	N	Y
78	-1.65	0	-0.27	-0.32	2.08	-1.32	0.8	1	0.41	Y	Y	Y
79	0	0	0	0	1.76	0	0	0.86	2.15	Y	N	Y
80	0	0	0.24	0	1.29	-0.5	-0.45	0.99	0.54	Y	Y	Y
81	0	0	0	0	1.25	-0.55	0	0.97	0.91	Y	N	Y
82	0	0	0	0	1.49	0	0	0.94	1.32	Y	N	Y
83	0	0.36	0	0	1.2	-0.4	0	1	0.38	Y	N	Y
84	0	0.37	0	0	0	0	0	0.9	1.98	Y	N	Y
85	0	0	0	0	1.43	0	0	0.9	3.74	Y	Y	Y
86	1.51	0	0	0	1.51	0	-0.29	0.99	1.027	Y	Y	Y
87	1.08	0.25	0.16	0	1.41	-0.61	-0.29	1	0.62	Y	Y	Y
88	0	0.33	0	0	1.3	-0.62	0	0.99	0.94	Y	N	Y
89	0	0	0	0	1.58	0	0	0.76	6.84	Y	N	Y
90	0	0	0	0	0	0	0	0.71	8.01	Y	N	Y
91	0	0	0	0	1.23	0	0	1	0.38	Y	N	Y
92	0	0	0	0	1.52	-0.72	0	1	0.56	Y	N	Y
93	0	0	0	0	1.57	0	-0.51	0.99	0.7	Y	Y	Y
94	0	0	0	0	1.35e-05	0	0	0.96	1.68	Y	N	Y
95	0	0	0	0	1.88	0	0	0.89	2.68	Y	N	N
96	0	0	0	0	1.86	-0.96	0	1	0.54	Y	N	Y

Estimation of $p^e_{h,t} = c + \sum_{i=1}^{3} o_i p_{t-i} + \sum_{i=1}^{3} s_i p^e_{h,t-i} + v_i$ in R Treatment.

Table C4: Simple Heuristic Rules Estimation Result Base Group

ID	σ	p-value	R^2	RSE	AC	$Chow_1$	$Chow_2$
1	0.443	0.0001	0.2243	2.567	Y	N	Y
2	0.6663	0.0000	0.6627	1.481	Y	Y	Y
3	1.1713	0.0000	0.246	6.388	Y	Y	Y
4	0.8196	0.0000	0.6207	1.996	Y	N	Y
5	-0.0045	0.9898	0.0000	8.547	N	N	Y
6	0.2813	0.3361	0.0152	7.061	N	N	Y
7	0.1571	0.027	0.0776	0.8162	Y	N	Y
8	-0.0182	0.8921	0.0003	1.575	N	N	N
9	0.2261	0.011	0.1012	1.015	Y	Y	Y
10	0.1397	0.295	0.018	1.557	N	Y	Y
11	0.1381	0.2492	0.0217	1.398	N	Y	Y
12	-0.0482	0.9274	0.0001	6.196	N	N	N
13	0.6475	0.0000	0.4295	1.471	Y	N	Y
14	0.8517	0.0000	0.5204	1.611	Y	N	Y
15	0.8405	0.0000	0.885	0.597	Y	N	Y
16	0.804	0.0000	0.7508	0.913	Y	N	Y
17	0.5987	0.0000	0.6176	0.9285	Y	N	Y
18	0.6471	0.0406	0.0669	4.761	Y	N	Y
19	0.2141	0.1127	0.0407	1.03	N	N	Y
20	-0.2411	0.1272	0.0377	1.207	N	N	Y
21	0.6704	0.0965	0.0446	3.074	N	N	N
22	0.7449	0.0000	0.3465	1.014	Y	Y	N
23	0.0824	0.3625	0.0136	0.6952	N	N	Y
24	0.7275	0.0000	0.6799	0.4947	Y	N	Y
25	-0.2082	0.0044	0.1255	1.081	Y	Y	Y
26	-0.4254	0.0439	0.0649	3.176	Y	Y	N
27	-0.3091	0.1848	0.0287	3.541	N	N	Y
28	0.4477	0.0000	0.2519	1.518	Y	N	N
29	-1.5229	0.0023	0.1421	7.36	Y	N	N
30	-0.1213	0.2879	0.0185	1.738	N	N	N

Estimation of $p^e_{h,t} = p_{t-1} + \gamma(p_{t-1} - p_{t-2})$ (trend rule) in Base Treatment. The first column shows the participant's ID. The second column shows the estimated coefficients. The AC is the overall significance of the model. The last two columns are the significance of the Chow test. $Chow_1$ is the comparison between the predictions before and after the time period 20 and $Chow_2$ is the comparison between the predictions before and after the time period 43. Y means that the null hypothesis is rejected. N means that the null hypothesis is not rejected.

Table C5: Simple Heuristic Rules Estimation Result Rank Information Group

ID	σ	p-value	R^2	RSE	AC	Chow_1	Chow_2
31	-0.0326	0.8768	0.0004	3.983	N	Y	N
32	1.7002	0.0011	0.1615	9.499	Y	N	N
33	-0.1918	0.6708	0.003	8.538	N	N	N
34	-0.105	0.3536	0.0141	2.135	N	N	N
35	0.2823	0.0001	0.2251	1.273	Y	N	N
36	0.035	0.6919	0.0026	1.672	N	N	N
37	0.0775	0.2968	0.0178	1.383	N	N	N
38	0.0708	0.1134	0.0406	0.8224	N	N	N
39	0.1112	0.0754	0.0509	1.147	N	Y	N
40	-0.0252	0.9722	0.0000	13.45	N	N	N
41	-0.1095	0.0463	0.0635	1.005	Y	N	N
42	-0.3722	0.0005	0.183	1.879	Y	Y	N
43	0.9776	0.0000	0.737	0.6521	Y	Y	N
44	0.8042	0.0000	0.747	0.5236	Y	Y	Y
45	0.888	0.0000	0.6702	0.6954	Y	N	Y
46	0.9305	0.0000	0.8268	0.4754	Y	Y	N
47	0.2797	0.0605	0.0566	1.323	N	N	Y
48	1.0673	0.0101	0.1036	3.506	Y	Y	Y
49	0.5009	0.0484	0.0624	6.701	Y	Y	Y
50	0.547	0.1918	0.0278	11.12	N	N	Y
51	0.6022	0.0000	0.5679	1.801	Y	Y	Y
52	0.6224	0.0000	0.62	1.679	Y	N	Y
53	0.2274	0.514	0.007	9.266	N	N	Y
54	1.0325	0.0000	0.6475	2.608	Y	N	N
55	-0.0609	0.4615	0.0089	1.529	N	Y	Y
56	0.7891	0.0999	0.0438	8.848	N	Y	Y
57	1.6208	0.0000	0.3183	5.652	Y	N	Y
58	-0.4637	0.0054	0.12	3.031	Y	N	N
59	0.8585	0.0189	0.087	6.654	Y	Y	Y
60	0.3579	0.0000	0.3722	1.124	Y	Y	Y

Estimation of $p^e_{h,t} = p_{t-1} + \gamma(p_{t-1} - p_{t-2})$ (trend rule) in RI Treatment.

Table C6: Simple Heuristic Rules Estimation Result Rank Group

ID	σ	p-value	R^2	RSE	AC	$Chow_1$	$Chow_2$
62	0.0898	0.122	0.0387	1.383	N	N	Y
63	0.3749	0.369	0.0133	9.993	N	N	Y
64	0.4716	0.193	0.0276	8.657	N	N	Y
65	0.0622	0.863	0.0005	8.654	N	N	Y
66	0.3065	0.0000	0.3423	1.313	Y	N	Y
67	0.3111	0.5881	0.0048	9.751	N	N	N
68	0.0901	0.2365	0.0229	1.285	N	Y	N
69	0.3843	0.0000	0.2836	1.335	Y	Y	Y
70	0.479	0.0067	0.1146	2.909	Y	Y	Y
71	0.2702	0.073	0.0517	2.528	N	Y	Y
72	0.0285	0.9367	0.0001	6.092	N	Y	N
73	1.2925	0.0446	0.0645	9.346	Y	N	Y
74	-0.1456	0.395	0.0119	2.52	N	N	Y
75	0.3061	0.0013	0.1573	1.345	Y	Y	Y
76	-0.0033	0.9692	0.0000	1.281	N	N	Y
77	0.2204	0.0223	0.0827	1.394	Y	N	Y
78	0.9758	0.0000	0.8988	0.6218	Y	Y	Y
79	0.7479	0.0108	0.1018	2.073	Y	N	Y
80	0.4823	0.0005	0.1816	0.9555	Y	Y	Y
81	0.3912	0.0029	0.1365	0.9184	Y	N	Y
82	0.467	0.0117	0.0996	1.31	Y	N	Y
83	0.4396	0.0000	0.3884	0.5148	Y	N	Y
84	-0.868	0.0725	0.0519	3.461	N	N	Y
85	0.5841	0.004	0.128	3.699	Y	Y	Y
86	0.6177	0.0000	0.6501	1.1	Y	Y	Y
87	0.6425	0.0000	0.6727	1.088	Y	Y	Y
88	0.4378	0.0000	0.499	1.065	Y	N	Y
89	0.3441	0.3302	0.0156	6.645	N	N	Y
90	0.4959	0.234	0.0231	7.82	N	N	Y
91	0.3857	0.0000	0.5339	0.4037	Y	N	Y
92	0.6428	0.0000	0.6177	0.5665	Y	N	Y
93	0.7121	0.0000	0.5443	0.7298	Y	Y	Y
94	0.6094	0.0019	0.1475	1.641	Y	N	Y
95	0.5511	0.0808	0.0492	2.715	N	N	N
96	0.9241	0.0000	0.7949	0.5258	Y	N	Y

Estimation of $p^e_{h,t} = p_{t-1} + \gamma(p_{t-1} - p_{t-2})$ (trend rule) in R Treatment.

Table C7: Adaptive Rules Estimation Base Group

ID	σ	p-value	R^2	RSE	AC	$Chow_1$	$Chow_2$
1	0.8722	0.0000	0.5942	3.002	Y	N	Y
2	1.2800	0.0000	0.5789	2.514	Y	Y	Y
3	0.2725	0.0448	0.0633	6.001	Y	Y	Y
4	1.1887	0.0000	0.7308	3.343	Y	N	Y
5	1.0697	0.0000	0.4747	8.496	Y	N	Y
6	1.0965	0.0000	0.4886	7.07	Y	N	Y
7	0.8922	0.0000	0.7038	0.8888	Y	N	Y
8	0.7214	0.0000	0.4552	1.492	Y	N	N
9	1.2824	0.0000	0.611	1.668	Y	Y	Y
10	0.8711	0.0000	0.5223	1.607	Y	Y	Y
11	0.5973	0.0000	0.3892	1.552	Y	Y	Y
12	1.1368	0.0000	0.5358	6.446	Y	N	N
13	1.3047	0.0000	0.5403	1.873	Y	N	Y
14	1.0108	0.0000	0.318	2.332	Y	N	Y
15	1.1855	0.0000	0.4161	1.742	Y	N	Y
16	1.3252	0.0000	0.6714	1.776	Y	N	Y
17	0.9002	0.0000	0.638	1.541	Y	N	Y
18	0.8542	0.0000	0.3762	5.072	Y	N	Y
19	1.0144	0.0000	0.8435	1.042	Y	N	Y
20	0.9429	0.0000	0.9292	1.198	Y	N	Y
21	0.9359	0.0000	0.3973	4.445	Y	N	N
22	1.1436	0.0000	0.5443	1.236	Y	Y	N
23	0.7145	0.0000	0.7	0.72	Y	N	Y
24	1.4004	0.0000	0.7418	0.7945	Y	N	Y
25	0.8169	0.0000	0.7128	1.083	Y	Y	Y
26	0.4576	0.0000	0.2216	2.927	Y	Y	N
27	0.9918	0.0000	0.4667	3.71	Y	N	Y
28	1.2940	0.0000	0.824	1.641	Y	N	N
29	1.4266	0.0000	0.7388	7.116	Y	N	N
30	0.7212	0.0000	0.405	1.682	Y	N	N

Estimation of $p^e_{h,t} = p^e_{t-1} + \omega(p_{t-1} - p^e_{t-1})$ (adaptive rule) in Base Treatment. The first column shows the participant's ID. The second column shows the estimated coefficients. The AC is the overall significance of the model. The last two columns are the significance of the Chow test. $Chow_1$ is the comparison between the predictions before and after the time period 20 and $Chow_2$ is the comparison between the predictions before and after the time period 43. Y means that the null hypothesis is rejected. N means that the null hypothesis is not rejected.

Table C8: Adaptive Rules Estimation Rank Information Group

ID	σ	p-value	R^2	RSE	AC	$Chow_1$	$Chow_2$
31	0.8315	0.0000	0.4255	3.913	Y	Y	N
32	1.1542	0.0000	0.5066	10.26	Y	N	N
33	1.2006	0.0000	0.5399	8.348	Y	N	N
34	0.8513	0.0000	0.6767	2.097	Y	N	N
35	1.1757	0.0000	0.6916	2.55	Y	N	N
36	0.8753	0.0000	0.6914	1.657	Y	N	N
37	0.9657	0.0000	0.7763	1.387	Y	N	N
38	1.0262	0.0000	0.9187	0.8513	Y	N	N
39	0.9810	0.0000	0.8191	1.37	Y	Y	N
40	1.0616	0.0000	0.4427	13.32	Y	N	N
41	0.7930	0.0000	0.8112	0.947	Y	N	N
42	1.0662	0.0000	0.6388	2.686	Y	Y	N
43	0.3897	0.0000	0.3038	1.341	Y	Y	Y
44	1.3373	0.0000	0.5968	0.9893	Y	Y	Y
45	1.3734	0.0000	0.7547	2.057	Y	N	N
46	1.3657	0.0000	0.4507	1.173	Y	Y	Y
47	1.2270	0.0000	0.6505	3.893	Y	N	Y
48	1.6893	0.0000	0.1918	3.698	Y	Y	Y
49	0.9976	0.0000	0.4496	6.871	Y	Y	Y
50	0.9955	0.0000	0.4158	11.2	Y	N	Y
51	1.3863	0.0000	0.7061	2.497	Y	Y	Y
52	1.2060	0.0000	0.757	2.627	Y	N	Y
53	0.9777	0.0000	0.4178	9.41	Y	N	N
54	1.1589	0.0000	0.6709	4.276	Y	N	Y
55	0.9334	0.0000	0.6676	1.773	Y	Y	Y
56	0.4534	0.0005	0.1779	7.828	Y	Y	Y
57	0.9628	0.0000	0.4142	7.012	Y	N	N
58	0.9327	0.0000	0.5135	3.519	Y	N	Y
59	1.0510	0.0000	0.473	6.908	Y	Y	Y
60	0.9053	0.0000	0.7035	1.583	Y	Y	Y

Estimation of $p^e_{h,t} = p^e_{t-1} + \omega(p_{t-1} - p^e_{t-1})$ (adaptive rule) in RI Treatment.

Table C9: Adaptive Rules Estimation Rank Group

ID	σ	p-value	R^2	RSE	AC	$Chow_1$	$Chow_2$
61	1.3297	0.0000	0.7926	2.858	Y	N	Y
62	1.1276	0.0000	0.7857	1.696	Y	N	Y
63	1.0285	0.0000	0.4322	9.977	Y	N	Y
64	0.9010	0.0000	0.3944	8.682	Y	N	Y
65	1.0930	0.0000	0.481	8.558	Y	N	Y
66	0.9585	0.0000	0.8694	1.683	Y	N	Y
67	1.0301	0.0000	0.4275	9.693	Y	N	N
68	1.0023	0.0000	0.7578	1.378	Y	Y	N
69	1.0175	0.0000	0.7023	1.613	Y	Y	Y
70	1.0567	0.0000	0.5425	3.075	Y	Y	Y
71	0.6912	0.0000	0.4431	2.392	Y	Y	Y
72	0.9056	0.0000	0.3967	6.021	Y	Y	N
73	0.7724	0.0000	0.3361	9.564	Y	N	Y
74	0.60819	0.0000	0.3128	3.416	Y	N	Y
75	1.2008	0.0000	0.8595	1.377	Y	Y	Y
76	0.9990	0.0000	0.8508	1.271	Y	N	Y
77	1.5712	0.0000	0.9212	1.145	Y	N	Y
78	1.8600	0.0000	0.8628	1.335	Y	Y	Y
79	1.0504	0.0000	0.4421	2.433	Y	N	Y
80	0.5705	0.0000	0.4278	0.9616	Y	Y	Y
81	1.2168	0.0000	0.7849	0.9937	Y	N	Y
82	0.9090	0.0000	0.4947	1.432	Y	N	Y
83	1.2510	0.0000	0.8317	0.6576	Y	N	Y
84	0.3796	0.0000	0.2255	2.856	Y	N	Y
85	0.9731	0.0000	0.7384	3.925	Y	Y	Y
86	1.1974	0.0000	0.7438	1.789	Y	Y	Y
87	1.3604	0.0000	0.6928	2.005	Y	Y	Y
88	1.0658	0.0000	0.7487	1.574	Y	N	Y
89	1.1317	0.0000	0.5062	6.618	Y	N	Y
90	0.8839	0.0000	0.4356	7.804	Y	N	Y
91	1.3438	0.0000	0.8645	0.5123	Y	N	Y
92	0.9152	0.0000	0.4582	2.171	Y	N	Y
93	1.1868	0.0000	0.7758	1.03	Y	Y	Y
94	0.9208	0.0000	0.4747	1.759	Y	N	Y
95	0.9153	0.0000	0.4173	2.754	Y	N	N
96	1.4919	0.0000	0.7809	1.367	Y	N	Y

Estimation of $p^e_{h,t} = p^e_{t-1} + \omega(p_{t-1} - p^e_{t-1})$ (adaptive rule) in R Treatment.

Table C10: MSE of the One-Period Ahead Prediction-Base Treatment

Specification	B1	B2	B3	B4	B5
RE fundamental	143.446	136.2982	110.9148	80.9702	108.8677
naive	9.0044	2.9172	3.0875	19.1997	13.6252
A&A	38.9787	13.3240	21.7183	14.9326	19.3682
ADA	9.6857	2.4168	3.8188	1.4926	4.1951
CTR	11.5681	1.6134	5.3682	10.2843	12.3778
TRE	8.4061	2.0021	0.3630	9.2243	17.6514
HSM Benchmark	0.1524	0.1299	0.1161	0.1386	0.1581
HSM Experiment	0.1097	0.1173	0.1055	0.1224	0.1465
HSM Group	**0.0927**	**0.1105**	**0.0933**	**0.1131**	**0.1436**
$\beta \in [0, 10]$	4.2	1.2	8.2	4.1	0.1
$\eta \in [0, 1]$	0	0.5	0	0	0.9
$\delta \in [0, 1]$	0.6	0.5	0.5	0.5	0.4

MSE of the one-period ahead forecast for groups in the base treatment. HSM Benchmark means the HSM with parameters $\beta = 0.4, \eta = 0.7, \delta = 0.9$. HSM Experiment means the HSM with parameters that give the best fit according to the average MSE of all groups in the three treatments, which is $\beta = 1.4, \eta = 0.2, \delta = 0.6$. HSM Group means the HSM with parameters that give the best fit according to the MSE for this group, with parameters β, η, δ shown in the bottom.

Table C11: MSE of the One-Period Ahead Prediction-RI Treatment

Specification	RI1	RI2	RI3	RI4	RI5
RE fundamental	189.1854	74.9226	153.1172	167.0135	89.5451
naive	69.7311	1.9714	1.0977	7.3253	12.1388
A&A	83.5766	11.8505	12.7244	30.2480	23.6865
ADA	5.8117	5.5928	1.7141	12.8358	6.0571
CTR	70.6542	2.3137	1.8729	12.5526	9.0627
TRE	77.50627	4.7630	0.2809	3.7036	19.3956
HSM Benchmark	0.1547	0.1608	0.1007	0.1297	0.1375
HSM Experiment	0.1448	0.1558	0.1018	0.1386	0.1455
HSM Group	**0.1341**	**0.1431**	**0.0929**	**0.1252**	**0.1314**
$\beta \in [0, 10]$	1.5	1.1	1.2	0.1	5.8
$\eta \in [0, 1]$	0	0	0.6	1	0
$\delta \in [0, 1]$	0.6	0.4	0	0.9	0.7

MSE of the one-period ahead forecast for groups in the RI treatment. HSM Benchmark means the HSM with parameters $\beta = 0.4, \eta = 0.7, \delta = 0.9$. HSM Experiment means the HSM with parameters that give the best fit according to the average MSE of all groups in the three treatments, which is $\beta = 1.4, \eta = 0.2, \delta = 0.6$. HSM Group means the HSM with parameters that give the best fit according to the MSE for this group, with parameters β, η, δ shown in the bottom.

Table C12: MSE of the One-Period Ahead Prediction-R Treatment

Specification	R1	R2	R3	R4	R5	R6
RE fundamental	274.8726	197.9462	129.5123	99.868	141.8674	119.7754
naive	74.4623	9.1909	1.7163	0.5744	43.0269	7.4088
A&A	81.0549	13.4164	19.2556	7.0435	75.7642	17.775
ADA	10.2803	4.9722	4.1395	0.9560	6.8033	1.4444
CTR	78.9780	11.0002	2.0958	0.8823	45.1284	8.0794
TRE	75.4205	9.1276	4.4751	0.4355	44.7059	7.3608
HSM Benchmark	0.1513	0.1712	0.1365	0.1371	0.1349	0.1417
HSM Experiment	0.1322	0.1622	0.1256	0.1287	0.1232	0.135
HSM Group	**0.1237**	**0.1535**	**0.1245**	**0.1266**	**0.1205**	**0.1253**
$\beta \in [0, 10]$	0.8	0.8	3.5	3.4	4.7	10
$\eta \in [0, 1]$	0	0	0.3	0	0.1	0.2
$\delta \in [0, 1]$	0.5	0.4	0.7	0.7	0.7	0.8

MSE of the one-period ahead forecast for groups in the R treatment. HSM Benchmark means the HSM with parameters $\beta = 0.4, \eta = 0.7, \delta = 0.9$. HSM Experiment means the HSM with parameters that give the best fit according to the average MSE of all groups in the three treatments, which is $\beta = 1.4, \eta = 0.2, \delta = 0.6$. HSM Group means the HSM with parameters that give the best fit according to the MSE for this group, with parameters β, η, δ shown in the bottom.

Table C13: High Ranked and Low Ranked Subjects' ID in Each Group

Round	1-20		21-43		44-65	
Group	High-Rank	Low-Rank	High-Rank	Low-Rank	High-Rank	Low-Rank
1	1	2	2	3	2	1
2	10	**12**	8	**12**	8	**12**
3	13	**18**	14	**18**	14	**18**
4	24	**21**	19	**21**	20	**21**
5	25	29	25	29	25	26
6	32	34	33	35	36	31
7	41	42	39	37	37	41
8	43	**47**	46	**47**	44	**47**
9	49	53	51	54	49	53
10	59	57	59	55	55	58
11	61	62	63	64	65	64
12	72	**71**	70	**71**	67	**71**
13	77	74	77	74	73	75
14	83	**84**	83	**84**	81	**84**
15	89	**90**	89	**90**	85	**90**
16	91	94	96	92	92	93

High-Rank player is the player who ranked 1 most within the group. Low-Rank player is the player who ranked 6 most within the group. They are different across time periods and there is no consistent high-ranked subjects. The bolded ID number is the consistent low-ranked player.

Table C14: Agents'(Period 1-20) Rankings in Following Time Periods

	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	ID	1	10	13	24	25	32	41	43	49	59	61	72	77	83	89	91
High-Rank	21-43	5	3	2	5	1	4	2	2	4	1	5	4	1	1	1	5
	44-65	6	5	3	2	1	5	6	3	1	2	5	5	2	5	3	4
	ID	2	12	18	21	29	34	42	47	53	57	62	71	74	84	90	94
Low-Rank	21-43	1	6	6	6	6	5	5	6	5	3	3	5	6	6	6	2
	44-65	1	6	6	6	5	4	4	6	6	5	3	6	5	6	6	2

High-Rank player is the player who ranked 1 most within the group in period 1-20. Low-Rank player is the player who ranked 6 most within the group in period 1-20. Their ranking in period 21-43 and 44-65 are listed. There is no consistent high-ranked agents