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The Ratchet Effect in Teams: The Impacts of Learning and Inequity Aversion

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ABSTRACT

This study theoretically and experimentally demonstrates that because of the interdependent nature of work environments, the mechanism of the ratchet effect in teams qualitatively differs from that in independent work environments. First, I theoretically proved that occurrence of the ratchet effect in teams depends on the agents' inequity aversion and that learning among teammates deters the ratchet effect. Then, I ran a laboratory experiment of a team-production task that was designed according to the theoretical model. The experiment results reveal that the ratchet effect occurs in teams. I confirm that participants' inequity-aversion levels were sufficiently low to fall within a range for which the ratchet effect is theoretically expected to occur. The results also reveal that the ratchet effect is significantly mitigated when learning is present than when learning is absent. These results demonstrate that the mechanism of the ratchet effect in teams differs from that in independent work environments. This also implies that encouraging learning indirectly benefits firms.

Keywords: target setting; ratchet effect; learning; inequity aversion.

Data Availability:
Contact the author.

1. INTRODUCTION

This study theoretically and experimentally demonstrates that the mechanism of the ratchet effect in teams differs qualitatively from that in independent work environments, which most previous studies have focused on.

While targets are an important factor in incentive systems, they are often determined based on past performance, and such a target-setting method is susceptible to an incentive problem, that is, the ratchet effect (Dekker et al., 2012; Murphy, 2000; Weitzman, 1980). Employees expect that once good performance is recorded, the next period's targets will be revised into more difficult ones, and thus, they have an incentive to limit their current performance to keep future targets easily attainable. If the ratchet effect prevails, then the firm's performance is lower than the performance level that could be attained if every employee exerts their maximum capability. Thus, it is important to overcome this problem.

Prior studies have empirically investigated the ratchet effect in firms (e.g., Bouwens & Kroos, 2011; Chaudhuri, 1998; Leone & Rock, 2002; Murphy, 2000), in addition to discussing how managers can overcome this problem (e.g., Aranda et al., 2014; Baron & Besanko, 1984; Cardella & Depew, 2018; Charness et al., 2011; Indjejikian et al., 2014a; Indjejikian & Nanda, 2002). However, these studies have investigated this incentive problem in an independent work environment.

In contrast to prior studies, this study investigates the ratchet effect in a team environment. A team is a situation in which agents work interdependently, and a principal cannot observe the output per agent but the output per team (Holmstrom, 1982). This interdependent nature of work environments, which is absent in independent work environments, may impact the agents' incentive to commit the ratchet effect and the principal's means to mitigate the ratchet effect. This study investigates how the interdependent work environment impacts the mechanism of the ratchet effect by focusing on two factors: inequity aversion and learning among teammates. In this study, I operationalized the notion of interdependence by employing a Leontief type production function, that is, the team's output is assumed to follow a minimum function of two agents' effort level.

First, this study investigates how the agents' incentive to commit the ratchet effect is affected by interdependency, focusing on inequity aversion. Inequity aversion is a social preference that represents individuals' preference for disliking inequity among members (Dhami, 2016). Since they work together and their rewards are determined depending on each other's behavior, employees are more likely to care about their colleagues in teams than in independent work environments. Thus, inequity aversion is expected to play more significant role in teams than in independent work environments. This study theoretically proves that the occurrence of the ratchet effect in teams depends on the agents' inequity aversion. If the agents have a standard preference and do not care about inequity at all, then the ratchet effect will occur. The more inequity-averse the agents, the less likely is the occurrence of the ratchet effect.

This is brought about by either of the following two logics. First, when a skilled agent misreports their type as unskilled, they will feel guilty from the dishonestly enhanced payoff compared to their teammates. If this feeling of guilt outweighs the benefit from easy future targets, then the agent refrains from committing the ratchet effect. Second, when a skilled agent misreports their type as unskilled and enjoys easy future targets, their teammates will envy that agent. If this feeling of envy is sufficiently strong, then the teammates penalize that agent by deciding not to cooperate in the team's production activity, which drastically reduces the team's performance and impairs the agent's benefits from the easy targets. Note here that the second logic arises from the interdependent nature and inequity aversion. Because of their interdependent nature, the agents can influence their teammates' payoffs by changing the team's output. In addition, sufficiently inequity-averse agents have an incentive to prevent teammates from committing the ratchet effect. Thus, teams with sufficiently inequity-averse agents can mutually govern their behavior and deter the ratchet effect by themselves[1].

Second, this study investigates how the principal's means to mitigate the ratchet effect is affected by interdependency, focusing on the impact of a phenomenon that is caused by interdependency. Given the interdependent work environment, employees can improve their skills by learning from their teammates. Berg et al. (1996) demonstrated that workers in production teams often informally teach shortcuts, problem-solving, or other ways to improve their teammates' work. Specifically, unskilled employees may grow the most in heterogeneous teams that consist of skilled and unskilled employees. This is because skilled employees pull up unskilled employees by teaching their knowledge (Hamilton et al., 2003), or unskilled employees who have a larger room for improvement spontaneously learn from a good role model. This study theoretically proves that the more prominent such learning, the more easily the principal can prevent the ratchet effect[2].

The logic is as follows[3]: The principal tries to adjust targets according to the agents' skill levels. When there is no learning, each agent's report provides information

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[1] The first logic could also hold in the case of independent work environments with multiple agents. On the other hand, the second logic can not be observed in independent work environments, because the agents cannot manipulate their colleagues' performance, and they can not penalize each other.

[2] The key concept of learning which this study deals with is that the agents' growth amount differs depending on the pair of their initial skill level and that of their teammates: unskilled agents who paired with skilled agents grow more than others. If every agent grows the same amount regardless of their initial skill level and that of their teammate, then the ratchet effect may not be deterred by the presence of such learning as explained in Footnote 4.

[3] Appendix A provides the detailed model analyses for the impact of learning on the ratchet effect.

about their own types only. If an agent reports their type as unskilled in the first period, then the principal cannot ascertain whether this agent is lying. Thus, in the first and the second periods, the principal assigns a target corresponding to the unskilled agent's skill level, accounting for the possibility that the agent actually has low skill and gives up to work under too demanding a target.

In contrast, in the presence of learning, the principal understands the correlation between the agents' skill levels in the second period, and then each agent's report becomes informative about their teammates' types. The principal can use this additional information to resolve the ratchet effect. Specifically, when one agent reports their type as unskilled and the other reports their type as skilled, then the principal can infer from the latter agent's report that the former agent's skill level in the second period will be no less than an improved skill level of initially unskilled employees who are paired with skilled employees. Then, in the second period, the principal can assign the former agent a target corresponding to the improved skill level of unskilled employees, and this target is more demanding than that for unimproved unskilled employees. This means that even if a skilled agent misreports their type, they will be assigned a target in the second period that is more demanding than in the case when the learning is absent, and their benefit from misreporting their type decreases[4].

This study experimentally investigates the above theoretical predictions using a laboratory experiment of a team-production task performed by undergraduate and graduate students. Combining the theoretical analyses and the laboratory experiment would be suitable for this study. Theoretical analyses contribute to clarify the logic of the ratchet effect in teams which is unclear up to now, and clarification of the logic of which we want to test is necessary for designing experiments properly. As theoretical predictions show, the theory expects multiple equilibria and it can not conclude which equilibrium is likely to occur without any empirical investigation. In addition, it is uneasy to identify the occurrence of the ratchet effect using non-experimental data,

[4] This logic of learning could be extended in the case of independent work environments as long as the following two conditions are satisfied: (1) low-skill type may grow more than high-skilled type at least on some occasion and (2) the principal knows the condition in which low-skill type grow significantly. Suppose there is an agent who conducts an independent task, the agent's possible type are low skill or high skill, and the agent's ability grows over time. In this case, if the low-skill type grows more than the high-skill type, then learning may deter the ratchet effect likewise in teams. In addition, if low-skill type grows more than high-skill type if and only if they attend some training or pass some in-house exams and the principal understands this fact, then learning may also deter the ratchet effect. If both types of agents grow the same amount, such learning may not contribute to deterring the ratchet effect.

because it is difficult to know the employees' true ability and discern whether the employees strategically reducing their performance (Cardella & Depew, 2018; Charness et al., 2011). I focused on reporting behaviors that the participants took in the task, and the principal's choices of targets given the reports were made by a computer program in the experiment[5].

The results of the experiment reveal that the ratchet effect occurs in teams. Skilled workers misrepresented their types as unskilled more frequently in a two-periods without learning treatment (*NOLEARN*) than in a one-period treatment (*ONE*). I measured Fehr and Schmidt (1999) inequity aversion for each participant, and confirmed that the participants' inequity-aversion levels were low enough to fall within a range for which the ratchet effect is theoretically expected to occur.

The experimental results also reveal that the ratchet effect is significantly mitigated when learning is most salient compared to when it is absent. Skilled workers represented their type truthfully more frequently in a two-periods with the most salient learning treatment (*LEARN*) than in a two-periods without learning treatment (*NOLEARN*).

The contributions of this study are as follows: First, this study sheds new light on the literature on the ratchet effect by considering the agents' incentive to commit the ratchet effect and the principal's means to mitigate the ratchet effect in teams. This study theoretically explains that the ratchet effect is deterred in teams with strongly inequity-averse agents because the agents mutually govern their behavior. This implies that the ratchet effect is automatically deterred in teams with strongly inequity-averse agents without any management activity by the principal. This can be a possible explanation for an unanswered question, that is, why is the practice of setting targets based on past performance prevalent? This study also theoretically and experimentally demonstrates that learning among teammates works as a tool for the principal to deter the ratchet effect by introducing the correlation between the agents' skill levels, which makes each agent's report on their own type informative about the other teammates' type. This suggests that managers can cope with the ratchet effect in teams by

[5] If the role of the principal is also played by real participants, then the participants who assume the role of the agents need to predict the strategic decision of the principal in addition to that of their teammates to make their decisions. This would be too demanding for participants. I operationalized the principal's decision as follows: I assumed the principal's utility is determined as profit minus the sum of rewards paid to the agents and analyzed their on-the-pass-of-the-equilibria behaviors as in the equilibrium analyses in Section 4. The computer principal is designed to take those on-the-pass-of-the-equilibria behaviors. The detail of the principal's decision rule is explained in subsection 3.1. This decision rule was informed to participants in the experimental instructions.

determining targets considering the mechanism of learning: the managers can cope with the ratchet effect problem by adjusting targets' level not only based on the past performance but also the ability improvement that would arise as a result of learning.

Second, this study reveals the indirect benefit of employees' learning for firms. The results reveal that facilitating learning in teams may benefit firms by not only inducing skill improvement in unskilled employees but also by preventing skilled employees from committing the ratchet effect. In terms of human resource management implications, this suggests that we need to account for this indirect role when discussing the role of employees' learning and training. As a practical implication, this also suggests that facilitating knowledge sharing among team members and/or cultivating a cooperative culture contributes to preventing skilled employees from shirking.

The remainder of this paper is organized as follows. Section 2 summarizes the related literature. Section 3 explains the experimental design of this study, and Section 4 develops the hypotheses based on the equilibrium analyses. Section 5 presents the results, and Section 6 concludes. Appendix A analyzes a theoretical model for the impact of learning on the ratchet effect. Appendix B analyzes the equilibrium behaviors in each experimental treatment. Appendix C explains the experimental procedure for measuring the inequity aversion.

2. RELATED LITERATURE

Prior literature has found that targets are commonly determined based on past performance (Dekker et al., 2012; Murphy, 2000). Such a target-setting method is called target ratcheting (Indjejikian et al., 2014b).

Although prevalent in practice, target ratcheting is theoretically considered to cause an incentive problem called the ratchet effect (Indjejikian et al., 2014b; Weitzman, 1980). Once good performance is recorded, the next period's targets will be revised into more difficult ones. Employees have an incentive to limit their current performance to keep future targets easy. This problem is considered as a dynamic adverse selection problem, namely, the principal and the agent contract with multiple periods, and there is information asymmetry on the agent's type. The principal needs to provide additional informational rent to resolve the information asymmetry (Laffont & Tirole, 1993). The major research themes in the literature on the ratchet effect are (1) empirical investigations on whether the ratchet effect occurs consistent with the theoretical arguments and (2) theoretical and empirical investigations on overcoming the ratchet effect problem. This study considers both these issues in teams.

2.1 The Existence of the Ratchet Effect

Prior studies have undertaken laboratory experiments and statistical analyses of actual firm data to empirically investigate the existence of the ratchet effect.

The classical experimental study was conducted by Chaudhuri (1998). Because of the complicated experimental design, it was not easy for participants to understand the strategic nature, and the ratchet effect was not observed. Subsequent studies modified experimental designs to simplify it (Cardella & Depew, 2018; Charness et al., 2011; Cooper et al., 1999). These studies introduced non-real players to reduce the participants' roles, or reduce the number of alternatives that participants can select. In line with the latter experiments' approach, this study simplifies an experimental design by having the role of principals played by a computer.

In prior studies, the output is determined interdependently for each observation unit; thus, it can be interpreted that prior studies investigate the ratchet effect problem in work environments without interdependency. In laboratory experiments based on a non-real-effort task, each participant individually selects their output level, and thus, the output is determined per person (Charness et al., 2011; Chaudhuri, 1998; Cooper et al., 1999). Another laboratory experiment based on a real-effort task also measures the output per person (Cardella & Depew, 2018). In Cardella and Depew's (2018) experimental task, each participant stuffs and seals mailing envelops. Each participant's output is measured as a number of assembled envelops within a time limit, and thus, there is no interdependency. The observation units of studies using data from actual firms are the regional retail store managers (Bouwens & Kroos, 2011), the business unit managers (Leone & Rock, 2002), and executives (Murphy, 2000). There seems to be no interdependency in the output between each observation unit. In contrast to these prior studies, in this study, the output is interdependently determined per team depending on the two agents' decisions.

2.2 Mitigating the Ratchet Effect

Prior literature theoretically proposes and empirically verifies various ways to cope with the ratchet effect. However, the correlation between teammates' private information, which this study considers, has not been studied so far as a key to mitigating the problem.

The most straightforward way considered in the literature is the principal's commitment power. If a principal can commit not to revise targets upward even after the agent records good performance, then revealing the true ability does not impair an agent's future utility (Aranda et al., 2014; Baron & Besanko, 1984; Bouwens et al., 2015; Indjejikian et al., 2014a; Indjejikian & Nanda, 2002). The logic here is the removal of the target revision itself, and it is irrelevant whether work environments are individual or group.

It is possible to reduce the ratchet effect without the principal's commitment power on some occasions. Existence of an outside option is one possibility (Charness et al., 2011). If a principal has an outside option and an incumbent agent records bad performance, then the principal can get the agent fired and recruit a new agent. As a result, this fear of being fired decreases an agent's incentive to deceive. Charness et al. (2011) experimentally demonstrated that an outside option reduces the ratchet effect. The logic is the threat of replacement by an outside agent, and no interaction exists between the incumbent agent and the outside agent. Thus, this approach is basically toward the ratchet effect in individual work environments.

Limiting an agent's strategic influence on their future contract is another possibility (Cardella & Depew, 2018). Cardella and Depew (2018) considered a situation in which a principal contracts with multiple agents. Each agent conducts a real-effort task and their performance is measured per person. Thus, their experimental task is an independent work environment. They found that the ratchet effect is less likely to occur when the second period's contract, which is a piece rate amount per output, is designed per group and everyone is paid at the same rate as the rate determined per person. When the second period's rate is designed per group, even if an agent lowers their output in the first period, as long as the majority of the others record high output, the second rate will decrease. Thus, the agents cannot be better off by restricting their output in the first period. The logic here is to eliminate the agent's benefits from restricting output by reducing the degree to which the agent can influence their future contracts.

Utilizing peer performance information and filtering out common exogenous shocks is also an alternative possibility (Casas-Arce et al., 2018). They considered a situation in which the agent's output is determined by their effort and two random shocks, and the principal can only observe the output amount but cannot know the effort level. One of the random shocks is common among agents, and the other one varies by person. The common shock is serially correlated, and the agent-specific shock is transitory. Casas-Arce et al. (2018) theoretically and empirically demonstrated that if a principal determines a target based not only on past output but also on past peer output, then the ratchet effect is reduced. The logic is that contrasting past peer outcomes with those of the agent removes the impact of the common shock and reduces information asymmetry between the principal and the agent. The rationale that the principal should reflect the peer's information is different from that of this study: the principal uses the peer's information because it contains information for guessing the agent's private information, which is determined regardless of the peer's strategic decisions. In contrast, in this study, the information content of teammates' behavior depends on teammates' strategic decisions.

2.3 Inequity Aversion

Prior literature on the ratchet effect has assumed that agents have a standard preference in that they only care about their own payoffs. Through experimental studies, however, it is now well-recognized that some people may also care about others (Fehr & Schmidt, 2006; Cooper & Kagel, 2015). Such preferences are referred to as "other-regarding preferences (or social preferences)" (Dhami, 2016). Inequity aversion is one type of other-regarding preference. Inequity-averse agents feel disutility when the payoffs are not equal among agents (Fehr & Schmidt, 2006; Cooper & Kagel, 2015). This study accounts for such inequity aversion when discussing the ratchet effect.

Various formalizations of inequity aversion have been proposed (Bolton & Ockenfels, 2000; Engelmann & Strobel, 2004). For the purpose of measurablity in a laboratory, I adopted the Fehr and Schmidt (1999) model of inequity aversion. They considered two agents: agent i and agent j. Let x_i be the agent i's monetary rewards. Then, the agent i's utility u_i is

$$u_i = x_i - \alpha \max\{x_j - x_i, 0\} - \beta \max\{x_i - x_j, 0\} \quad (1)$$

$$\text{where, } 0 < \beta < \alpha, \text{and } \beta < 1$$

Parameter α represents *envy*. Agent i suffers from envy when the agent j gets more monetary rewards than the agent i. Parameter β represents *guilt*. Agent i feels guilty when agent i gets more monetary rewards than agent j.

Various methods have been applied for measuring parameters α and β in experimental studies (Bellemare et al., 2008). I adopted Blanco et al.'s (2011) method as it provides interval estimations for α and β for each subject, using a set of dictator games with binary choices. These estimations allow for an empirical analysis of each agent's behavior in the team-production task with respect to their inequity aversion.

3. EXPERIMENTAL DESIGN[6]

This is a laboratory experiment using z-Tree (Fischbacher, 2007). The experiment has two parts. The first part is a team-production task. The second part is a measurement of the inequity aversion parameters α and β based on the BDM mechanism (Becker et al., 1964). In the following, I mainly explain the team-production task[7].

3.1 The Team-Production Game

First, I explain the team-production game that underlies the team-production task. The game is based on a two-period adverse selection model in which a principal contracts with two agents who work as a team as same as the model in Appendix A[8]. In this experiment, the role of the principal is played by a computer. Participants assume the role of an agent. In each period, each agent puts in their effort with some effort cost. The marginal cost differs depending on the agent type. There are two types: a low-cost type (i.e., a skilled worker) and a high-cost type (i.e., a newcomer). The type is the agents' private information. Knowing their own type, each agent sends an opinion on the production schedule. Based on the agents' reports, the principal executes the production schedule of the team that consists of the units of production and rewards for each agent. The team's output is determined based on the agents' efforts in a completely complementary manner. Both agents must exert the same level of effort required to derive the output amount.

Insert Figure 1 here

Figure 1 shows the flow of decisions in this game. In the beginning, each participant was privately informed of their own type. An agent is a skilled worker with

[6] Experimental instructions are available upon request.

[7] A procedure of the second part is explained in Appendix C.

[8] We can say the model in Appendix A captures the ratchet effect problem because that accompanies the following incentive problem. Since the principal cannot commit to any long-term contract, the principal revises the second period's contract considering the first period's results. If the good-type agent reveals their high-capability in the first period, then in the second period, the principal will assign the first-best offer which is tuned to the good-type agent's true capability. Such a first-best offer requires the agent to exert their maximum level of effort, while pays only the amount which just compensates their effort cost (it implies payment is minimum and the agents cannot enjoy rent). On the other hand, if the good-type agent misreports their type as bad, then in the second period, they will be assigned the first-best offer which is tuned to the bad-type agent's true capability. Since the good-type agent has higher capability than the bad-type agent, the good-type agent can achieve that effort requirement with lower cost and it renders some rent to the agent (i.e., if the good-type agent misreports their type in the first period, then they can earn some benefit in the second period). Thus, if the agents correctly expect what would happen in the second period, then they have an incentive to misreport their type in the first period for the sake of the second periods' rent.

probability two thirds and an agent is a newcomer with probability one thirds.

After informing the type, the first period starts. First, participants were told that to determine a team's production schedule, a manager asked workers' opinions on how much they could work in this period. Then, participants make the following decision simultaneously. Each participant selects one of the three alternatives to represent the opinion: *Much*, *Less*, or *Reject*[9]. The principal interprets the opinion such that selecting the alternative *Much* (*Less*) corresponds to reporting the type as a skilled worker (newcomer). Depending on the pair of participants' choices, the principal determines the units of production requirement for this team and rewards for each agent. Each agent bears effort costs by conducting a production activity. Agents' payoffs are calculated by subtracting the cost of production effort from the rewards[10]. The units of production follow the following order: "the amount when both select *Much*" ＞ "the amount when one selects *Much* and the other selects *Less*" ＞ "the amount when both select *Less*" It suggests that the production requirement becomes more demanding when the agent selects *Much* than when they selects *Less*. The cost of production effort depends on the units of production and the agent's type. The cost increases as the units of production increase and the newcomer bears more cost than the skilled workers when they conduct the same amount of production activity. As will be explained shortly, the agents' decisions in the first period impact their first and second period's payoffs, thus we can consider this experimental design captures the feature of the ratchet effect problem.

Insert Tables 1 and 2 here

After the first period's decision, participants were informed of their teammates' type.

Then, based on two participants' decisions in the first period, the second period's schedule is determined by the principal according to Tables 3 and 4. The principal assumes that the first period's decisions correctly revealed the agents' types as explained in the above, then the principal believes there is no information asymmetry with respect to the agents' types and offers the first-best production schedule that corresponds to the agents' type pair in the second period. In other words, the second period's contract becomes more demanding if the agent selected *Much* in the first period

[9] Four payoff charts (1st and 2nd period's payoff charts for each type of worker) are printed as a one-pager. I hand them out to each participant. Participants can refer to the payoff charts at any time during this task.
[10] To facilitate better understanding of participants, I do not show the units of production or rewards. Only payoffs are shown in the experimental payoff charts. The payoffs are calculated based on the model shown in Appendix A.

than if they selected *Less*. As will be explained shortly, the agents' payoffs are impacted by the principals' schedule selection. Participants know how their first period's decisions impact the second period's schedule and their payoffs before they make the first period's decision. Thus, the agents' decisions in the first period impact their second period's payoffs through the determination of the second period's production schedule, and the agents need to make their first period's decision considering its impact on their first and second period's payoffs.

Insert Tables 3 and 4 here

In the second period, participants make the following decision simultaneously, given the selected second period's schedule. Each participant selects one of two alternatives: *Accept* or *Reject*. If both participants select *Accept*, then both get non-zero payoffs. Otherwise, both payoffs are zero. The concrete payoffs are shown in Tables 5, 6, 7, and 8.

Insert Tables 5, 6, 7, and 8 here

After the second period's decision, all results were fed back to each participant. Then the game ends.

3.2 Treatments

There are three treatments with the between-subject design: *ONE*, *NOLEARN*, and *LEARN*. The base treatment is *NOLEARN*, in which participants play the team-production game described above. *ONE* is a treatment manipulated such that participants play the first period only in the team-production game. *LEARN* is a treatment manipulated such that participants can improve their ability by learning over periods. The mechanism of learning here is consistent with the definition of learning that I analyze in Appendix A. Specifically, when a newcomer is paired with a skilled worker, the newcomer learns from the skilled teammate in the first period and then attains the same ability level as the skilled worker in the second period. However, the skilled workers never learn from any type of teammate, and their ability levels remain the same in the second period[11]. In this *LEARN* treatment, participants were informed of the outcome of learning after the end of the first period. More precisely, participants are first informed of the type of their teammates that are given at the beginning of the first period. Participants are then informed whether ability improvement occurs in their team,

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[11] In the experiment, I normalize $\epsilon = 0$ without loss of generality, and $\Delta = \theta_B - \theta_G$ to highlight the impact of learning.

and if so, they are also told whose ability is improved.

In all three treatments, the team-production task had 20 rounds. In each round, two participants were randomly paired without knowing each other. The participants' types are assigned such that two-thirds of participants randomly selected in each session are assigned the role of a skilled worker and the remaining one-third are assigned the role of a newcomer. Over 20 rounds, the team is randomly rematched by rounds[12]. In addition, each participant's type is randomly re-assigned by rounds.

3.3 Participants and Sessions

Participants were undergraduate and graduate students of Osaka University. They are recruited via an online recruitment system for economic experiments (ORSEE) run by the Institute of Social and Economic Research at Osaka University[13].

I ran two sessions per treatment (six sessions in total). Each recruited student was assigned to one of the six sessions. Each session was conducted with either 18 or 24 participants due to no shows. Participants are randomly assigned to a separate computer terminal and conduct tasks independently. Each session took 90–120 minutes, including ex-post questionnaires.

3.4 Payment Scheme

From this experiment, every participant receives a sum of the show-up fee and rewards from the two tasks. The show-up fee is 800 JPY. The rewards from the team-production task are determined based on participants' earned payoffs in the following way. After the 20 rounds end, one round is randomly selected. Each participant's rewards from this task are determined according to their total payoffs in this selected round by converting one payoff point to one JPY.

The method of determining rewards from the second task is explained in Appendix C.

4. EQUILIBRIUM PREDICTIONS AND HYPOTHESES

Using the team-production game, I derived hypotheses about the ratchet effect in teams and the impact of learning on the ratchet effect in teams. To derive these

[12] The re-matching protocol that this study used allows the same participants to be matched as a team again.

[13] This study received approval from the Institute of Social and Economic Research at Osaka University.

hypotheses, I used a game-theoretic equilibrium analysis.

Before conducting the analyses, I reconfirmed the situations wherein the ratchet effect does and does not occur. As explained in Section 2, the ratchet effect is a problem in that a high-ability agent misreports their type as a low-ability one, and then the principal cannot properly adjust the team's production schedule based on the agents' ability. This problem is caused by the high-ability agent's incentive to pursue the information rent from being assigned a relatively easy task in the future periods. In the experiment, the ratchet effect occurs if both skilled workers and newcomers select the same alternative in the first period, since the manager cannot obtain any additional information to distinguish each worker's type based on their first period's decisions. However, the ratchet effect does not occur if each type of worker selects a different alternative in the first period, since the manager can distinguish each worker's type based on their first period's decisions and assign the second period's schedule based on that ability.

For the equilibrium analysis, I focus on the following two strategy profiles as a candidate for equilibrium: separation and pooling[14]. Separation is a strategy profile in which skilled workers select *Much* and newcomers select *Less* in the first period, and everyone selects *Accept* in the second period. This separation corresponds to the situation wherein the ratchet effect does not occur. In this case, the manager assigns the second period's schedule corresponding to the pair of skills: (Skilled, Skilled), (New, Skilled), and (New, New). Pooling is a strategy profile in which both types of workers select *Less* in the first period, and everyone selects *Accept* in the second period. This pooling corresponds to the situation wherein the ratchet effect occurs. In this case, the manager can only assign the second period's schedule based on the prior information on the type.

Table 9 summarizes the results of the equilibrium analyses for each treatment[15]. It shows which strategy profile—separation or pooling—becomes an equilibrium in each case.

Insert Table 9 here

Based on the above equilibrium analyses, I derived the following three hypotheses that investigate the existence of the ratchet effect in teams and the mechanism of mitigating the ratchet effect in teams.

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[14] For simplicity, this study restricts its analysis to pure strategies.
[15] All analyses are shown in Appendix B.

The first hypothesis intends to test the existence of the ratchet effect in teams, and it is built on the comparison of *ONE* and *NOLEARN* in the case of agents with standard preferences. The above equilibrium analysis shows that separation is the only equilibrium in *ONE*. The logic is as follows: if skilled workers select *Much* in the first period, then they will get either 560 or 615, depending on their teammates' choices. However, if skilled workers select *Less*, then they will receive either 500 or 427. Thus, skilled workers can strictly better off by selecting *Much* in *ONE*.

However, pooling is the only equilibrium in *NOLEARN*. If skilled workers select *Much* in the first period, then they will get either 560 + 440 or 615 + 440 in total, depending on their teammates' choices. However, if skilled workers select *Less*, then they will get either 500 + 773 or 427 + 628 in total, depending on their teammates' choices. Thus, skilled workers can be better off by selecting *Less* in *NOLEARN*.

The choice of *Less* by the skilled workers in *NOLEARN* is the ratchet effect. The logic of this behavior is as follows: if the skilled workers select *Less* in the first period, then the units of production in the first period become lower and their payoffs from the first period are lower—500 or 427 compared to 560 or 615. However, the choice of *Less* brings them higher rent in the second period: 773 or 628 compared to 440. This benefit outweighs the loss in the first period. Thus, skilled workers have an incentive to select *Less* in the first period. In contrast, in *ONE*, there is no such incentive for skilled workers since they do not have an opportunity to earn any information rent in the second period.

From the above, I derive H1. H1 is tested by observing that separation occurs in *ONE* and pooling occurs in *NOLEARN*, which confirms that pooling is driven by the dynamics of the relationship.

H1: *The ratchet effect occurs in a team without learning.*

The second hypothesis tests that learning mitigates the ratchet effect in teams and is built on the comparison of *NOLEARN* and *LEARN* in the case of agents with standard preferences. The equilibrium results reveal that there are two equilibria—separation and pooling—in *LEARN*.

The logic of separating equilibrium is as follows. The payoffs when they earn by selecting *Much* are the same as in the *NOLEARN* treatment. If skilled workers select *Much* in the first period, they will earn either 560 + 400 or 615 + 400 in total, depending on their teammates' decisions. However, if the skilled workers select *Less* in the first period, then their payoffs may differ from *NOLEARN*, depending on their teammate's decision. Specifically, the skilled workers will earn either 500 + 440 or 427 + 628 in total. In the second period, they will earn only 440 in *LEARN*, in contrast to 773 in

NOLEARN, when their teammate selects *Much*. This is because the manager knows that the agent who selected *Less* will improve the ability by learning from their skilled teammate even if the agent initially has low skill, and the manager assigns the second period's schedule considering that both agents have high skill. Thus, as long as their teammate selects *Much* in the first period, they will not get any additional rent in the second period. Hence, the skilled workers' benefit from selecting *Less* does not compensate for the loss in the first period and their incentive to select *Les*s in the first period vanishes; the ratchet effect does not occur in *LEARN*.

The logic of the pooling equilibrium in *LEARN* is similar to that in *NOLEARN*. More precisely, in *LEARN*, the principal knows that the probability that both agents have high skill in the second period is 8/9, much higher than that in *NOLEARN*. However, the principal still assigns the production schedule for two low-skilled agents in the second period fearing that both agents have low skill and reject the second period's schedule for high-skilled agents.

Given H1 is supported, if separation occurs, then it implies that the ratchet effect is mitigated by the existence of learning. From the above, I derive H2. H2 is tested by observing that separation occurs in *LEARN* and pooling occurs in *NOLEARN*.

H2: *Given H1 is supported, the ratchet effect is less likely to occur in a team with learning than in cases without learning.*

The third hypotheses investigates the impact of inequity aversion on the ratchet effect in teams and is built on the comparative static analysis of equilibria in *NOLEARN* with respect to the inequity aversion of the agents. For analyzing inequity-averse agents' behavior, I assume that agents have Fehr and Schmidt's (1999) inequity-averse utility function, as shown in Equation (1). Figure 2 shows how the equilibria differ depending on the agents' inequity-aversion parameters[16].

Insert Figure 2 here

The orange region in Figure 2 shows the pair of α and β for which separation is an equilibrium, whereas pooling is not. In the yellow region, both separation and pooling are equilibria. In the green region, pooling is an equilibrium, whereas separation is not. This result means that even without learning, agents prefer to tell their type truthfully if they feel strong envy and guilt, and thus, the ratchet effect does not occur.

From the above, I derive H3. H3 is tested by observing that separation occurs in

[16] For this equilibrium analysis, I put the following two assumptions. First, α and β are symmetric among agents. Second, the value of α and β are common knowledge.

NOLEARN when participants' inequity-aversion parameters belong to the yellow or orange region of Figure 2. To do so, I investigated each participant's behavior paired with their inequity aversion. The inequity-aversion parameters are measured based on the second part of this experiment, as explained in Appendix C.

***H3:** The ratchet effect does not arise for those who have strong inequity aversion.*

5. RESULTS

The total number of participants was 126, of which 29.37% were female, and this proportion of female students is not far away from the population of Osaka University students (Osaka University, 2019). Table 10 shows the summary statistics. The observation unit of Table 10 is the decision of each round. Since 126 participants conduct 20 rounds of decisions, I have 2,520 observations in total. Recall that two-thirds of the participants become skilled workers and one-third of participants become newcomers in each round. For example, since *NOLEARN* has 48 participants in total, there are 640 observations of skilled workers' decisions in the first period[17]. The average earnings of *ONE*, *NOLEARN*, and *LEARN* are 1,477.639 JPY, 1,936.292 JPY, and 1,962.095 JPY, respectively.

Based on Table 10, more than 90% of newcomers select *Less* in *ONE*, *NOLEARN*, and *LEARN* (90.8%, 96.9%, and 97.9%, respectively). However, skilled workers' behavior differs between *ONE* and *NOLEARN*. More than 90% of skilled workers in *ONE* select *Much* (98.3%), whereas skilled workers in *NOLEARN* select *Less* more than *Much* (81.6% select *Less*). These observations are consistent with H1. This implies that the ratchet effect does occur.

Additionally, the ratio of skilled workers who select *Much* in *LEARN* is higher than that in *NOLEARN* (67.5% vs. 18.4%). This observation is consistent with H2. This implies that skilled workers are less likely to misrepresent their type in *LEARN* than in *NOLEARN*, that is, the ratchet effect is less likely to occur in the presence of learning.

Table 10 also shows the average value of inequity aversion by treatment. Figure 3 shows the scatter plot of the pair of inequity-aversion parameters. Based on these results, I confirm that most of the participants are weakly inequity-averse or do not care for inequity at all. Therefore, the inequity aversion does not relate to this participant's behavior.

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[17] In *NOLEARN*, one newcomer who is paired with a newcomer selected *Reject* in the first period and that team did not experience the second period. Therefore, the number of observations of newcomers' decision in the second period is reduced to 318.

Insert Table 10 and Figure 3 here

5.1 Definitions of Variables

Since each participant repeatedly conducted 20 rounds of decisions, each decision data might not be independent. To cope with this problem, I created the following two variables and used them for testing:

Denote the participant i's observed choice frequency that they select *Much* in the first period when they are a skilled worker as $Rate\_MuchSkilled_i$.

$$Rate\_MuchSkilled_i = \frac{\sum_{t=1}^{20} \mathbb{I}\left(Decision1_{i,t} = Much, Role_{i,t} = Skilled\right)}{\sum_{t=1}^{20} \mathbb{I}\left(Role_{i,t} = Skilled\right)} \tag{6}$$

Both $\mathbb{I}\left(Decision1_{i,t} = Much, Role_{i,t} = Skilled\right)$ and $\mathbb{I}\left(Role_{i,t} = Skilled\right)$ are indicator functions that take 1 when the condition in each bracket is satisfied and 0 otherwise.

Likewise, I denote participant i's observed choice frequency that they select *Less* in the first period when they are a newcomer as $Rate\_LessNew_i$.

$$Rate\_LessNew_i = \frac{\sum_{t=1}^{20} \mathbb{I}\left(Decision1_{i,t} = Less, Role_{i,t} = Newcomer\right)}{\sum_{t=1}^{20} \mathbb{I}\left(Role_{i,t} = Newcomer\right)} \tag{7}$$

There were two sessions per treatment. I examine whether a difference exists in the above two variables by session within the same treatment. Based on the Kolmogorov–Smirnov test, I did not find any statistically significant difference between sessions. Subsequently, I pooled the data by treatment.

5.2 Testing the Existence of the Ratchet Effect (H1 & H3)

I examined whether the ratchet effect is observed in teams comparing *ONE* and *NOLEARN*. Specifically, I examined (1) whether skilled workers are less likely to select *Much* in *NOLEARN* than in *ONE* and (2) whether newcomers are likely to select *Less* regardless of treatments. To do so, I compared the distribution of the observed choice frequency I defined above. Figures 4 and 5 show the empirical cumulative distribution functions of $Rate\_MuchSkilled_i$ and, $Rate\_LessNew_i$ respectively.

Insert Figure 4 and Figure 5 here

First, I examined skilled workers' behavior. Figure 4 shows that more than 80% of participants in *ONE* always select *Much*. However, in *NOLEARN*, participants who always select the alternative *Much* are almost zero. Moreover, approximately 40% of participants always select *Less*. The results of the Kolmogorov–Smirnov test revealed that the empirical cumulative distribution function $Rate\_MuchSkilled_i$ of *NOLEARN* is statistically significantly greater than that of *ONE* ($D = 0.93056,\ p = 3.368e - 16$, one-sided[18]). Table 11 shows that the Wilcoxon's rank-sum test also provides consistent statistically significant evidence ($W = 2368,\ p < 0.001$, one-sided). Based on these results, I conclude that skilled workers in *NOLEARN* are less likely to select *Much* compared to those in *ONE*.

Insert Table 11 here

Second, I examined newcomers' behavior. Figure 5 shows that newcomers are highly likely to select *Less* in both *ONE* and *NOLEARN*. In both treatments, more than 60% of participants always selected *Less*. Consistent with the equilibrium predictions, the results of the Kolmogorov–Smirnov test do not reveal any statistical difference in the empirical cumulative distribution function $Rate\_LessNew_i$ of *ONE* and *NOLEARN* ($D = 0.18056$, $p = 0.5137$, two-sided). Likewise, the results of Wilcoxon's rank-sum test also reveal that these two distributions do not statistically differ ($W = 1411,\ p = 0.0668$, two-sided). Based on these results, I conclude that newcomers are highly likely to select *Less*, and their behavior does not differ between *ONE* and *NOLEARN*.

The above results demonstrate that the ratchet effect occurs; thus, H1 is supported.

The analyses so far are based on the assumption that participants are self-regarding individuals. I make sure whether inequity-averse participants exist, and if so, how they behave. First, I divided participants of *NOLEARN* into two subsamples. Recall that separation can be an equilibrium when individuals' inequity-aversion parameters belong to the orange and yellow regions of Figure 2. The downward-sloping line in Figure 3 shows the boundary of the yellow and green regions in Figure 2. Figure 3 shows that almost all participants do not belong to the yellow region. Moreover, the only participant who belongs to the yellow region is that of *LEARN*. Therefore, no participant of *NOLEARN* belongs to the yellow region. From the above, I concluded that the behavior predicted in H3—that individuals refrain from committing the ratchet effect due to their strong inequity aversion—is not observed in this experiment.

[18] Since the data include ties, all of the Kolmogorov–Smirnov test results rely on bootstrapping for calculating the confidence interval. Likewise, for the Wilcoxon's rank-sum test, I assigned each observation in a tie its average rank and deflated the variance of test statistics considering the number of ties.

5.3 Testing the Impact of Learning on the Ratchet Effect (H2)

I examined whether the ratchet effect is mitigated in the presence of learning by comparing *NOLEARN* and *LEARN*. Specifically, I examined (1) whether skilled workers are more likely to select *Much* in *LEARN* compared to *NOLEARN* and (2) whether newcomers are likely to select *Less* regardless of treatments.

First, I investigated skilled workers' behavior. Figure 4 shows that approximately 30% of participants in *LEARN* always select *Much*. In contrast, participants of *NOLEARN* who always select *Much* are less than 5%. The results of the Kolmogorov–Smirnov test revealed that the empirical cumulative distribution function $Rate\_MuchSkilled_i$ of *LEARN* is statistically significantly less than that of *NOLEARN* ($D = 0.66071,\ p = 3.21e - 09$, one-sided). In addition, the Wilcoxon's rank-sum test also provides consistent statistically significant evidence, as shown in Table 11 ($W = 1509.5,\ p < 0.001$, one-sided). Based on these results, I concluded that skilled workers in *LEARN* are more likely to select *Much* compared to those in *NOLEARN*.

Second, I examined newcomers' behavior. Figure 5 shows that newcomers are highly likely to select *Less* in both treatments. In addition, the results of both the Kolmogorov–Smirnov test ($D = 0.047619,\ p = 0.823$, two-sided) and the Wilcoxon's rank-sum test ($W = 2142.5,\ p = 0.2912$, two-sided) revealed that the empirical cumulative distribution functions $Rate\_LessNew_i$ of *NOLEARN* and *LEARN* are not statistically significantly different. Based on these results, I concluded that newcomers are highly likely to select *Less*, and their behavior does not differ between *NOLEARN* and *LEARN*.

In addition, I examined whether the presence of learning completely resolved the ratchet effect, comparing skilled workers' behavior in *LEARN* and *ONE*. The results of both the Kolmogorov–Smirnov test ($D = 0.57937,\ p = 4.46e - 06$, two-sided) and the Wilcoxon's rank-sum test ($W = 1892,\ p < 0.001$, one-sided) revealed that the empirical cumulative distribution functions $Rate\_MuchSkilled_i$ of *LEARN* is statistically significantly less than that of *ONE*. These results imply that the presence of learning partially reduces the likelihood that the ratchet effect occrs.

The reason for why the ratchet effect is only partially reduced is asked for the following discussions. As the equilibrium analyses in Section 3 proved, both separation and pooling are equilibria in *LEARN*. Figure 4 shows that the empirical cumulative distiribution function of $Rate\_MuchSkilled_i$ of *LEARN* has two mass points. It suggests that both equilibria occurs in the experiment. Although the difference is not statistically significant[19], Figure 6 shows two empirical cumulative distribution functions of $Rate\_MuchSkilled_i$ of *LEARN* dividing them into the first-half rounds' data and the latter-half rounds' data. Figure 6 suggests that skilled workers in the latter-half rounds are more likely to select *Much* compared to that in the first-half rounds. This implies that separation is more likely to be selected over pooling as the rounds proceed. From the above, the reason for the partial reduction of the ratchet effect can be understood because of the multiple equilibria, and data is consistent with the theoretical predictions.

6. CONCLUSION

This study theoretically and experimentally demonstrated that the mechanism of the ratchet effect in teams differs qualitatively from that in independent work environments. First, I theoretically proved that the occurrence of the ratchet effect in teams depends on the agents' inequity aversion and that learning among teammates deters the ratchet effect. Then, I ran a laboratory experiment to test these theoretical predictions. The results of the experiment demonstrate that the ratchet effect occurs in teams. I confirmed that participants' inequity-aversion levels were sufficiently low to fall within a range for which the ratchet effect is theoretically expected to occur. The results also reveal that the ratchet effect is significantly mitigated in the presence of learning compared to when learning is absent.

The contributions of this study are as follows. First, this study extends the literature on target ratcheting and the ratchet effect by demonstrating that the mechanism of the ratchet effect in teams differs from that of independent work environments. This study theoretically explains that the ratchet effect is deterred in teams with strongly inequity-averse agents because such agents mutually govern their behavior. This study also theoretically and experimentally demonstrated that learning among teammates works as a tool for the principal to deter the ratchet effect by introducing a correlation between the agents' skill levels, which makes each agent's report on their own type informative of the other teammates' type.

Second, this study reveals the indirect benefit of employees' learning for firms, which is not discussed in the prior literature on learning. The results imply that facilitating knowledge sharing among team members and/or providing mentoring opportunities for low-performing employees can contribute to mitigating the ratchet

[19] The result of Kolmogorov–Smirnov test is as follows: $D = 0.19048$, $p = 0.2179$, one-sided.

effect. In other words, such management activities are beneficial to firms as a means of not only improving the employees' abilities but also preventing skilled employees from shirking.

The limitation of this study is that the experiment was not designed for directly testing the impact of inequity aversion on the ratchet effect. Based on the results of this experiment, I cannot conclude whether strictly inequity-averse individuals refrain from committing the ratchet effect. Future research can test this impact more directly by recruiting participants with various inequity aversion and comparing the behavior based on their inequity aversion.

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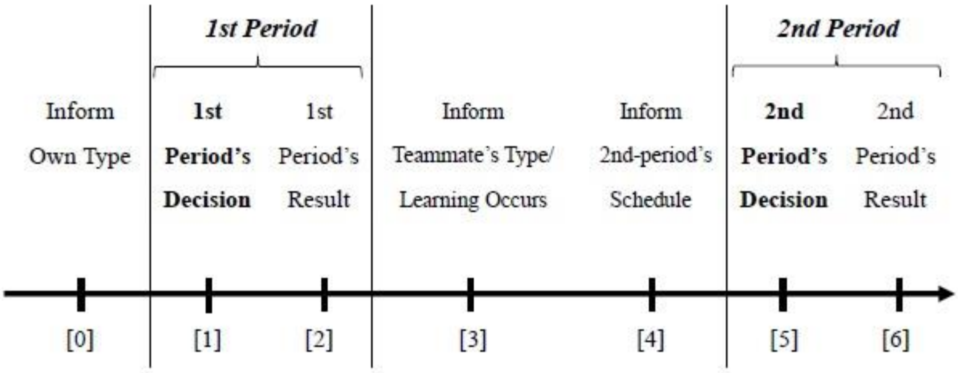
Figures

FIGURE 1

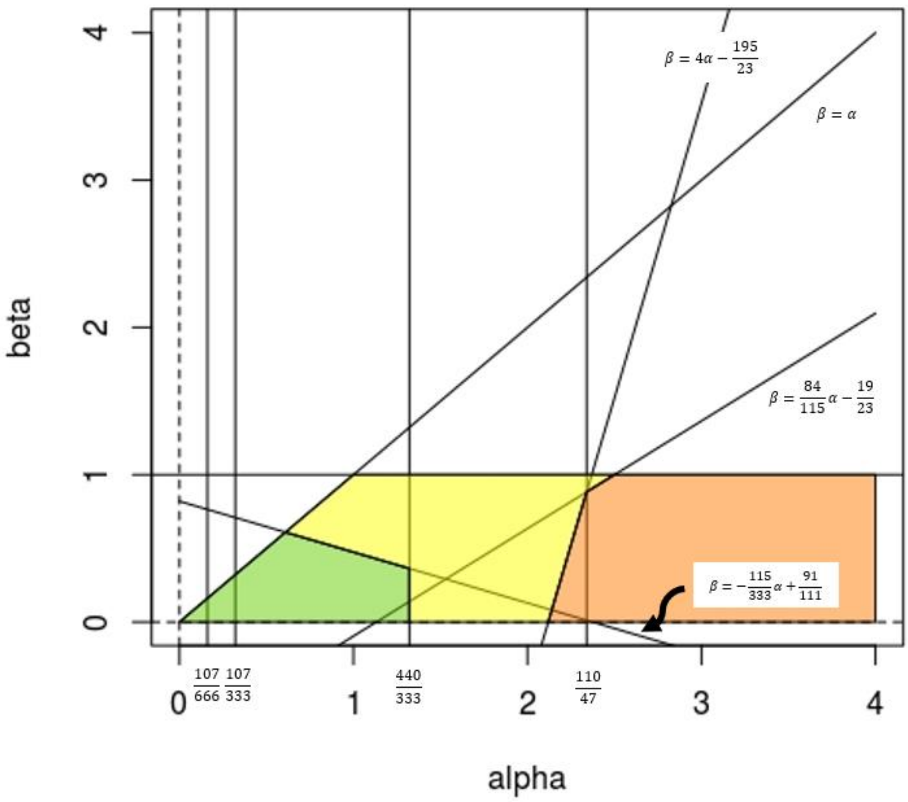
Timeline of a Round in Two-periods Treatments



NOTE: At the timing of 3, learning occurs only in *LEARN* treatment.

FIGURE 2

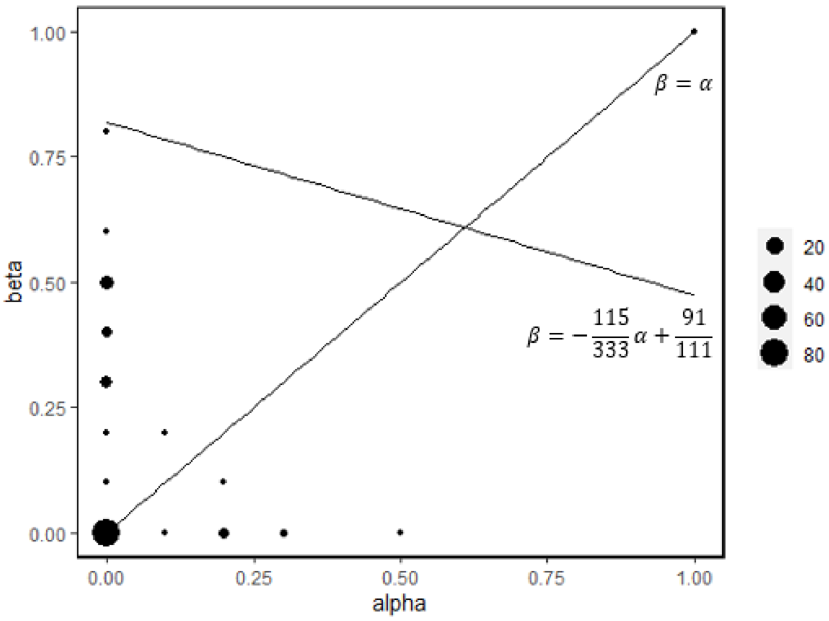
Equilibriums in *NOLEARN* depending on the Inequity Averseness



NOTE: [Green region] pooling is an equilibrium while separation is not, [Yellow region] both pooling and separation is an equilibrium, [Orange region] separation is an equilibrium while pooling is not.

FIGURE 3

The Scatter Plot of Participants' Inequity Averseness



NOTE: The values of α and β are calculated as shown in Appendix C. These two parameters can take a value from 0 to 1 at an interval of 0.1. Two participants who represent more than two switching points are omitted; thus, the total observation number is 124. The number of participants who have $(\alpha, \beta) = (0,0)$ is 84. The number of participants who have $(\alpha, \beta) = (1,1)$ is 1 and that participant participates in the *LEARN* treatment.

FIGURE 4

The Empirical Cumulative Distribution Function of Skilled Workers' Decisions in the First Period

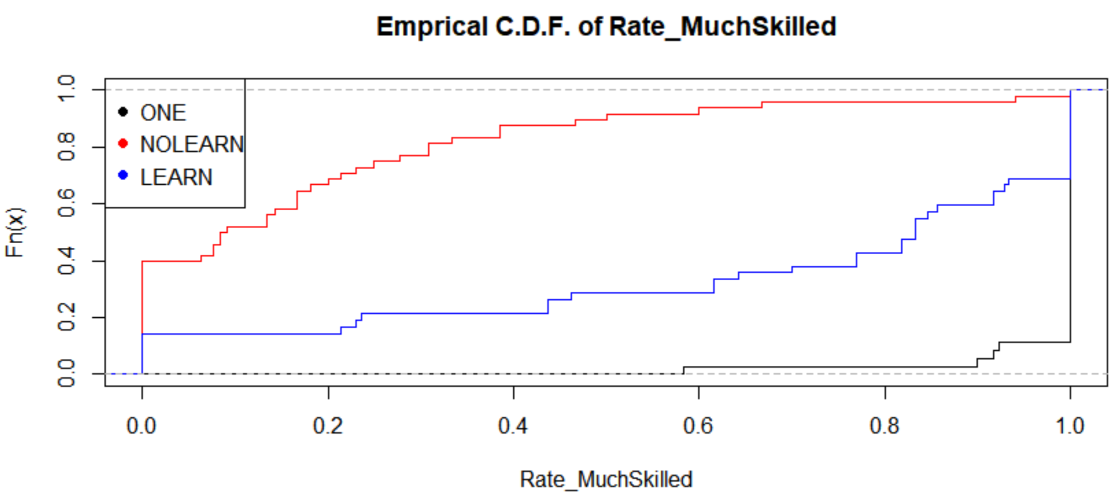


FIGURE 5

The Empirical Cumulative Distribution Functions of Newcomers' Decisions in the First Period

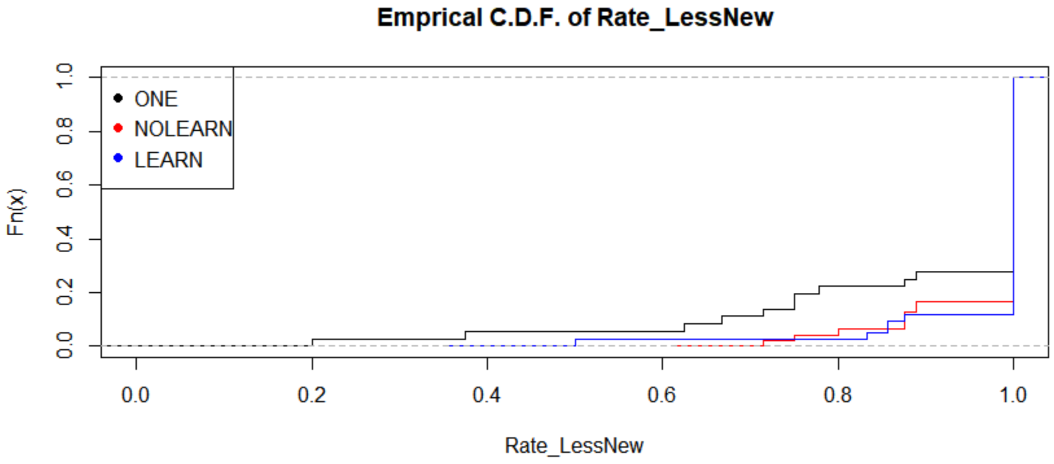
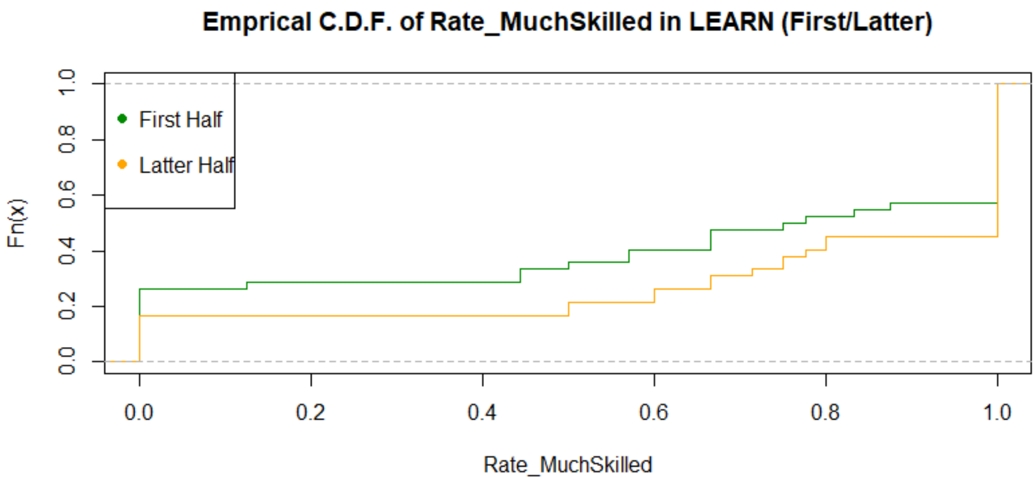


FIGURE 6

The Empirical Cumulative Distribution Functions of Skilled Workers's First Period's Decisions in *LEARN* Treatment: Comparison of 1–10 Rounds' Data and 11–20 Rounds' Data



Tables

TABLE 1

A Payoff Chart for the First period's Decision when a Decision-maker is a Skilled Worker

Your Choice	Teammate's Choice	Your Payoff	Teammate's Payoff (if a skilled worker)	Teammate's Payoff (if a newcomer)
Much	*Much*	560	560	-190
	Less	615	500	380
	Reject	0	0	0
Less	*Much*	500	615	495
	Less	427	427	380
	Reject	0	0	0
Reject	-	0	0	0

TABLE 2

A Payoff Chart for the First period's Decision when a Decision-maker is a Newcomer

Your Choice	Teammate's Choice	Your Payoff	Teammate's Payoff (if a skilled worker)	Teammate's Payoff (if a newcomer)
Much	*Much*	-190	560	-190
	Less	495	500	380
	Reject	0	0	0
Less	*Much*	380	615	495
	Less	380	427	380
	Reject	0	0	0
Reject	-	0	0	0

Table 3

The Relationship between the First Period's Decisions and the Second Schedule in *NOLEARN*

Your Choice in the First Period	Teammate's Choice in the First Period	The Second Period's Schedule
Much	*Much*	A
Much	*Less*	B
Less	*Much*	C
Less	*Less*	D

TABLE 4

The Relationship between the First Decisions and the Second Schedule in *LEARN*

Your Choice in the First Period	Teammate's Choice in the First Period	The Second Period's Schedule
Much	*Much*	X
Much	*Less*	
Less	*Much*	
Less	*Less*	Y

TABLE 5

A Payoff Chart for the Second period's Decision when a Decision-maker is a Skilled Worker in *NOLEARN*

2nd period's Schedule	Choices of You and Teammate	Your Payoff	Teammate's Payoff (if a skilled worker)	Teammate's Payoff (if a newcomer)
A	Both *Accept*	440	440	-310
	Others	0	0	0
B	Both *Accept*	440	773	440
	Others	0	0	0
C	Both *Accept*	773	440	107
	Others	0	0	0
D	Both *Accept*	628	628	440
	Others	0	0	0

TABLE 6

A Payoff Chart for the Second period's Decision when a Decision-maker is a Newcomer in *NOLEARN*

2nd period's Schedule	Choices of You and Teammate	Your Payoff	Teammate's Payoff (if a skilled worker)	Teammate's Payoff (if a newcomer)
A	Both *Accept*	-310	440	-310
	Others	0	0	0
B	Both *Accept*	107	773	440
	Others	0	0	0
C	Both *Accept*	440	440	107
	Others	0	0	0
D	Both *Accept*	440	628	440
	Others	0	0	0

TABLE 7

A Payoff Chart for the Second period's Decision when a Decision-maker is a Skilled Worker in *LEARN*

2nd period's Schedule	Choices of You and Teammate	Your Payoff	Teammate's Payoff (if a skilled worker)	Teammate's Payoff (if a newcomer)
X	Both *Accept*	440	440	440
	Others	0	0	0
Y	Both *Accept*	628	628	628
	Others	0	0	0

TABLE 8

A Payoff Chart for the Second period's Decision when a Decision-maker is a Newcomer in *LEARN*

2nd period's Schedule	Choices of You and Teammate	Teammate's Type	Your Payoff	Teammate's Payoff
X	Both *Accept*	Skilled worker	440	440
		Newcomer	-310	-310
	Others	-	0	0
Y	Both *Accept*	Skilled worker	628	628
		Newcomer	440	440
	Others	-	0	0

Table 9

Equilibriums in Each Treatment

	Self-regarding Agents	Inequity-averse Agents
ONE	Separation only	Separation only
NOLEARN	Pooling only	Separation and Pooling (Depending on parameters)
LEARN	Separation and Pooling	Separation and Pooling

TABLE 10

Summary Statistics

	ONE	*NOLEARN*	*LEARN*
First period:			
Skilled workers' choices:			
Much	472/480 (98.3)	118/640 (18.4)	378/560 (67.5)
Less	8/480 (1.7)	522/640 (81.6)	182/560 (32.5)
Reject	0/480 (0.0)	0/640 (0.0)	0/560 (0.0)
Newcomers' choices:			
Much	19/240 (7.9)	9/320 (2.8)	6/280 (2.1)
Less	218/240 (90.8)	310/320 (96.9)	274/280 (97.9)
Reject	3/240 (1.3)	1/320 (0.3)	0/280 (0.0)
Second period:			
Skilled workers' choices:			
Accept	-	637/640 (99.5)	558/560 (99.6)
Reject	-	3/640 (0.5)	2/560 (0.4)
Newcomers' choices:			
Accept	-	315/318 (99.1)	278/280 (99.3)
Reject	-	3/318 (0.9)	2/280 (0.7)
Average of α	0.029	0.034	0.067
Average of β	0.023	0.120	0.139
Average Earnings (JPY)	1477.639	1936.292	1962.095
Number of Participants	36	48	42

NOTE: Percentages are in parentheses.

Table 11

The Results of the Wilcoxon Rank-Sum Tests for Decisions in the First Period

	Rate_MuchSkilled		*Rate_LessNew*	
	Test Statistics	*p*-value	Test Statistics	*p*-value
ONE v.s. NOLEARN	W=2368	p<0.001, one-sided	W=1411	p=0.0668, two-sided
NOLEARN v.s. LEARN	W=1509.5	p<0.001, one-sided	W=2142.5	p=0.2912, two-sided
ONE v.s. LEARN	W=1892	p<0.001, one-sided		

Appendix

A. The Model for the Impact of Learning on the Ratchet Effect

A.1. Setting

Consider a principal that manages a team with two agents ($n = 1, 2$) to conduct a productive activity for two periods. Suppose that every party is risk-neutral. Each agent exerts their own effort with private cost, and the pair of two agents' efforts determines the team's output. Agent n's effort in period t is $a_t^n \in [0, \bar{a}] \equiv \mathrm{A}$. Let the output of the team in period t be $x_t = \min\{a_t^1, a_t^2\} \in \mathrm{X} \subseteq \mathbb{R}$. Agents are heterogeneous in terms of their marginal cost of effort. Suppose there are two types of agents: good and bad. I denote the type of agent n in period t as θ_t^n. Let $\theta_1^n \in \{\theta_G, \theta_B\}$ and $0 < \theta_G < \theta_B$. The cost of each agent is $C(a_t^n, \theta_t^n) = \theta_t^n a_t^n$. Therefore, θ_G is a low-cost and efficient type. Denote the pair of team members' types in period 1 as $\theta^{ij} \equiv (\theta_1^1 = \theta_i, \theta_1^2 = \theta_j)$. Suppose $Pr(\theta^{ij}) = p_{ij} \geq 0$, $\sum_{ij} p_{ij} = 1$, $\sum_j p_{Gj} = \sum_i p_{iG} = p > 0$, and $\sum_j p_{Bj} = \sum_i p_{iB} = 1 - p$. Based on the team's output, income from the team's productive activity is realized. Let the team's income when the team's output is x_t be $b(x_t)$. Suppose $b(\cdot)$ is a twice continuously differentiable function. Let $b(0) = 0$, $b'(0) = +\infty$, $b'(\bar{x}) = 0$, for any $x < \bar{x}$, $b'(x) > 0$, and for any $x \geq 0$, $b''(x) \leq 0$. Agent n receives a reward w_t^n based on the team's output. The agent's utility in period t is determined by $w_t^n - \theta_t^n a_t^n$. The principal's utility in period t is determined by $b(x_t) - w_t^1 - w_t^2$. Suppose the principal cannot commit to any long-term contract. Therefore, the principal uses a short-term contract that can refine the contracts for the subsequent periods at the beginning of each period.

The timeline of this two-periods transaction is as follows.

Period 0

1. Nature determines the type of agents. Each agent privately observes their own type.

Period 1

2. The principal offers a contract for two periods for both agents. If at least one agent rejects the contract, then everyone gets 0 and the transaction ends.
3. If both agents accept the contract, then each agent submits a report on their type.
4. Based on the reports, the amount of outputs and rewards for the first period is determined. The agents produce outputs as prescribed in the selected contract. Thereafter, each party receives their payoff for the first period. Then, the first period ends.

<u>*Period 2*</u>

5. At the beginning of the second period, ability improvement by learning arises if possible.
6. The principal offers a contract for the second period to both agents. If at least one agent rejects the contract, then everyone receives zero and the transaction ends.
7. If both agents accept the contract, then each agent submits a report on their type.
8. Based on the reports, the contract to be executed is selected. Agents exert effort in the second period, as prescribed in the selected contract, and the team's output is realized. Thereafter, each party receives their payoff for the second period and the period ends.

Assumption 1 (Learning)**.** *As a result of learning in the first period, at the beginning of the second period, the marginal cost of each agent improves as follows*[20].

$$If\ \ (\theta_1^1, \theta_1^2) = (\theta_G, \theta_G), then\ \ (\theta_2^1, \theta_2^2) = (\theta_G - \epsilon, \theta_G - \epsilon)$$
$$If\ \ (\theta_1^1, \theta_1^2) = (\theta_G, \theta_B), then\ \ (\theta_2^1, \theta_2^2) = (\theta_G - \epsilon, \theta_B - \epsilon - \Delta)$$
$$If\ \ (\theta_1^1, \theta_1^2) = (\theta_B, \theta_G), then\ \ (\theta_2^1, \theta_2^2) = (\theta_B - \epsilon - \Delta, \theta_G - \epsilon)$$
$$If\ \ (\theta_1^1, \theta_1^2) = (\theta_B, \theta_B), then\ \ (\theta_2^1, \theta_2^2) = (\theta_G - \epsilon, \theta_G - \epsilon)$$

where, $\epsilon \geq 0$ *and* $0 \leq \Delta \leq \theta_B - \theta_G$.

A.2. Benchmark

Suppose that the principal knows agents' types perfectly. Then, the principal offers the first-best contract, which is a solution to the following problem.

$$\max_{w,x} b(x_t) - w_t^1 - w_t^2 \qquad \text{for } t = 1,2 \tag{A.1}$$

$$\text{s.t.}\, w_t^n - \theta_t^n a_t^n \geq 0 \ \text{ for } n = 1,2 \tag{A.2}$$

Let the first-best offer to the team with θ^{ij} be $\{x_t^{FB}(\theta^{ij}), a_t^{n,FB}(\theta^{ij}), w_t^{n,FB}(\theta^{ij})\}$ for any *t* and any *n*. The first-best offer satisfies the following Lemma:

Lemma 1. *The first-best offer satisfies the following two properties.*

$$x_t(\theta^{ij}) = a_t^1(\theta^{ij}) = a_t^2(\theta^{ij}) \tag{A.3}$$
$$w_t^n(\theta^{ij}) = \theta_t^n a_t^n(\theta^{ij}) \quad \text{for } n = 1,2 \tag{A.4}$$

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[20] For simplicity, ϵ is zero in the experiment. In *NOLEARN*, $\Delta = 0$. Whereas in *LEARN*, $\Delta = \theta_B - \theta_G$.

The first property is driven by the characteristic of $x_t = \min\{a_t^1, a_t^2\}$. The second property is driven by the binding of participation constraints.

By Lemma 1, the first-best offer is characterized as follows.

$$w_t^{n,FB}(\theta^{ij}) = \theta_t^n a_t^{n,FB}(\theta^{ij}) = \theta_t^n x_t^{FB}(\theta^{ij}) \quad \forall \ n, t, i, j \tag{A.5}$$

$$b'\left(x_t^{FB}(\theta^{ij})\right) = \theta_t^1 + \theta_t^2 \quad \forall \ t, i, j \tag{A.6}$$

A.3. Short-term Contracts

In this section, I analyze a case in which the principal cannot observe the agents' types. Since this study assumes that the principal cannot commit to any long-term contract, the principal designs a short-term contract satisfying the incentive-compatibility constraints[21].

The next subsection shows the best short-term contract when the principal fully distinguishes the agent's type in the first period (fully separating). This means that the ratchet effect does not occur under this contract. In other words, this contract allows a principal to prevent the ratchet effect. In contrast, the subsection entitled fully pooling shows the best short-term contract when the principal gives up to distinguish the agent's type in the first period at all. Since distinguishing the agents' type requires the principal to owe informational rent, and such required rent may become too large, the principal cannot bear such cost in some cases. Therefore, it is not always feasible to distinguish the agents' types. The condition for fully separating becomes feasible is shown in the subsequent subsection.

As in the benchmark case, any optimal short-term contract satisfies Lemma 2.

Lemma 2. *Any optimal short-term contract satisfies the following property.*

$$x_t(\theta^{ij}) = a_t^1(\theta^{ij}) = a_t^2(\theta^{ij}) \tag{A.7}$$

Fully Separating

I analyze the contract backward. By Lemma 2, let the best fully separating short-term contract be $S^S = \{x_t^S(\theta^{ij}), w_t^{1,S}(\theta^{ij}), w_t^{2,S}(\theta^{ij})\}_{ij\in\{G,B\},t=1,2}$.

Since the agents' types are fully revealed as a result of the first period, the principal knows the agent's type and there is no information asymmetry at this point. That is, the

[21] For simplicity, this study restricts its analysis to pure strategies. Thus, this study does not deny the possibility that any partially separating contract outperforms the other two contracts.

principal's problem in the second period is the same as in the benchmark case. Therefore, the principal offers the first-best offer in the second period.

$$w_2^{n,S}(\theta^{ij}) = w_2^{n,FB}(\theta^{ij}) = \theta_2^n x_2^{FB}(\theta^{ij}) \quad \forall \; n, i, j \tag{A.8}$$

$$b'\left(x_2^S(\theta^{ij})\right) = b'\left(x_2^{FB}(\theta^{ij})\right) = \theta_2^1 + \theta_2^2 \quad \forall \; i, j \tag{A.9}$$

Then, the principal's problem in the first period is formalized as follows.

$$\max_{w_1, x_1} \sum_{ij} p_{ij}[b\left(x_1(\theta^{ij})\right) - w_1^1(\theta^{ij}) - w_1^2(\theta^{ij})$$

$$+\delta\left\{b\left(x_2^{FB}(\theta^{ij})\right) - w_2^{1FB}(\theta^{ij}) - w_2^{2,FB}(\theta^{ij})\right\}] \tag{A.10}$$

$$s.t. \quad \sum_j \frac{p_{Gj}}{p}\left[w_1^1(\theta^{Gj}) - \theta_G x_1(\theta^{Gj}) + \delta \times 0\right] \geq 0$$

$$\sum_j \frac{p_{Bj}}{1-p}\left[w_1^1(\theta^{Bj}) - \theta_B x_1(\theta^{Bj}) + \delta \times 0\right] \geq 0 \tag{A.12}$$

$$\sum_i \frac{p_{iG}}{p}\left[w_1^2(\theta^{iG}) - \theta_G x_1(\theta^{iG}) + \delta \times 0\right] \geq 0$$

$$\sum_i \frac{p_{iB}}{1-p}\left[w_1^2(\theta^{iB}) - \theta_B x_1(\theta^{iB}) + \delta \times 0\right] \geq 0$$

$$\sum_j \frac{p_{Gj}}{p}\left[w_1^1(\theta^{Gj}) - \theta_G x_1(\theta^{Gj}) + \delta \times 0\right]$$

$$\geq \sum_j \frac{p_{Gj}}{p}\left[w_1^1(\theta^{Bj}) - \theta_G x_1(\theta^{Bj}) + \delta\{w_2^{1,FB}(\theta^{Bj}) - \theta_2^1 x_2^{FB}(\theta^{Bj})\}\right]$$

$$\sum_j \frac{p_{Bj}}{1-p}\left[w_1^1(\theta^{Bj}) - \theta_B x_1(\theta^{Bj}) + \delta \times 0\right]$$

$$\geq \sum_j \frac{p_{Bj}}{1-p}\left[w_1^1(\theta^{Gj}) - \theta_B x_1(\theta^{Gj}) + \delta\{w_2^{1,FB}(\theta^{Gj}) - \theta_2^1 x_2^{FB}(\theta^{Gj})\}\right]$$

$$\sum_i \frac{p_{iG}}{p}\left[w_1^2(\theta^{iG}) - \theta_G x_1(\theta^{iG}) + \delta \times 0\right]$$

$$\geq \sum_i \frac{p_{iG}}{p}\left[w_1^2(\theta^{iB}) - \theta_G x_1(\theta^{iB}) + \delta\{w_2^{2,FB}(\theta^{iB}) - \theta_2^2 x_2^{FB}(\theta^{iB})\}\right]$$

$$\sum_i \frac{p_{iB}}{1-p}\left[w_1^2(\theta^{iB}) - \theta_B x_1(\theta^{iB}) + \delta \times 0\right]$$

$$\geq \sum_i \frac{p_{iB}}{1-p}\left[w_1^2(\theta^{iG}) - \theta_B x_1(\theta^{iG}) + \delta\{w_2^{2,FB}(\theta^{iG}) - \theta_2^2 x_2^{FB}(\theta^{iG})\}\right]$$

Solving the above problem, the first period's offer is characterized as follows.

$b'\left(x_1^S(\theta^{GG})\right) = \theta_G + \theta_G$

$b'\left(x_1^S(\theta^{GB})\right) = b'\left(x_1^S(\theta^{BG})\right) = \theta_G + \theta_B + \dfrac{p}{1-p}(\theta_B - \theta_G)$

$b'\left(x_1^S(\theta^{BB})\right) = \theta_B + \theta_B + \dfrac{2p}{1-p}(\theta_B - \theta_G)$

$$w_1^{1,S}(\theta^{GG}) = \theta_G x_1^S(\theta^{GG}) + (\theta_B - \theta_G)x_1^S(\theta^{BG}) + \delta(\theta_B - \theta_G - \Delta)x_2^{FB}(\theta^{BG}) \quad (A.22)$$

$$w_1^{1,S}(\theta^{GB}) = \theta_G x_1^S(\theta^{GB}) + (\theta_B - \theta_G)x_1^S(\theta^{BB}) + \delta(\theta_B - \theta_G)x_2^{FB}(\theta^{BB}) \quad (A.23)$$

$$w_1^{1,S}(\theta^{Bj}) = \theta_B x_1^S(\theta^{Bj}) \qquad j = G, B$$

$$w_1^{2,S}(\theta^{GG}) = \theta_G x_1^S(\theta^{GG}) + (\theta_B - \theta_G)x_1^S(\theta^{GB}) + \delta(\theta_B - \theta_G - \Delta)x_2^{FB}(\theta^{GB}) \quad (A.25)$$

$$w_1^{2,S}(\theta^{BG}) = \theta_G x_1^S(\theta^{BG}) + (\theta_B - \theta_G)x_1^S(\theta^{BB}) + \delta(\theta_B - \theta_G)x_2^{FB}(\theta^{BB}) \quad (A.26)$$

$$w_1^{2S}(\theta^{iB}) = \theta_B x_1^S(\theta^{iB}) \qquad i = G, B$$

The above results reveal that first, the source of the ratchet effect is confirmed by comparing the above results with the second-best contract for a case in which a principal–agent relationship is a one-shot relationship. The major difference between these two contracts is the amount of rent the good-type agent can earn. In the fully separating contract, the good type receives more rent than in the one-shot case. To induce agents to report their type truthfully, the principal needs to provide some rent that is at least as much as the benefit that agents can accrue by misreporting their types. Moreover, in the two-period relationship, misreporting their type in the first period benefits the good-type agent not only in the first period but also in the second period. Therefore, in the two-period case, the principal needs to provide rent that covers the agent's deceiving benefit for the entire two periods. In other words, to prevent this rent-seeking behavior caused by the dynamics of the relationship (i.e., the ratchet effect), the principal needs to provide additional rent in the first period compared to a one-shot relationship case—at least as much as the agent's total deceiving benefit from two periods.

Second, as a bad type paired with a good type grows significantly (i.e., as Δ becomes large), the benefit that the good-type agent accrues by misereporting their type decreases. Suppose both agents are of the good type. In this case, the misreporting benefit that agent 1 can enjoy in the second period is $\delta(\theta_B - \theta_G - \Delta)x_2^{FB}(\theta^{BG})$. This term decreases as Δ increases. Thus, the ratchet effect is less likely to occur as Δ increases. This implies that firms can mitigate the ratchet effect by facilitating knowledge sharing among teammates and/or investing in employees' training systems to increase Δ.

Fully Pooling

Let $S^P = \{x_1^P, w_1^P, x_2^P(\theta^{ij}), w_2^{1,P}(\theta^{ij}), w_2^{2,P}(\theta^{ij})\}_{ij\in\{G,B\}}$ denotes the best fully pooling short-term contract.

Since the first period is fully pooling, the principal designs the optimal contract for the second period based on the common prior p. The principal's problem is written as follows[22]:

$$\max_{w_2,x_2} \sum_{ij} p_{ij}\left[b\left(x_2(\theta^{ij})\right) - w_2^1(\theta^{ij}) - w_2^2(\theta^{ij})\right]$$

$$s.t. \quad w_2^1(\theta^{Gj}) - (\theta_G - \epsilon)x_2(\theta^{Gj}) \geq 0 \qquad j = G, B$$

$$w_2^1(\theta^{BG}) - (\theta_B - \epsilon - \Delta)x_2(\theta^{BG}) \geq 0$$

$$w_2^n(\theta^{BB}) - (\theta_B - \epsilon)x_2(\theta^{BB}) \geq 0 \qquad n = 1,2$$

$$w_2^2(\theta^{iG}) - (\theta_G - \epsilon)x_2(\theta^{iG}) \geq 0 \qquad i = G, B$$

$$w_2^2(\theta^{GB}) - (\theta_B - \epsilon - \Delta)x_2(\theta^{GB}) \geq 0$$

$$w_2^1(\theta^{Gj}) - (\theta_G - \epsilon)x_2(\theta^{Gj}) \geq w_2^1(\theta^{Bj}) - (\theta_G - \epsilon)x_2(\theta^{Bj}) \qquad j = G, B \qquad (A.34)$$

$$w_2^1(\theta^{BG}) - (\theta_B - \epsilon - \Delta)x_2(\theta^{BG}) \geq w_2^1(\theta^{GG}) - (\theta_B - \epsilon - \Delta)x_2(\theta^{GG}) \qquad (A.35)$$

$$w_2^1(\theta^{BB}) - (\theta_B - \epsilon)x_2(\theta^{BB}) \geq w_2^1(\theta^{GB}) - (\theta_B - \epsilon)x_2(\theta^{GB}) \qquad (A.36)$$

$$w_2^2(\theta^{iG}) - (\theta_G - \epsilon)x_2(\theta^{iG}) \geq w_2^2(\theta^{iB}) - (\theta_G - \epsilon)x_2(\theta^{iB}) \qquad i = G, B \qquad (A.37)$$

$$w_2^2(\theta^{GB}) - (\theta_B - \epsilon - \Delta)x_2(\theta^{GB}) \geq w_2^2(\theta^{GG}) - (\theta_B - \epsilon - \Delta)x_1(\theta^{GG}) \qquad (A.38)$$

$$w_2^2(\theta^{BB}) - (\theta_B - \epsilon)x_1(\theta^{BB}) \geq w_2^1(\theta^{BG}) - (\theta_B - \epsilon)x_2(\theta^{BG}) \qquad (A.39)$$

Solving the above problem, the second period's offer is characterized as follows.

$$b'\left(x_2^P(\theta^{GG})\right) = \theta_G - \epsilon + \theta_G - \epsilon$$

$$b'\left(x_2^P(\theta^{GB})\right) = b'\left(x_2^P(\theta^{BG})\right) = \theta_G - \epsilon + \theta_B - \epsilon - \Delta + \frac{p}{1-p}(\theta_B - \theta_G - \Delta) \quad (A.41)$$

$$b'\left(x_2^P(\theta^{BB})\right) = \theta_B - \epsilon + \theta_B - \epsilon + \frac{2p}{1-p}(\theta_B - \theta_G)$$

$$w_2^{1,P}(\theta^{GG}) = (\theta_G - \epsilon)x_2^P(\theta^{GG}) + (\theta_B - \theta_G - \Delta)x_2^P(\theta^{BG}) \qquad (A.43)$$

$$w_2^{1,P}(\theta^{GB}) = (\theta_G - \epsilon)x_2^P(\theta^{GB}) + (\theta_B - \theta_G)x_2^P(\theta^{BB}) \qquad (A.44)$$

$$w_2^{1,P}(\theta^{BG}) = (\theta_B - \epsilon - \Delta)x_2^P(\theta^{BG})$$

$$w_2^{n,P}(\theta^{BB}) = (\theta_B - \epsilon)x_2^P(\theta^{BB}) \qquad n = 1,2$$

$$w_2^{2,P}(\theta^{GG}) = (\theta_G - \epsilon)x_2^P(\theta^{GG}) + (\theta_B - \theta_G - \Delta)x_2^P(\theta^{GB}) \qquad (A.47)$$

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22 Each constraint for the second-period analysis is written as an ex-post constraint. This assumption could be acceptable because agents may understand each other's ability by working together in the first period.

$$w_2^{2,P}(\theta^{BG}) = (\theta_G - \epsilon)x_2^P(\theta^{BG}) + (\theta_B - \theta_G)x_2^P(\theta^{BB}) \quad (A.48)$$
$$w_2^{2,P}(\theta^{GB}) = (\theta_B - \epsilon - \Delta)x_2^P(\theta^{GB})$$

Since the principal does not distinguish each agent's type at all in the first period, the principal's problem in the first period is formalized as follows.

$$\max_{w_1, x_1} \sum_{ij} p_{ij} \left[b(x_1) - w_1 - w_1 + \delta \left\{ b\left(x_2^P(\theta^{ij}) \right) - w_2^{1,P}(\theta^{ij}) - w_2^{2,P}(\theta^{ij}) \right\} \right] \quad (A.50)$$

$$\text{s.t.} \quad \sum_j \frac{p_{Gj}}{p} \left[w_1 - \theta_G x_1 + \delta \left\{ w_2^{1,P}(\theta^{Gj}) - (\theta_G - \epsilon)x_2^P(\theta^{Gj}) \right\} \right] \geq 0 \quad (A.51)$$

$$\sum_j \frac{p_{Bj}}{1-p} \left[w_1 - \theta_B x_1 + \delta \left\{ w_2^{1,P}(\theta^{Bj}) - \theta_2^1 x_2^P(\theta^{Bj}) \right\} \right] \geq 0 \quad (A.52)$$

$$\sum_i \frac{p_{iG}}{p} \left[w_1 - \theta_G x_1 + \delta \left\{ w_2^{2,P}(\theta^{iG}) - \theta_G x_2^P(\theta^{iG}) \right\} \right] \geq 0 \quad (A.53)$$

$$\sum_i \frac{p_{iB}}{1-p} \left[w_1 - \theta_B x_1 + \delta \left\{ w_2^{2,P}(\theta^{iB}) - \theta_2^2 x_2^P(\theta^{iB}) \right\} \right] \geq 0 \quad (A.54)$$

Solving the above, the first period's offer is characterized as follows.

$$b'(x_1^P) = \theta_B + \theta_B \quad (A.55)$$
$$w_1^P = \theta_B x_1^P \quad (A.56)$$

Feasibility of Fully Separating

Fully separating is feasible as long as the incentive-compatibility constraint for a bad type is satisfied. From (A.16),

$$\frac{p_{BG}}{1-p}\left[(\theta_B - \theta_G)\{x_1^S(\theta^{BG}) - x_1^S(\theta^{GG})\} + \delta(\theta_B - \theta_G - \Delta)\{x_2^{FB}(\theta^{BG}) - x_2^{FB}(\theta^{GG})\}\right]$$
$$+ \frac{p_{BB}}{1-p}\left[(\theta_B - \theta_G)\{x_1^S(\theta^{BB}) - x_1^S(\theta^{GB})\} + \delta(\theta_B - \theta_G)x_2^{FB}(\theta^{BB})\right] \leq 0 \quad (A.57)$$

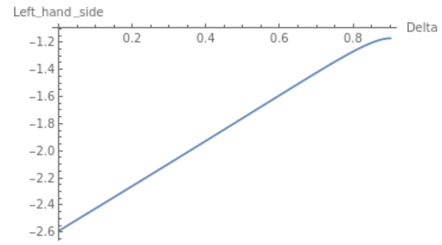
Remember that $\delta(\theta_B - \theta_G)x_2^{FB}(\theta^{BB})$ is a part of a rent for a good-type agent in the first period when his teammate is bad, and this rent is non-negative. The above inequality (A.57) suggests that if a rent for a good-type agent becomes sufficiently large, then fully separating might not be feasible. The intuition is as follows: If the principal provides sufficiently large rent to the agent who chooses to report a good type in the first period, then not only a good-type agent but also a bad-type agent prefers to report a good type in the first period.

Since the main focus of this model analysis is the impact of learning, I investigate how does learning (the parameter Δ) impact the feasibility of the full-separation contract using numerical examples. Specifically, I use the following two sets of parameters.

The first set of parameters is $(p = 0.3,\ \delta = 1,\ \theta_G = 0.1,\ \theta_B = 1,\ \epsilon = 0.01)$. Figure 7 shows the left-hand side's value of inequation (A.57) depending on the value of Δ. It shows that inequation (A.57) is always satisfied for any possible value of Δ under these parameters. Figure 7 also shows that the more Δ increases the more the left-hand side's value gets close to the boundary of inequation (A.57).

Figure 7

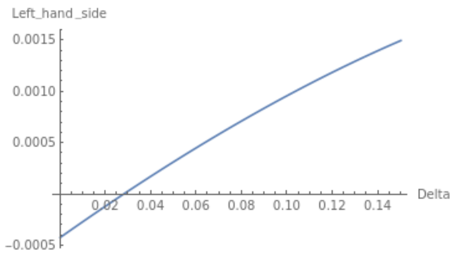
Feasibility of Full-separation when $\boldsymbol{p = 0.3,\ \delta = 1,\ \theta_G = 0.1,\ \theta_B = 1,\ \epsilon = 0.01}$



The second set of parameters is $(p = 0.3,\ \delta = 1,\ \theta_G = 0.7,\ \theta_B = 1,\ \epsilon = 0.01)$. Under these parameters, inequation (A.57) is violated for some possible values of Δ as shown in Figure 8. Figure 8 shows that the more Δ increases the less the feasibility constraint is likely to be satisfied under these parameters.

Figure 8

Feasibility of Full-separation when $\boldsymbol{p = 0.3,\ \delta = 1,\ \theta_G = 0.7,\ \theta_B = 1,\ \epsilon = 0.01}$



Comparing Contracts

I denote the present value of the principal's expected payoff for two periods under each contract as, Π_{FB}, Π_{SEP}, and Π_{POOL}. Then, in the region where full separation is feasible, Π_{SEP} always outperforms Π_{POOL}. Thus, as long as it is feasible, the fully separating short-term contract is the second-best contract.

$$\Pi_{FB} = \sum_{ij} p_{ij}[\, b\left(x_1^{FB}(\theta^{ij})\right) - w_1^{1,FB}(\theta^{ij}) - w_1^{2,FB}(\theta^{ij})$$

$$+\delta\left\{b\left(x_2^{FB}(\theta^{ij})\right) - w_2^{1,FB}(\theta^{ij}) - w_2^{2,FB}(\theta^{ij})\right\}] \qquad (A.58)$$

$$\Pi_{SEP} = \sum_{ij} p_{ij} \left[b\left(x_1^S(\theta^{ij})\right) - w_1^{1,S}(\theta^{ij}) - w_1^{2,S}(\theta^{ij}) \right.$$

$$\left. + \delta \left\{ b\left(x_2^{FB}(\theta^{ij})\right) - w_2^{1,FB}(\theta^{ij}) - w_2^{2,FB}(\theta^{ij}) \right\} \right] \qquad (A.59)$$

$$\Pi_{POOL} = b(x_1^P) - w_1^P - w_1^P + \delta \sum_{ij} p_{ij} \left[b\left(x_2^P(\theta^{ij})\right) - w_2^{1,P}(\theta^{ij}) - w_2^{2,P}(\theta^{ij}) \right] \quad (A.60)$$

In the following, I numerically compare each contract. Specifically, I use two sets of parameters which I also used in the above.

Let me start with the first set of parameters ($p = 0.3,\ \delta = 1,\ \theta_G = 0.1,\ \theta_B = 1,\ \epsilon = 0.01$). As shown in Figure 7, the full-separation is always feasible under these parameters. Figure 9 shows the value of Π_{SEP} and Π_{POOL} depending on the value of Δ. It shows that the full-separation contract outperforms the full-pooling contract if Δ is lower than a certain value. If Δ becomes larger than that certain value, the full-pooling contract outperforms the full-separation contract.

In the case of the second set of parameters ($p = 0.3,\ \delta = 1,\ \theta_G = 0.7,\ \theta_B = 1,\ \epsilon = 0.01$), the full-separation contract is not feasible in a certain region. Within the region where the full-separation contract is feasible, Figure 10 shows that the full-separation contract outperforms the full-pooling contract.

Figure 9

Π_{SEP} and Π_{POOL} when $p = 0.3,\ \delta = 1,\ \theta_G = 0.1,\ \theta_B = 1,\ \epsilon = 0.01$

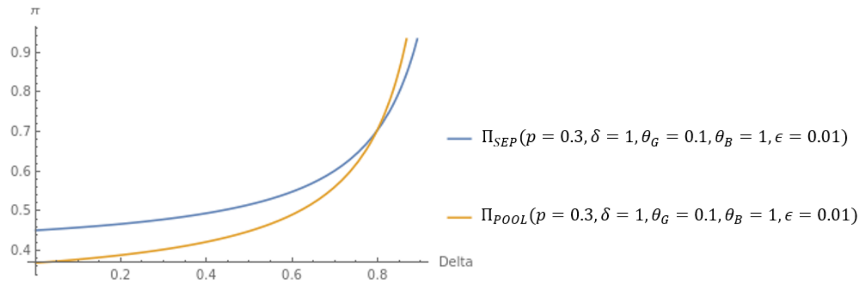
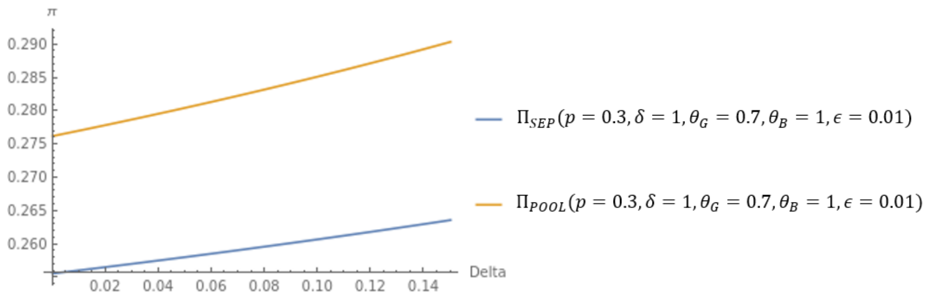


Figure 10

Π_{SEP} and Π_{POOL} when $p = 0.3,\ \delta = 1,\ \theta_G = 0.7,\ \theta_B = 1,\ \epsilon = 0.01$



B. Equilibria

B.1. *ONE* with Self-regarding Individuals

Suppose that the teammate reports their type truthfully. Let the skilled worker's expected utility when they select *Much* be $u_1(Skilled, Much)$. Then,

$$u_1(Skilled, Much) = \frac{2}{3} \times 560 + \frac{1}{3} \times 615 > \frac{2}{3} \times 500 + \frac{1}{3} \times 427 = u_1(Skilled, Less) \quad (B.1)$$

Thus, skilled workers strictly prefer *Much*. Likewise, newcomers strictly prefer *Less* as shown in the following.

$$u_1(New, Much) = \frac{2}{3} \times (-190) + \frac{1}{3} \times 495 < 380 = u_1(New, Less) \qquad (B.2)$$

Hence, separation is an equilibrium in this case.

B.2. *NOLEARN* with Self-regarding Individuals

First, I confirm that the separation is not an equilibrium in this case. The analyses are conducted backward.

In the second period, suppose that the first period achieved the separation. In this situation, all agents face the first-best offer for their true types. Then, the agents' expected utility is the same regardless of their true type. The agents' expected utility when they select *Accept* is 440, and this is strictly larger than that in case they select Reject. Thus, every agent selects *Accept* in the second period.

In the first period, the expected utility of skilled workers evaluated at the time of the first period[23] is

$$u_1(Skilled, Much)_{SEP} = \frac{2}{3}(560 + 440) + \frac{1}{3}(615 + 440)$$
$$< \frac{2}{3}(500 + 773) + \frac{1}{3}(427 + 628) = u_1(Skilled, Less)_{SEP} \qquad (B.3)$$

Thus, skilled workers strictly prefer *Less*, and separation cannot be an equilibrium.

Next, I confirm that the pooling is an equilibrium. Suppose that every agent selects *Less* in the first period. In this situation, all agents face plan D in the second period. Skilled workers' expected utility when they select *Accept* is 628 and is strictly greater than that when they select *Reject*. Moreover, newcomers' expected utility when they select *Accept* is 440 and is also strictly greater than what they can obtain when they select *Reject*. From the above, every agent strictly prefers *Accept* in the second period.

---

[23] For simplicity, I assume the common discount factor as 1.

In the first period, the expected utility of skilled workers evaluated at the time of the first period is

$$u_1(Skilled, Much)_{POOL} = \frac{2}{3}(615 + 440) + \frac{1}{3}(615 + 440)$$

$$= \frac{2}{3}(427 + 628) + \frac{1}{3}(427 + 628) = u_1(Skilled, Less)_{POOL} \qquad (B.4)$$

Thus, skilled workers weakly prefer *Less*.

Whereas, newcomers strictly prefer *Less* as shown in the following.

$$u_1(New, Much)_{POOL} = \frac{2}{3}(495 - 330) + \frac{1}{3}(495 - 330)$$

$$< \frac{2}{3}(380 + 440) + \frac{1}{3}(380 + 440) = u_1(New, Less)_{POOL} \qquad (B.5)$$

Altogether, the pooling is an equilibrium in this case.

B.3. *LEARN* with Self-regarding Individuals

Suppose that every agent reports their type truthfully in the first period. In this case, all agents face the first-best offer for their true type, and such a contract renders 440 when they select *Accept*. Thus, all agents strictly prefer Accept in the second period.

In the first period, skilled workers' expected utility is,

$$u_1(Skilled, Much)_{SEP} = \frac{2}{3}(560 + 440) + \frac{1}{3}(615 + 440)$$

$$> \frac{2}{3}(500 + 440) + \frac{1}{3}(427 + 628) = u_1(Skilled, Less)_{SEP} \qquad (B.6)$$

Therefore, skilled workers strictly prefer *Much*. On the other hand, newcomers strictly prefer *Less*.

$$u_1(New, Much)_{SEP} = \frac{2}{3}(-190 + 440) + \frac{1}{3}(495 + 0)$$

$$< \frac{2}{3}(380 + 628) + \frac{1}{3}(380 + 440) = u_1(New, Less)_{SEP} \qquad (B.7)$$

Hence, separation is an equilibrium in this case.

B.4. *ONE* with Inequity-averse Individuals

Suppose the agents have an inequity-averse utility function, as defined in equation (1).

Skilled workers' expected utility when they select *Much* is,

$$u_1(Skilled, Much) = \frac{2}{3}[560] + \frac{1}{3}[615 - 235\beta] \qquad (B.8)$$

Whereas, their expected utility when they select *Less* is,

$$u_1(Skilled, Less) = \frac{2}{3}[500 - 115\alpha] + \frac{1}{3}[427 - 47\beta] \qquad (B.9)$$

Because $\beta < 1$, the value of equation (B.8) is strictly greater than that of equation (B.9) regardless of the pair of α and β. This implies that skilled workers always strictly prefer *Much* regardless of the extent of their inequity aversion.

Likewise, newcomers' expected utility when they select either *Much* or *Less* is,

$$u_1(New, Much) = \frac{2}{3}[-190 - 750\alpha] + \frac{1}{3}[495 - 115\beta] \qquad (B.10)$$

$$u_1(New, Less) = \frac{2}{3}[380 - 235\alpha] + \frac{1}{3}[380] \qquad (B.11)$$

Since both α and β are strictly greater than zero, the value of equation (B.11) is always greater than that of equation (B.10). Thus, newcomers strictly prefer *Less*, regardless of their inequity aversion.

B.5. *NOLEARN* with Inequity-averse Individuals

First, I examine the separation equilibrium.

As in the above, I start with the analysis on the second period's on-the-pass-of-the-equilibrium behavior. Suppose every agent reports their type truthfully in the first period. Then, in the second period, all agents' expected utility when they select *Accept* is simply equal to 440. This is because everyone earns the same payoff and there is no room for the parameters α nor β impacts on. Thus, everyone strictly prefers *Accept*.

In the first period, skilled workers' expected utility when they select *Much* is,

$$u_1(Skilled, Much)_{SEP} = \frac{2}{3}[560 + 440] + \frac{1}{3}[615 - 235\beta + 440] \qquad (B.12)$$

Whereas, their expected utility when they select *Less* differs depending on the second period's off-the-pass-of-the-equilibrium behavior. In the following, I analyze the condition when skilled workers prefer *Much* in each case.

[Case1: $\alpha \leq \frac{440}{333}$]

In this case, both types of agents select *Accept* in the second period. Thus, the skilled workers' expected utility when they select *Less* is,

$$u_1(Skilled, Less)_{SEP} = \frac{2}{3}[500 - 115\alpha + 773 - 333\beta] + \frac{1}{3}[427 - 47\beta + 628 - 188\beta] \quad (\mathrm{B.13})$$

Comparing (B.12) and (B.13), skilled workers weakly prefer *Much* as long as the following equation (B.14) is satisfied. Otherwise, they strictly prefer *Less*.

$$\beta \geq -\frac{115}{333}\alpha + \frac{91}{111} \qquad (B.14)$$

[Case2: $\frac{440}{333} < \alpha \leq \frac{110}{47}$]

In this case, newcomers select *Accept* in the second period likewise in Case 1. In contrast, skilled workers who selected on-the-pass-of-the-equilibrium behavior, *Much*, in the first period refuse to work in the second period. They select *Reject* because of their non-negligible envy. Since they will suffer sufficient envy over their teammate who took off-the-pass-of-the-equilibrium behavior in the first period, they prefer *Reject*. Thus, the skilled workers' expected utility when they select *Less* is,

$$u_1(Skilled, Less)_{SEP} = \frac{2}{3}[500 - 115\alpha + 0]$$
$$+\frac{1}{3}[427 - 47\beta + 628 - 188\beta] \qquad (B.15)$$

Comparing (B.12) and (B.15), skilled workers weakly prefer *Much* as long as the following equation (B.16) is satisfied. From the assumption, $\alpha \geq 0$. Thus, (B.16) is always satisfied.

$$\alpha \geq -\frac{100}{23} \qquad (B.16)$$

[Case3: $\frac{110}{47} < \alpha$]

In this case, skilled workers who selected on-the-pass-of-the-equilibrium behavior, *Much*, in the first period select *Reject* as in Case 2. In addition, newcomers who selected on-the-pass-of-the-equilibrium also become to select *Reject*. This is because of they will suffer non-negligible envy if they select *Accept*. Thus, the skilled workers' expected utility when they select *Less* is,

$$u_1(Skilled, Less)_{SEP} = \frac{2}{3}[500 - 115\alpha + 0] + \frac{1}{3}[427 - 47\beta + 0] \qquad (B.17)$$

Comparing (B.12) and (B.17), skilled workers weakly prefer *Much* as long as the following equation (B.18) is satisfied.

$$\beta \leq \frac{115}{94}\alpha + \frac{407}{47} \qquad (B.18)$$

Now we move on to the analyses of newcomers' behavior. Newcomers' on-the-pass-of-the-equilibrium expected utility is,

$$u_1(New, Less)_{SEP} = \frac{2}{3}[380 - 235\alpha + 440] + \frac{1}{3}[380 + 440] \qquad (B.19)$$

Their off-the-pass-of-the-equilibrium expected utility differs depending on their envy parameters. If the envy parameter α becomes sufficiently large, then the newcomers who took off-the-pass-of-the-equilibrium behavior in the first period prefer to reject in the second period. Hence,

$$u_1(New, Much)_{SEP} \begin{cases} = \frac{2}{3}[-190 - 750\alpha + 0] + \frac{1}{3}[495 - 115\beta + 107 - 333\alpha] & ,\text{if } \alpha \leq \frac{107}{333} \\ = \frac{2}{3}[-190 - 750\alpha + 0] + \frac{1}{3}[495 - 115\beta] & ,otherwise \end{cases} \qquad (B.20$$

Since $\alpha, \beta > 0$, the value of the equation (B.19) is always greater than that of the equation (B.20). Therefore, newcomers strictly prefer *Less* regardless of their inequity averseness.

From the above, separation is an equilibrium if at least either the equation (B.14) or (B.18) is satisfied. Otherwise, separation is not an equilibrium.

Next, I confirm how the inequity aversion impacts on the pooling equilibrium.

Let me begin with the analysis of the second period. Suppose every agent selects *Less* in the first period and plan D is offered in the second period.

Skilled workers' expected utility when they select *Accept* differs depending on the type of their teammate. Let a skilled worker's expected utility when he selects *Accept* and his teammate is a newcomer be $u_2(Skilled, Accept, New)$. Then, each type of agent's on-the-pass-of-the-equilibrium payoff in the second period is as follows.

$$u_2(Skilled, Accept, Skilled)_{POOL} = 628 \qquad (B.21)$$

$$u_2(Skilled, Accept, New)_{POOL} = 628 - 188\beta \qquad (B.22)$$

$$u_2(New, Accept, Skilled)_{POOL} = 440 - 188\alpha \qquad (B.23)$$

$$u_2(New, Accept, New)_{POOL} = 440 \qquad (B.24)$$

Since $\beta < 1$, the value of equation (B.22) is always strictly greater than zero. The value of the equation (B.23) becomes weakly greater than zero if,

$$\alpha \leq \frac{110}{47} \qquad (B.25)$$

Based on (B.21) and (B.22), skilled workers always select *Accept* on the pass of the equilibrium. Based on (B.24), newcomers who paired with newcomers also always select *Accept* on the pass of the equilibrium. On the other hand, newcomers who paired with skilled workers select *Accept* if the equation (B.25) is satisfied, otherwise, they select *Reject*.

Before moving to the first period's analysis, I examine off-the-pass-of-the-equilibrium behavior at the second period. If skilled workers deviate and select *Much*, then both agents select *Accept* as long as the following condition (B.26) is satisfied. (B.26) is a condition when the deviator who paired with a skilled worker attains utility which is weakly greater than zero. Since the deviator's teammate always prefer *Accept* and also the deviator himself prefer *Accept* as long as he is paired with a newcomer, (B.26) is the only condition we need to care about.

$$\alpha \leq \frac{440}{333} \tag{B.26}$$

Besides, if a newcomer selects *Much* and he is paired with a skilled worker, then both team members select *Accept* if,

$$\alpha \leq \frac{107}{666} \tag{B.27}$$

If a newcomer selects *Much* and he is paired with a newcomer, then both of team members select *Accept* if,

$$\alpha \leq \frac{107}{333} \tag{B.28}$$

Next I start the first period's analysis. First, I derive conditions when skilled workers prefer *Less* in each case. Then, I also derive conditions when newcomers prefer *Less* in each case.

[Case1: $0 < \alpha \leq \frac{440}{333}$]

In this case, skilled worker's on-the-pass-of-the-equilibrium expected utility is,

$$u_1(Skilled, Less)_{POOL} = \frac{2}{3}[427 + 628] + \frac{1}{3}[427 - 47\beta + 628 - 188\beta] \tag{B.29}$$

Their off-the-pass-of-the-equilibrium expected utility is,

$$u_1(Skilled, Much)_{POOL} = \frac{2}{3}[615 - 115\beta + 440 - 333\alpha] + \frac{1}{3}[615 - 235\beta + 440] \tag{B.30}$$

Comparing (B.29) and (B.30), then skilled workers always strictly prefer *Less* in this case.

[Case2: $\frac{440}{333} < \alpha \leq \frac{110}{47}$]

In this case, skilled worker's on-the-pass-of-the-equilibrium expected utility is the same as (B.29).

Their off-the-pass-of-the-equilibrium expected utility is,

$$u_1(Skilled, Much)_{POOL} = \frac{2}{3}[615 - 115\beta + 0] + \frac{1}{3}[615 - 235\beta + 440] \tag{B.31}$$

Comparing (B.29) and (B.31), then skilled workers always strictly prefer *Less* in this case.

[Case3: $\frac{110}{47} < \alpha$]

In this case, skilled worker's on-the-pass-of-the-equilibrium expected utility is,

$$u_1(Skilled, Less)_{POOL} = \frac{2}{3}[427 + 628] + \frac{1}{3}[427 - 47\beta + 0] \qquad (B.32)$$

Their off-the-pass-of-the-equilibrium expected utility is the same as (B.31).

Comparing (B.32) and (B.31), then skilled workers prefer *Less* as long as the following (B.33) is satisfied.

$$\beta \geq -\frac{252}{418} \qquad (B.33)$$

By the assumption, $\beta > 0$. Thus, (B.33) is always satisfied.

From the above analyses for Case 1 to Case 3, skilled workers always prefer *Less*.

Now we move on to the analysis on the newcomers' behavior.

[Case1: $0 < \alpha \leq \frac{107}{666}$]

In this case, newcomer's on-the-pass-of-the-equilibrium expected utility is,

$$u_1(New, Less)_{POOL} = \frac{2}{3}[380 - 47\alpha + 440 - 188\alpha] + \frac{1}{3}[380 + 440] \qquad (B.34)$$

Their off-the-pass-of-the-equilibrium expected utility is

$$u_1(New, Much)_{POOL} = \frac{2}{3}[495 - 5\alpha + 107 - 666\alpha] + \frac{1}{3}[495 - 115\beta + 107 - 333\alpha] \quad (B.35)$$

Comparing (B.34) and (B.35), then skilled workers always prefer *Less.*

[Case2: $\frac{107}{666} < \alpha \leq \frac{107}{333}$]

In this case, newcomer's on-the-pass-of-the-equilibrium expected utility is the same as (B.34).

Their off-the-pass-of-the-equilibrium expected utility is

$$u_1(New, Much)_{POOL} = \frac{2}{3}[495 - 5\alpha] + \frac{1}{3}[495 - 115\beta + 107 - 333\alpha] \qquad (B.36)$$

Comparing (B.34) and (B.36), then skilled workers prefer *Less* as long as the following (B.37) is satisfied.

$$\beta \geq \frac{127}{115}\alpha - \frac{868}{115} \tag{B.37}$$

Since $\frac{107}{666} < \alpha \leq \frac{107}{333}$ and $\beta > 0$, (B.37) is always satisfied in this case.

[Case3: $\frac{107}{333} < \alpha \leq \frac{110}{47}$]

In this case, newcomer's on-the-pass-of-the-equilibrium expected utility is the same as (B.34).

Their off-the-pass-of-the-equilibrium expected utility is,

$$u_1(New, Much)_{POOL} = \frac{2}{3}[495 - 5\alpha] + \frac{1}{3}[495 - 115\beta] \tag{B.38}$$

Comparing (B.34) and (B.38), then skilled workers prefer *Less* as long as the following (B.39) is satisfied.

$$\beta \geq 4\alpha - \frac{195}{23} \tag{B.39}$$

[Case4: $\frac{110}{47} < \alpha$]

In this case, newcomer's on-the-pass-of-the-equilibrium expected utility is,

$$u_1(New, Less)_{POOL} = \frac{2}{3}[380 - 47\alpha + 0] + \frac{1}{3}[380 + 440] \tag{B.40}$$

Their off-the-pass-of-the-equilibrium expected utility is the same as (B.38).

Comparing (B.40) and (B.38), then skilled workers prefer *Less* as long as the following (B.41) is satisfied.

$$\beta \geq \frac{84}{115}\alpha - \frac{19}{23} \tag{B.41}$$

The above results are summarized in Figure 2.

B.6. *LEARN* with Inequity-averse Individuals

Suppose every agent reports their type truthfully in the first period. Then, as discussed in section B.5, all agents' expected utility when they select *Accept* is 440. Therefore, everyone strictly prefers *Accept* in the second period.

Skilled workers' expected utility depending on their choice in the first period is,

$$u_1(Skilled, Much) = \frac{2}{3}[560 + 440] + \frac{1}{3}[615 - 235\beta + 440] \qquad (B.42)$$

$$u_1(Skilled, Less) = \frac{2}{3}[500 - 115\alpha + 440] + \frac{1}{3}[427 - 47\beta + 628] \qquad (B.43)$$

Since $\alpha \geq \beta$, the value of the equation (B.42) is always greater than that of the equation (B.43). Therefore, skilled workers strictly prefer *Much* regardless of their inequity averseness.

Similarly, newcomers' expected utility depending on their decision in the first period is,

$$u_1(New, Much) = \frac{2}{3}[-190 - 750\alpha + 440] + \frac{1}{3}[495 - 115\beta + 0] \qquad (B.44)$$

$$u_1(New, Less) = \frac{2}{3}[380 - 235\alpha + 440] + \frac{1}{3}[380 + 440] \qquad (B.45)$$

Since $\alpha, \beta > 0$, newcomers strictly prefer *Less* regardless of their inequity averseness.

C. An Experimental Procedure for Measurement of Inequity Averseness

I measured the inequity-aversion parameters using the BDM mechanism (Becker et al., 1964). In this experiment, participants were randomly matched as a pair. This experiment consists of two parts. The first part is for the measurement of α, and the latter one is for measurement of β.

In the first part, each participant answered the following 11 binary-choice problems.

FIGURE 11

Choice Problems for Measuring the Preference Parameter of Envy

I measured α based on the following equation.

$$\alpha = \frac{150 - SwitchingPoint_{\alpha}}{100} \qquad (C.1)$$

$SwitchingPoint_{\alpha}$ is identified as the minimum value where participants select the right-hand-side alternative. For participants who have more than two kinks in their choice behavior, I do not define α and let it be a missing value.

In the latter part, I measure β using a similar procedure. Figure 12 shows 11 binary-choice problems in this section. β is measured using equation (C.2). The definition of $SwitchingPoint_{\beta}$ is similar to that of $SwitchingPoint_{\alpha}$.

$$\beta = \frac{250 - SwithchingPoint_{\beta}}{100} \qquad (C.2)$$

FIGURE 12

Choice Problems for Measuring the Preference Parameter of Guilt

When every participant finished answering the above choice problems, one out of 22 problems was randomly selected. In addition, within each pair, either one participant was randomly selected. Based on the selected participant's answer at the selected problem, each participant's rewards from this task were determined.