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IMPROVING COORDINATION AND COOPERATION THROUGH COMPETITION

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Abstract

We use game theory and experimental economics approaches to analyze the relationships between corporate culture and the persistent performance differences among seemingly similar enterprises. First, we show that competition leads to higher minimum effort levels in the minimum effort coordination game. This implies that, organizations with competitive institutional design are more likely to have better coordination, hence better performance outcome. Furthermore, we show that organizations with better coordination also lead to higher rates of cooperation in the prisoner's dilemma game. This supports the theory that the high-efficiency culture developed in coordination games act as a focal point for the outcome of subsequent prisoner's dilemma game. In turn, we argue that these endogenous features of culture developed from coordination and cooperation can help explain the persistent performance differences.

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Improving Coordination and Cooperation Through Competition *

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1 Introduction

Industrial, labor, and organizational economists are intrigued by the existence of persistent performance differences (PPD) among seemingly similar enterprises (SSE). Many empirical researches demonstrated that performance differences do exist, whether measured in productivity or profit in various sectors of industry. These results are prevalent between and within countries and even at the more narrow level of 5-digit industries. For example, there is a 156% difference in productivity between the top 10 and bottom 10 decile in UK manufacturing industries (Disney, Haskel, and Heden 2003), corporate effects alone can explain up to 18% of variance in profit in the US (Brush, Bromiley, and Hendrickx (1999) and Roquebert, Phillips, and Westfall (1996)), and initial defect rates varies by factor of five in the semiconductor manufacturing industry (Macher and Mowery 2003). We refer the readers to an excellent survey paper by Gibbons, Henderson, Repenning, and Sterman (In Press) for a more detailed discussion of empirical results regarding performance differences.

Because an organization is in essence a repeated game, the folk theorem argues that any outcome we observe is just different equilibria reached by the organizations. This paper takes it one step further and states how certain equilibrium results may occur. Various studies explained some of the reasoning behind the PPD among SSE. For example, in addition to Gibbons, Henderson, Repenning, and Sterman (In Press), Bloom and van Reenen (2007) presents well-studied empirical data which argues that management skills are part of the explanation for PPD.[1] However, management skill is just another form of

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[1] In fact, they detail other interesting results. US companies are usually better managed, competition leads to better management, and family-owned firms that pass down control to the eldest son usually do worse.

labor input. Something that is more general and endogenous to the firm is *corporate culture*. Our paper shows the importance of culture that is developed from coordination and cooperation among the individuals which can help explain the performance differences among seemingly similar enterprises.

Corporations evolve through different phases as they develop. At the initial stage, the coordination and the cooperation phases have long-lasting effects on corporate performance. Consider the following thought exercise: At the initial phase, an organization deals with many coordination problems. Members in the organization may come from different social cultures, experiences, ethics, linguistics, or educational backgrounds. Is working overtime expected? Should people work individually or in teams? Is email an acceptable form of communication? It may take some time before the organization establishes a particular corporate culture. We denote this phase as the coordination phase. After corporate culture matures, individuals can choose to cooperate or to defect for self-benefit. For example, if email has become an acceptable form of communication even in urgent matters, one employee may deny receiving it when it is to his advantage to do so. Or the culture could be such that the management usually gives proper credit to subordinates, but takes sole credit when an extraordinary idea is suggested. We denote this as the cooperation phase. Our experiment replicates a similar time line. We show, in a laboratory setting, that we can endogenously generate different corporate cultures for a group in the coordination phase by using different organizational structures, and predict their individual behavior in the cooperation phase.

In short, our experiment shows the following two main results. First, to show that organizations with competitive institutional design are more likely to have better coordination, and, in turn, better performance outcome, we show that that competition leads to higher minimum effort levels in the minimum effort coordination game. Next, to support the theory that the high-efficiency culture developed in coordination games acts as a focal point in the cooperation phase, we show that organizations with higher minimum effort in the coordination game also have a higher rate of cooperation in the prisoner's dilemma game, and, in turn, a better performance outcome. These two endogenous features have significant performance differences in our experiment.

1.1 Corporate Culture

Corporate culture is broadly defined as "the specific collection of values and norms that are shared by people and groups in an organization and that control the way they interact with each other..." (Hill and Jones 2001). Corporate culture is undeniably prevalent and influential. Many organizational theorists have studied the psychological and sociological impacts and the measurements of corporate culture (e.g., Cameron and Quinn (2005), Kotter and Haskett (1992), Sorensen (2002)) and some have studied formation of norms (Bettenhausen and Murnighan (1991), and Bettenhausen and Murnighan (1985)). Southwest Airline once used an ad depicting a multiple choice exam which question asked "A customer forgets to pack extra baby formula and has an hour layover in Albuquerque.

What do you do?" (Figure 1). The choices of answers were a) Wish her luck, b) Suggest an excellent restaurant across town, or c) Go find some formula and pick up a coloring book for her older child. Answer c) is going beyond what is expected of an employee at a typical airline but it portrays that Southwest airline's culture is to do exactly that: go beyond what is expected (Camerer and Malmendier 2007).

Another example is the culture at the California Institute of Technology (Caltech). Although not a corporation in the usual sense, Caltech operates under a honor code system that states that a student will not take advantage of another Caltech member. Students from other universities may have hard time grasping the concept and how it is enforced. However, Caltech's honor code system works extremely well; students are usually given take home exams that may be timed or un-timed, closed or open book, but ultimately self administered.[2] Lastly, one of the most important cultural understandings of the US military is the retrieval of US soldiers. If there is even a remote chance that a fellow soldier is alive, the soldiers do everything within their means to save the fellow soldier, even if it threatens additional lives. This type of culture helped develop the US military to be the most elite all-volunteer military force in the world. Consider for a second that the corporate culture was to leave the soldier behind enemy lines. How dedicated would the soldier be in dangerous missions?

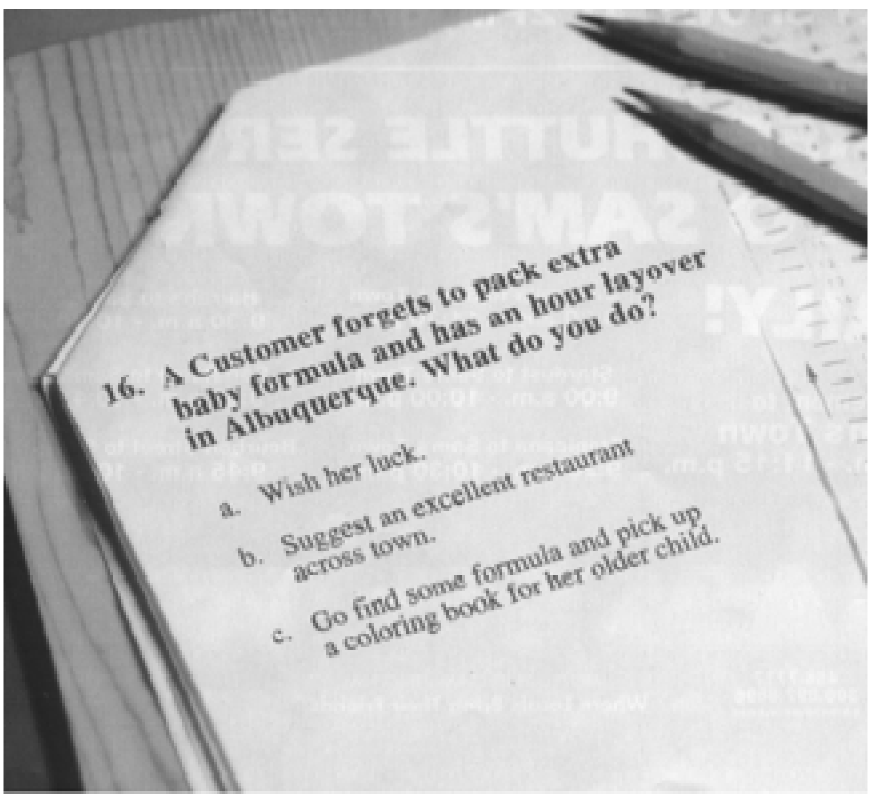

Figure 1: Ad from Southwest Airline Inflight Magazine

[2]Having done my undergrad education at another university and being an economist, I too was very surprised by Caltech's system. However, I too saw myself self-enforcing the honor code system.

Although it is not as widely studied nor as mature as it is in management science, economists have begun to acknowledge that corporate culture is an integral part of studying the theory of firm. Culture is studied indirectly by using a relational contract in a repeated game theory framework (Baker, Gibbons, and Murphy 2002). It is also studied in a direct manner: Kreps (1990) emphasized the culture as a focal point (Schelling 1960), Cremer (1993) and Cremer (1986) viewed culture as an investment, and Hermalin (2001) argued culture as an efficiency improving mechanism. Hermalin (In Press) provides a helpful literature review of where the economic field is in terms of corporate culture. Furthermore, experimental economists contributed to a complementary ways of studying corporate culture. Feiler and Camerer (In Press) and Weber and Camerer (2003) have conducted an experimental study of how firms may endogenously create codes to communicate and how mergers will create a disruption in production due to "language barrier" in codes.

Although corporate cultures can be seen as a firm-specific technology, it cannot be easily transferred or purchased even in similar industries.[3] These literature all point to the crucial roles corporate culture plays in affecting corporate performance. First, it is a cheap way of increasing productivity. For example, having a well-implemented culture of "do no evil", like Google, Inc., can reduce principal's monitoring cost. Second, it provides us researchers with an equilibrium prediction. With a good understanding of the culture, we can better predict whether the members in the organization will be more self-serving or cooperative.

1.2 Overview of the Paper

In this paper, we use both game theory and experimental economics approaches to demonstrate two relationships between corporate culture and PPD among SSE. First, we show that competition leads to better coordination in the minimum effort coordination game: organizations with institutional design that induces competition are more likely to have better coordination. This result is consistent with previous findings where competition provides higher performance, such as in the tournament structure (Lazear and Rosen 1981) or managerial performance (Bloom and van Reenen 2007). Furthermore, we show that stronger coordination also leads to higher rate of cooperation in the prisoner's dilemma game, even when non-cooperation is individually beneficial. In sum, we show that high-efficiency culture developed in coordination games act as a focal point for the outcome of a subsequent prisoner's dilemma game.

We operationalize minimum effort coordination games as organizations' coordination problems, and prisoner's dilemma game as cooperation problems. We have two experimental treatments for the coordination phase: competitive and non-competitive setting. In the competitive treatment, there are two firms, where firms are independently playing the minimum effort coordination game. In the non-competitive setting, there is only

[3] It is probably harder for a similar industry to adopt since there is a first mover's advantage.

one firm. In both treatments, there are external investors whose payoff is determined by the performance of the firm. Furthermore, the investment linearly increases the payoff for the workers in the firm, and they know the investment prior to any decision making. As will be detailed in the experimental design section, this procedure is done to control for risk-dominance. Our experimental design benefited greatly from Bornstein, Gneezy, and Nagel (2002)'s (BGN) experiment that supports the idea that competition can improve coordination. Three major differences distinguish our research from BGN's. First, as mentioned, we control for risk-dominance in the competition setting. Second, our investment is constructed endogenously and is more aligned with the principal-agent framework. Lastly, both the competitive and non-competitive setting has investors in our design, providing a way to compare one-firm and two-firm treatments. Our design also benefited from results by Brandts and Cooper (2006) and Hamman, Rick, and Weber (2007) (HRW). Both papers are excellent experimental papers that study the relationship between effort choices and exogenous one-time changes to the payoff function. Here, exogenous change means that the change is not controlled by anyone participating in the experiment. Brandts and Cooper and HRW showed that, after observing coordination failure, periodic and exogenous changes of the payoff function in a non-affine manner[4] to increase the benefits from coordinating (compared to previous period's payoff) improve coordination. Adapting from their studies, our experiment deals with endogenous changes and affine transformations to the payoff function. We show that the effort levels from the competitive setting stochastically dominate the non-competitive setting. Interestingly, the distribution of effort levels from the one-firm treatment is not statistically different from the distribution of effort levels made by the lower performing firm in the competitive setting. Furthermore, even though the experiment was designed so that the investors cannot lose any of their investments, we observe that the investors do not fully invest their endowment in the poor performing firm even in the non-competitive setting. This punishment mechanism does not increase the effort levels.

Similar to Knez and Camerer (2000)'s design, given that the corporation has developed a culture of high levels of coordination, we also find that this induces the agents to be more likely to cooperate even in the one-shot prisoner's dilemma game. Our paper provides a stronger result in that our prisoner's dilemma game is a one-shot game rather than a repeated game. Furthermore, unlike Knez and Camerer (2000), our organization for the coordination game consists of group size strictly greater than 2.[5] When we present the subjects with a prisoner's dilemma game which is played with another member from the group with whom they played the coordination game, cooperation is approximately 30% more likely than defection when there is a higher level of coordination.[6]

[4]A non-affine transformation may change risk-domiance. An affine function is a function that is both concave and convex.

[5]A problem with having a coordination game with group size of 2 is that the individuals coordinate very well. Therefore, Knez's study was not able to get much variation in level of coordination (they all fully coordinated) to genuinely study the relationship between coordination and cooperation.

[6]One caveat we like to acknowledge from the start is that an experiment conducted at an university with group of students cannot fully generalize the complexity of standard organization in the business world. For example, this experiment is done without communication which surely exist in a typical corporation. However, one of the objectives of this paper is to study how the initial equilibrium se-

1.3 Agenda

The paper proceeds as follows. We first introduce the general setup and review of the game of interest. Then we present the experimental design and the main hypotheses. We then follow with detailed analysis in the result section. We finish with a summarizing conclusion.

lection of an organization effects the future selections. When an organization first begins, there is a coordination problem (due to language barrier, cultural differences, jargons, etc.) which becomes an obstacle to communication. One can see this no-communication experiment as an extreme version of that scenario. There have been studies which state that student's behavior at the lab is a good predictor of professional's behavior in these abstract settings (Ball and Cech 1996) but further studies of how the short-run organizational behavior in lab will generalize to the long-run organizational behavior is definitely needed. Experiments are extreme simplifications but that is their advantage. We view experiments as another form of methodology to gain data and insights. By using this controlled and simple environment, we are able to better understand how certain features will effect the organization.

2 General Setup and Review

2.1 Minimum Effort Coordination Game

Minimum effort coordination game (MECG, and also known as the weak-link game) takes the following form: Given N agents, every agent chooses an effort level $e_i \in \{1, 2, ..., M\}$, M finite, with payoff function

$$p_i = \alpha \left(\min_{j \in N} \{e_j\} \right) - \beta(e_i) + \delta \text{ where } \alpha > \beta > 0, \delta \in \mathbb{R} \text{ for all agents } i \in N \quad (1)$$

Best response in this game is for agent i to match the lowest effort from everyone else:

$$e_i = \min_{j \in N \setminus i} \{e_j\}$$

Hence, there are M many pure strategy equilibria: everyone choosing $e_i = 1$, everyone choosing $e_i = 2$ and so on. Let's consider an example of which $M = 7, \alpha = 400, \beta = 200$, and $\delta = 1100$. The game can be then summarized by Table 1.

	Minimum effort of all the agents						
Agent i's effort	7	6	5	4	3	2	1
7	2500	2100	1700	1300	900	500	100
6	-	2300	1900	1500	1100	700	300
5	-	-	2100	1700	1300	900	500
4	-	-	-	1900	1500	1100	700
3	-	-	-	-	1700	1300	900
2	-	-	-	-	-	1500	1100
1	-	-	-	-	-	-	1300

Table 1: Minimum Effort Coordination Game Payoff for Agent i

This game has several features. First off, it has 7 pure strategy Nash Equilibria: $e_i = 1$ $\forall i \in N$, $e_i = 2$ $\forall i \in N$, ..., $e_i = 7$ $\forall i \in N$. An interesting question to address in games with multiple equilibria is the equilibrium selection. However, given this particular game structure with strict Nash Equilibria, many of the standard notions of refinements, such as *trembling hand perfection*, will not help to reduce any equilibria. Using the reasoning of Harsanyi and Selton (1988), we are able to focus on two particularly interesting equilibria: the *payoff dominant equilibrium* and the *risk dominant equilibrium*. Everyone choosing effort level 7 is the payoff dominant equilibrium since this equilibrium pareto dominates all other equilibria. Choosing an effort level 1 is the least-efficient equilibrium but it can be seen as maximizing the worst-case scenario. In terms of Harsanyi and Selten, this equilibrium is the risk dominant equilibrium; by choosing an effort level of 1, the agent minimizes the uncertainty and, in MECG, secures a specific payoff regardless of the actions of other agents. Harsanyi and Selten further argue that payoff dominance should be the first criterion applied.

However, in tacit environment, experiments have shown that people fail to coordinate to a payoff dominant equilibrium. Rather they end up at the risk dominant equilibrium. The leading example is produced by van Huyck, Battalio, and Beil (1990) (VHBB). In VHBB's experiment, participants played the minimum effort coordination game without communication. The only statistics observable by the participant was the minimum effort of the group. The size of the group consisted of 14-16 participants and each were instructed to choose an integer effort level of 1 to 7 with 1 being the risk dominant and 7 being the payoff dominant equilibrium. In this and other similar experiments (See Camerer (2003) for survey), the game generally converges to a minimum effort of 1 by the 5th period when $N > 3$. One of the intuitions behind this experimental result is *strategic uncertainty*. In short, strategic uncertainty is the uncertainty arising from not knowing which equilibrium strategy the other players will implement. The strategic uncertainty increases as the group size increases (N increases) since agents now have more people to consider, and as the number of strategies increase (M increases) since the agent now has more Nash Equilibria to consider.

One of the leading theories of behavior we observe in these experiments is provided by Crawford, who uses the adaptive learning framework to explain the data for VHBB (Crawford 1995). After observing the minimum effort level that is weakly lower than the effort level any one agent has chosen ($e_i = \min_{j \in N \setminus i}\{e_j\}$), the agent uses the new information to update his next period strategy, in turn, converging to a minimum effort level of 1.

Two questions one might ask are 1. what would happen if group size is $N \leq 3$? and 2. if the distribution of choices were available instead of just the minimum effort statistics? VHBB also addresses those two questions. When the group size is small, the participants coordinate very well. However, with a bigger group size, showing the distribution of choices does not improve coordination. This can be because when the group size is small, there is hope in leading by example and being patient. However, when the group size is 'big', seeing the distribution of many low-effort levels is not much of an encouragement.

Many variations of the minimum effort coordination game have shown improvement of minimum effort in addition to the papers pervious mentioned by Bornstein, Gneezy, and Nagel (2002), Brandts and Cooper (2006), and Hamman, Rick, and Weber (2007). For example, Cooper, DeJong, Forsythe, and Ross (1992) showed that having a non-binding pregame communication improves coordination. Even without communication, Weber (2006) provides an experimental result where one slowly grows the organization to improve coordination. Schmidt, Shupp, Walker, and Ostrom (2003) provide experimental data that shows coordination improves when risk dominance is weaker. Furthermore, Cachon and Camerer (1996) showed that people coordinate better when they are charged a fee to participate which leads to losses of money in poor equilibrium (loss-avoidance).

2.2 Prisoner's Dilemma Game

Given the heavy exposure of prisoner's dilemma game, we will not cover the related literature in this paper. However, we briefly touch on the game in the experimental design section.

3 Experimental Design

The experiments were conducted at 2 laboratories: the Social Science Experimental Laboratory (SSEL) at the California Institute of Technology (Caltech), Pasadena, CA, and the California Social Science Laboratory (CASSEL) at the University of California, Los Angeles (UCLA). A total of 128 subjects participated in the experiments. The average performance-based payment was 19USD. All students were registered subjects with SSEL / CASSEL (signed a general consent form) and the experiment was approved by the local research ethics committee at both universities. These labs consist of over 30 working computers divided into cubical setting, which prevents the students from viewing another student's screen.

The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher 2007). The instructions were available both in print as well as on screen for the participants and the Experimenter explained the instructions in detail out-loud. Participants were also given a brief quiz after instruction to insure proper understanding of the game and the software. A sample instruction that was provided to the participants is on author's website.

The subjects were randomly assigned their roles in the experiment and did not change their roles for the entire experiment. Furthermore, no subjects participated in more than one experiment. The identity of the participants as well as their individual decisions were kept as private information. However, each group knew the total investment their group received, their own group's minimum effort (not the other group's effort level), and the investors only knew their own investment level as well as the minimum effort of all the groups. The experiment used fictitious currency called francs and the expected payment for the investors and group members were comparable. The participants were told that the experiment consisted of undetermined number of rounds to prevent end game effect. All participants filled out a survey immediately after the experiment.

Terminology: In terms of terminology, we avoided any priming effects by using neutral language during the experiment. More specifically, we used language such as *groups* and *numbers* instead of *firms* and *effort levels*. For consistency of this paper, we will refer to groups as *firms* and *investors* henceforth. The members in a firm will be called *workers*. However, we can consider these not only as firms but also as different divisions within a firm. In other words, this setting can be applied to both inter- and intra-organization levels. Lastly, we will refer to the number chosen by the subject as *effort level* throughout the paper.

3.1 Two-Firm (Competitive) Treatment

Below is the sequence of the experiment.

1. Investors privately decide on how much to invest in Firm 1 and Firm 2.

2. The workers observe the aggregate investment for their firm.

3. The workers privately select a number between 1 - 7.

4. The minimum number for each firm is shown to the investors along with their current period payoff and total payoff.

5. The workers are shown the minimum number selected with their own firm. In addition, the workers are shown their individual payoff for the current period and the total payoff.

6. The period comes to an end and the next period begins.

7. Experiment concludes at an indefinite period.

We conducted 4 sessions of the two-firm treatment (3 at UCLA and 1 at Caltech). Subjects in the two-firm treatment were divided into three groups: Firm 1, Firm 2, and Investors. Each of the firms had 6 workers and there were total of 4 investors.

Investors: In each period, investors were given 100 francs to invest. Investors were allowed to invest in any combination such that for any investor i, investment to Firm 1 is $I_1^i \geq 0$, investment to Firm 2 is $I_2^i \geq 0$ and $I_1^i + I_2^i \leq 100$. Investors kept any endowment not invested. The payoffs from the investment were determined by the performance of the two firms

$$R\left(\min_{i \in firm1}\{e_i\}\right) \times I_1^i + R\left(\min_{j \in firm2}\{e_j\}\right) \times I_2^i \tag{2}$$

where $R(min\{e_i\})$ represents the following multiplier in Table 2.

$min\{e_i\}$	7	6	5	4	3	2	1
$R(min\{e_i\})$	2.5	2.25	2.0	1.75	1.5	1.25	1.0

Table 2: Multiplier for $R(min\{e_i\})$ for Both Firms

These multipliers are standard in experimental economics, such as the trust game, centipede game, and many others. Notice that investors cannot lose money from investment and it is weakly dominant to always invest.

Workers: Each firm consisted of 6 people and the composition of the firm did not change for the entire experiment. The workers played the MECG explained before with the following variation. Worker i in firm j was choosing a number $e_i \in \{1, 2, ..., 7\}$ with his payoff given by

$$p_i = 400\left(\min_{i \in N} e_i\right) - 200e_i + 1100 + I_j \tag{3}$$

where $I_j = \sum_{k \in investors} I_j^k$, the sum of total investment made to the firm j. Notice that the best response does not change: $e_i = \min_{j \in N \setminus i}\{e_j\}$. Furthermore, the entire equilibrium structure remains the same. In particular, risk dominance is invariant with respect to isomorphisms (Harsanyi and Selton 1988). The worker's payoff matrix can be summarized by Table 3. These parameters were chosen so that in the worst case the worker will end with at least 100 francs and not a negative amount. This is to reduce confounding effects such as loss aversion.

The design choice was made with simplicity in mind. Obviously, there are more complex contracts that can induce better performance than a fixed-wage contract, such as an option-based or benchmark contract. Our goal was to design a simple wage schedule that is less likely to induce coordination improvement. The focus of the study is not whether different contracts can induce coordination but whether competition can help improve coordination. We want to minimize the confounding effects. The design of the I_j parameters were again chosen for simplicity of computation during the experiment, as well as to not change the risk dominance of the game. Instead of using the payoff to workers $p_i = 400\left(\min_{i \in N} e_i\right) - 200e_i + 1100 + I_j$, we could have also used the payoff $p_i = 400\left(\min_{i \in N} e_i\right) - 200e_i + 1100 + \frac{I_j}{N}$, but there is no a priori reason to think scalar multiplication of investment will make a difference. The profit function for firm j which constructs the model above is $\prod_j = I_j(R(min(e_i)) + 6) + 6(\alpha min(e_i) + \delta)$ and was not shown to the subjects in the experiment.

	Minimum effort of all the agents						
Agent i's effort	7	6	5	4	3	2	1
7	2500 + I_j	2100 + I_j	1700 + I_j	1300 + I_j	900 + I_j	500 + I_j	100 + I_j
6	-	2300 + I_j	1900 + I_j	1500 + I_j	1100 + I_j	700 + I_j	300 + I_j
5	-	-	2100 + I_j	1700 + I_j	1300 + I_j	900 + I_j	500 + I_j
4	-	-	-	1900 + I_j	1500 + I_j	1100 + I_j	700 + I_j
3	-	-	-	-	1700 + I_j	1300 + I_j	900 + I_j
2	-	-	-	-	-	1500 + I_j	1100 + I_j
1	-	-	-	-	-	-	1300 + I_j

Table 3: MECG with Investment Payoff for Agent i in Firm j

3.2 One-Firm (Non-Competitive) Treatment

The one-firm treatment is identical to the two-firm treatment except that there is now only one firm. We conducted 4 sessions of the one-firm treatment (3 at UCLA and 1 at Caltech). Again, the equilibrium structure does not change. The comparison between the design of the two treatments can be summarized by the Table 4.

	Two-Firm Treatment	One-Firm Treatment
Investor's Choice: How much to invest in	Firm 1, Firm 2, and Nobody	Firm 1 and Nobody
Performance knowledge	Investors: All Workers: Own Firm	Investors: All Workers: Own Firm
Investment Knowledge	Own Firm	Own Firm
Can investors lose money?	No	No

Table 4: Comparing the Two-Firm and One-Firm Treatments

3.3 Standard Treatment

We ran 2 sessions at UCLA and 2 at Caltech of the standard minimum effort coordination game using the payoff from Table 1.

3.4 Cooperation Design

We used a one-shot prisoner's dilemma game to test whether subjects are more likely to cooperate (Table 5).

		Your pair's decision A	Your pair's decision B
Your decision	A	\$3, \$3	\$1, \$4
	B	\$4, \$1	\$2, \$2

Table 5: Prisoner's Dilemma Game

We did not inform the subjects beforehand that they would be playing a prisoner's dilemma game. The subjects were randomly (anonymously) matched to one other person from the same group that they were part of during the coordination game. For example, someone from Firm 1 was paired with another person from Firm 1. Subjects were clearly told that this was being played only once and we have obtained the data from the cooperation design only from the UCLA subjects.[7] We chose the prisoner's dilemma game

[7] We only obtained the data from UCLA because this part of the experiment was incorporated after we had already finished running the experiments at Caltech.

because this game has one pure strategy Nash equilibrium which is dominant solvable. In the example from Table 5, the pareto-efficient outcome is to cooperate-cooperate but it is not an equilibrium. Nash equilibrium is to chose B. Following the standard prisoner's dilemma terminology, we consider choosing A as *cooperating* while choosing strategy B as *not cooperating*. Given the structure of the game, choosing to cooperate in one shot prisoner's dilemma provides a strong result.

3.5 Hypothesis

For the coordination phase, we tested whether the workers in the two-firm treatment coordinated better than in the one-firm treatment. Better coordination can mean three things: 1. achieve higher minimum effort level, 2. achieve lower wasted effort, or 3. achieve faster convergence to an equilibrium. For consistency with other literatures, we are referring to *higher minimum effort* level when we state that some setting has a better coordination. However, we will show that there is no difference in wasted effort and rate of convergence between different settings in the result section. For the cooperation phase, we test whether subjects coming from a better-coordinating firm are also more likely to cooperate.

Hypothesis 1 *Higher Minimum Effort. Subjects in the two-firm treatment will choose higher minimum effort level than the one-firm treatment.*

Hypothesis 2 *Likelihood of Cooperation. Subjects are more likely to cooperate in the prisoner's dilemma game if they have also coordinated well in the MECG.*

4 Results

4.1 Two Firm

Figure 2 and 3 show the summary results aggregated over all four sessions of the two-firm treatment. For the analysis, we have separated the sample into two sets. The first set, denoted *higher performing firm*, consists of firms that had higher minimum effort for a given session. The second set, denoted *lower performing firm*, is the complement set of the *higher performing firm*. Of the two firms per session, we define a firm as higher performing if it achieves a higher minimum effort by period 5. There were no cases in which a firm with a higher effort by period 5 ended up having a lower minimum effort at any time from period 5 to 10 (10 being the last period).

We observe that mean choice of effort was between 6-3 with all firms, while the mean choice of effort was between 6-4 and 5-2 for the higher and lower performing firm, respectively (Figure 3). The average minimum effort was between 3-4 with all firms, while the average minimum effort was between 3-5 and 1-3 for the higher and lower performing firm, respectively (Figure 2). We compared the distribution of average choice per period of each subsample to show that the difference in performance between higher and lower performing firms is statistically significant. Table 6 contains the results from the two-sample Kolmogorov-Smirnov test. Furthermore, Figure 4 graphs the kernel estimated cumulative distribution function of each of the subsamples. Results from the KS test and the CDF graph show that the higher performing firm indeed chose statistically significantly higher (p-value of 0) effort levels than the lower performing firm.[8] Lastly, we conclude from Table 7, a cross-sectional time series FGLS regression for average effort level, that average effort level for period t is predominately determined by firm's previous period's minimum effort (coefficient: 0.699 for higher performing firm and 0.91 for the lower performing firm), and minimally, but statically significantly, determined by the percent wealth invested to the firm. The effect of investment for the higher performing firms is negative (coefficient: -0.016) while for the lower performing firm is positive (coefficient: 0.0145). This is because there is an upper and lower bound to the possible effort and investment level. The investors will end up investing 100% of their wealth in the higher performing firm, so decrease in average effort in time will show up as a negative effect. Yet, the investors have no reason to shift their investment from higher performing to lower performing firm as long as the higher performing firm is indeed outperforming the lower firm. Also, as the average effort approaches 1 for the lower performing firm, even modest investment will show up as a positive effect.

Table 8 and 9 further analyzes the investment behavior. Although investors start out by investing 50-50 between both firms[9], Table 8 shows that on the last period, over 98% of the wealth is invested to the higher performing firm. These means are significantly

[8] The cdf of the higher performing firm stochastically dominates the cdf of the lower performing firm.

[9] From Figure 2 and 3, it may seem as if the investors invested more in the lower performing firm at first but that is not the case. The investors did invest 50-50 but did not invest their entire endowment in the first period

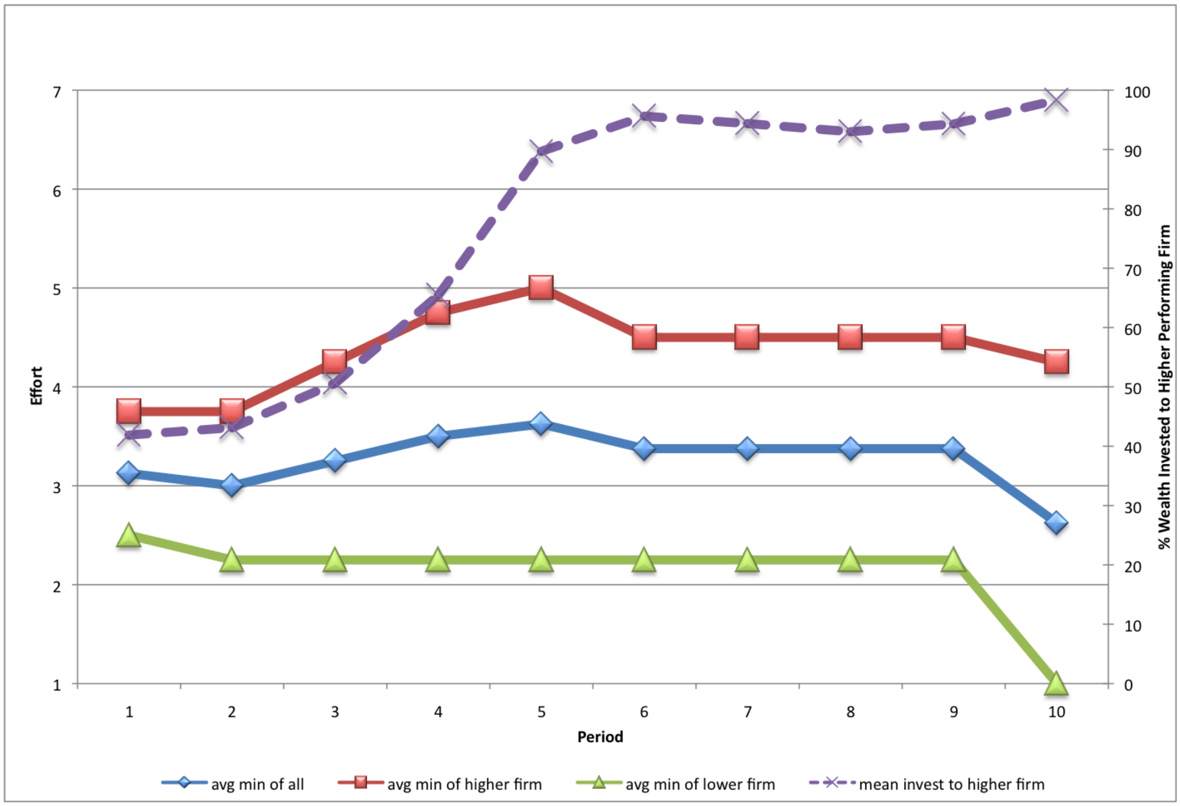

Figure 2: Average Minimum Effort for Two-Firm Treatment

	Smaller group	D	P-value
2 firm setting: higher of the two per session	lower	1	0
vs	higher	0	1
2 firm setting: lower of the two per session	Combined K-S	1	0
2 firm setting: both firms	1 firm	0.567	0.008
vs	2 firm	-0.033	0.983
1 firm setting	Combined K-S	0.567	0.012
2 firm setting: only higher of the two per session	1 firm	0.9	0
vs	2 firm	0	1
1 firm setting	Combined K-S	0.9	0
2 firm setting: only lower of the two per session	1 firm	0.3	0.407
vs	2 firm	-0.1	0.905
1 firm setting	Combined K-S	0.3	0.418

Table 6: Two-Sample Kolmogorov-Smirnov Test: Average Effort Choice Per Period

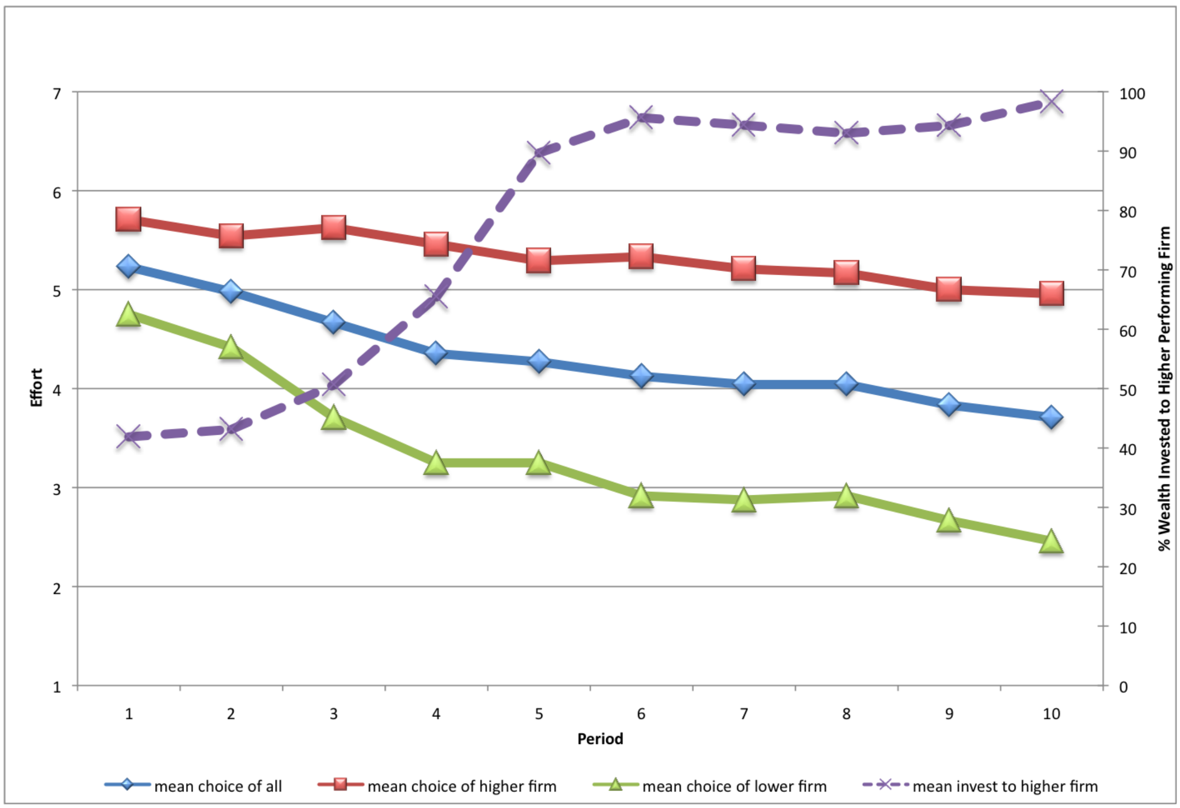

Figure 3: Mean Choice of Effort for Two-Firm Treatment

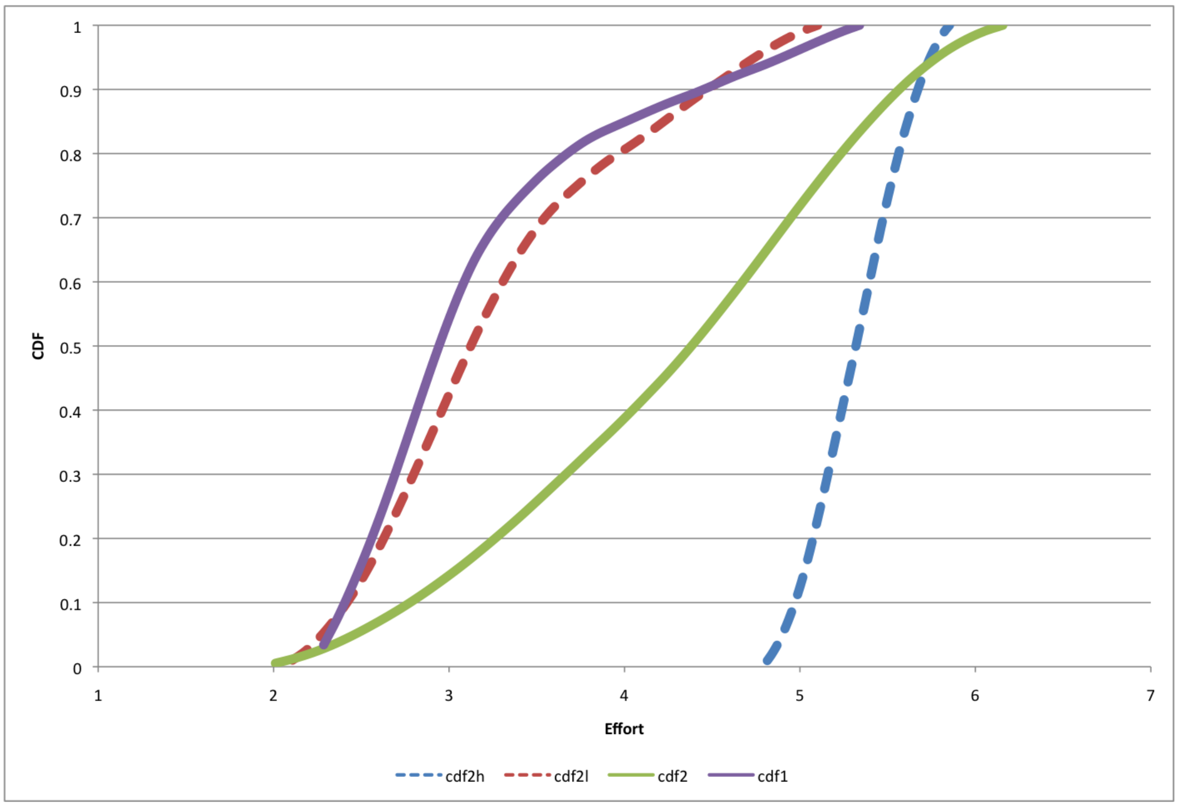

Figure 4: Kernel Estimated CDF of Average Effort Choice

cdf2h is the CDF of the higher performing firm from the two-firm treatment. cdf2l is the CDF of the lower performing firm from the two-firm treatment. cdf2 is the CDF of the two-firm treatment and cdf1 is the CDF of the one-firm treatment. These CDFs were generated using the Kernel estimation.

Independent Variable	Dependent Variables: Average Effort Level			
	1 Firm	2 Firm (higher performer)	2 Firm (lower performer)	2 Firm (difference)
Constant	-0.049	3.540***	0.831***	0.443*
	(0.278)	(0.305)	(0.197)	(0.247)
Firm's minimum (lag 1 period)	0.917***	0.699***	0.909***	
	(0.085)	(0.052)	(0.061)	
% wealth invested	0.013***	-0.016***	0.014***	
	(0.005)	(0.003)	(0.005)	
Minimum difference (lag 1 period)				0.864***
				(0.100)
Investment difference				-0.002
				(0.003)
Common AR(1) for all panels	-0.041	0.297	0.121	0.248
Log likelihood	-22.833	-15.105	-36.884	-36.528
Number of obs: 36. Number of panels: 4. Time period: 9				
*p < 0.1, **p < 0.05, ***p <0.01. (Two-tailed test). Numbers in parentheses are standard errors				

Table 7: Cross-Sectional Time Series FGLS Regression for Average Effort Level
Difference: Higher performing firm - Lower performing firm

different (p<0.000). Another important feature is that the investors invest their entire endowment, which is not the case in the one-firm treatment. Table 9 suggests that the investment behavior at period t is not driven by the firm's minimum effort in period $t-1$ but by the *difference* in the two firm's minimum effort in period $t-1$. The difference in the two firm's minimum effort is higher performing firm's minimum effort minus the lower performing firm's minimum effort. Unsurprisingly, the investment has gravitated towards the higher performing firm such that bigger differences in minimum effort level cause bigger differences in investment level.

Subject Categories	Mean	SE	Min	Max	Obs	P-value
Higher performing firm	98.313	1.305	94.5	100	4	0
Lower performing firm	1.688	1.305	0	5.5	4	
All firms	100	0	100	100	8	
Ho: mean(higher performing) - mean(lower performing) = diff = 0. Ha: diff != 0						

Table 8: Descriptive Statistics & T-Test of % Wealth Invested in Two-Firm Treatment at Last Period

Independent Variable	Dependent Variables: Investment			
	1 Firm	2 Firm (higher performer)	2 Firm (lower performer)	2 Firm (difference)
Constant	51.229***	54.265***	45.615***	24.536*
	(6.412)	(12.990)	(11.942)	(14.405)
Firm's minimum (lag 1 period)	11.475***	2.219	-2.24	
	(2.468)	(2.983)	(2.712)	
Minimum difference (lag 1 period)		7.068**	-10.122***	16.587***
		(2.818)	(2.983)	(5.051)
Common AR(1) for all panels	0.373	0.583	0.555	0.583
Log likelihood	-144.530	-148.378	-146.508	-172.381

Number of obs: 36. Number of panels: 4. Time period: 9

*p < 0.1, **p < 0.05, ***p < 0.01. (Two-tailed test). Numbers in parentheses are standard errors

Table 9: Cross-Sectional Time Series FGLS Regression for Investment

Difference: Higher performing firm - Lower performing firm

4.2 One Firm

Figure 5 shows the summary results aggregated over all four sessions of the one-firm treatment. Here we see that the mean choice (average minimum) effort level ranges from 2-5 (2-3). According to the FGLS of average effort level in Table 7, we find that the average effort level is predominately determined by the firm's minimum in the previous period (coefficient: 0.917), while the percent of wealth invested only has a small but statistically significant effect (coefficient: 0.013).

One might think that investors will always invest everything since they have nothing to lose, given that they are guaranteed at least their investment in return (firm's minimum effort of 1). However, that is not the case. Investors start out by investing over 90% (not 100%) of their wealth in the first period and invest even smaller percentage of their wealth in later periods. Referring to Table 10, by last period, the investors are only investing on average of 66% of their wealth. If we subdivide the sample to two groups, firms with minimum higher than 1 and firms with minimum equal to 1, we observe that the average investment to the firm with minimum effort of 1 is only 37.75%. However, over 95% of the wealth is invested whenever the firm's minimum effort is greater than 1. The investment level difference is statistically different at p-value of 0.047. In addition, according to the FGLS in Table 9, we conclude that the investment is significantly driven by the previous period's firm's minimum in a positive manner (coefficient: 11.47). Although we cannot distinguish whether the lack of investment is due to spitefulness or a punishment to encourage a higher effort level, we observe that there are lower investments to firms performing poorly. However, withholding investment does not accomplish an increase in effort level since, according to Table 7, the investment variable has a positive coefficient of 0.013, which suggests that lowering investment does not increase average effort level.

Subject Categories	Mean	SE	Min	Max	Obs	P-value
Firms with min $>$ 1	95.625	4.375	91.25	100	2	0.047
Firms with min = 1	37.75	12.250	25.5	50	2	
All firms	66.688	17.531	25.5	100	4	
Ho: mean(firms with min>1) - mean(firms with min=1) = diff = 0. Ha: diff != 0						

Table 10: Descriptive Statistics & T-Test of % Wealth Invested in One-Firm Treatment at Last Period

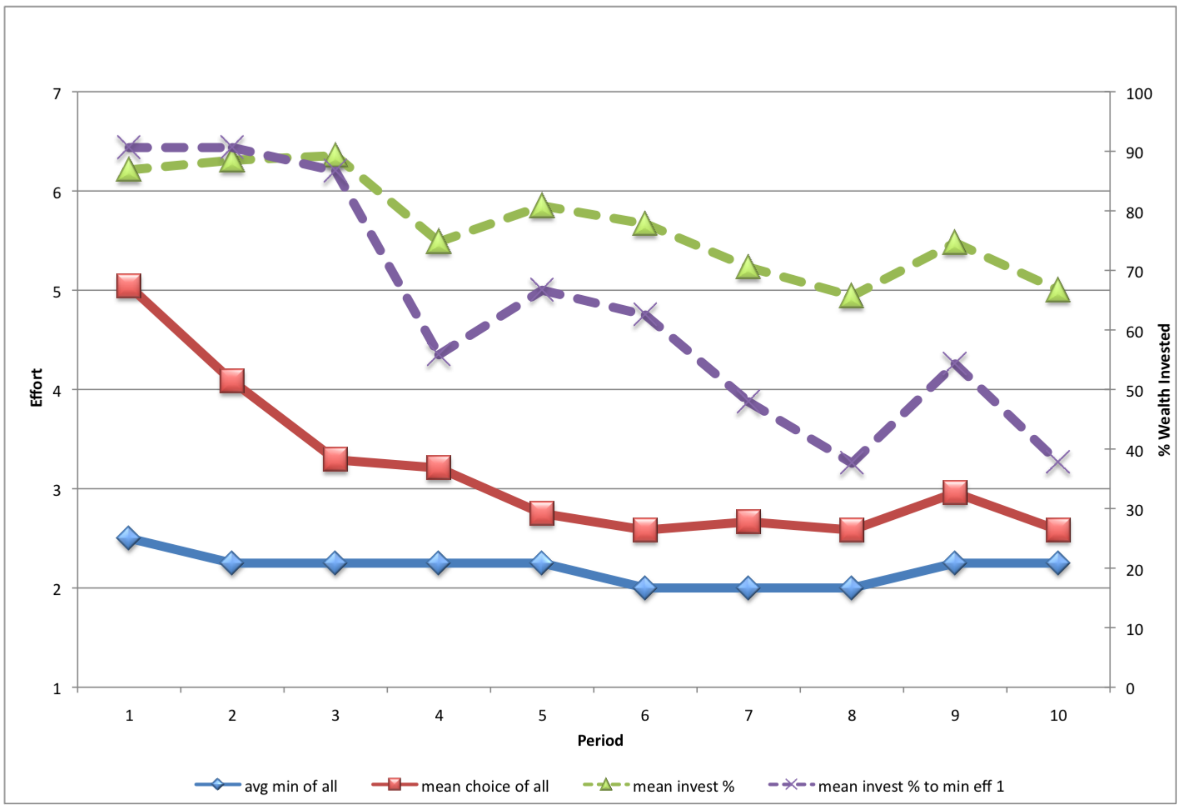

Figure 5: Mean Choice and Average Minimum Effort for One-Firm Treatment

4.3 Two Firm vs One Firm

Recall that the difference between one-firm and two-firm treatment is on the investor's outside option depicted by Table 4. Figure 6 and 7 are the pooled graph from the one-firm and two-firm treatment. An important feature of the graph is that the mean choice (average minimum) of effort of the one-firm treatment is statistically no different from the lower performing firm in the two-firm treatment. If there were no effects between having two firms or one firm, we would expect that mean choice (average minimum) of the one firm to be statistically no different compared to the mean choice (average minimum) of both the higher and lower performing firms combined. Referring back to Table 6, the two-sample K-S test comparing the distribution of average effort choices, and Figure 4 (the CDF of average choices), we can make the following conclusions regarding the comparison of one-firm and two-firm treatment. First, we can reject the null that the distributions from one-firm and two-firm treatment are not different ($p<0.05$). Furthermore, we can state that the two-firm treatment stochastically dominates the one-firm treatment ($p<0.01$). Next, when we compare the higher performing of the two-firm treatment to one-firm treatment, we can reject the null at p-value of 0 that they have the same distribution. In addition, we conclude that the higher performing of two-firm treatment also dominates the one-firm treatment ($p<0.01$). However, when comparing the lower performer of the two-firm treatment to the one-firm treatment, we cannot reject the null that (i) the distributions are the same (p-value of 0.418), (ii) neither one-firm treatment nor the lower performer dominate one another (p-value of 0.407 and 0.905, respectively). In sum, our data supports hypothesis 1. The subjects in two-firm treatment choose a higher minimum effort level than the one-firm treatment. Furthermore, we observe that the results from the one-firm treatment are similar to the results from the lower performing firm.

One reason why we might see such a difference between one-firm and two-firm treatment is that workers start out with only about half of the wealth invested in each firm. Therefore, they work "harder" to earn the rest of the investment. However, in the one-firm treatment, they are offered almost the entire investment from the beginning. Although, it does not change the fact that everyone exerting higher effort, in turn getting a higher minimum effort, is pareto improvement regardless of the treatment, we tested whether firms who had lower levels of initial investment also coordinate to the higher minimum effort in the one-firm treatment. The idea is that the workers will work "harder" to earn the rest of the investment. Our data shows that the initial investment level has no significant effect on individual's initial effort level. By regressing period 1's individual effort level on the first period's investment[10], we obtain a negative but statistically insignificant coefficient of -0.0235 with SE of 0.04737. This is evidence against the argument that workers are exerting higher efforts when they observe low investment in the first period because they want to "earn" higher level of investment in the subsequent period.

[10]Recall that investment decisions are made and shown to the workers before effort levels are chosen.

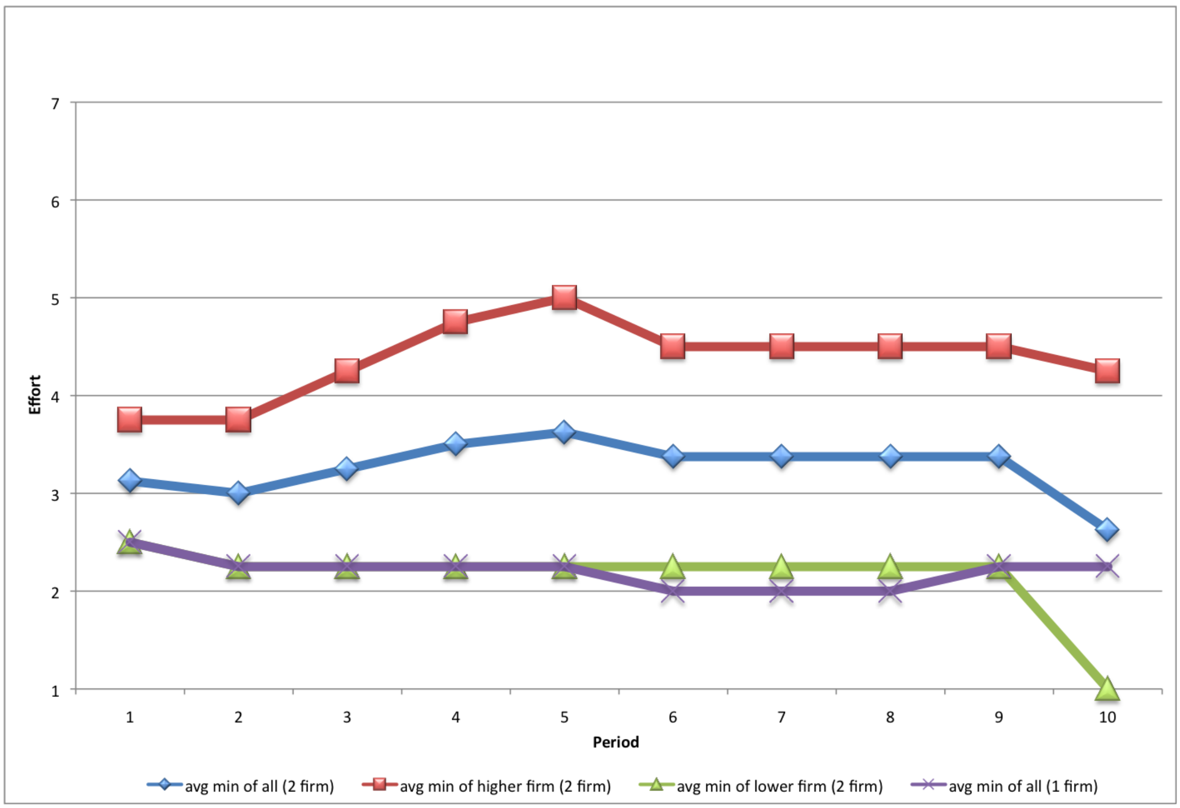

Figure 6: Average Minimum Effort: One-Firm Treatment vs Two-Firm Treatment

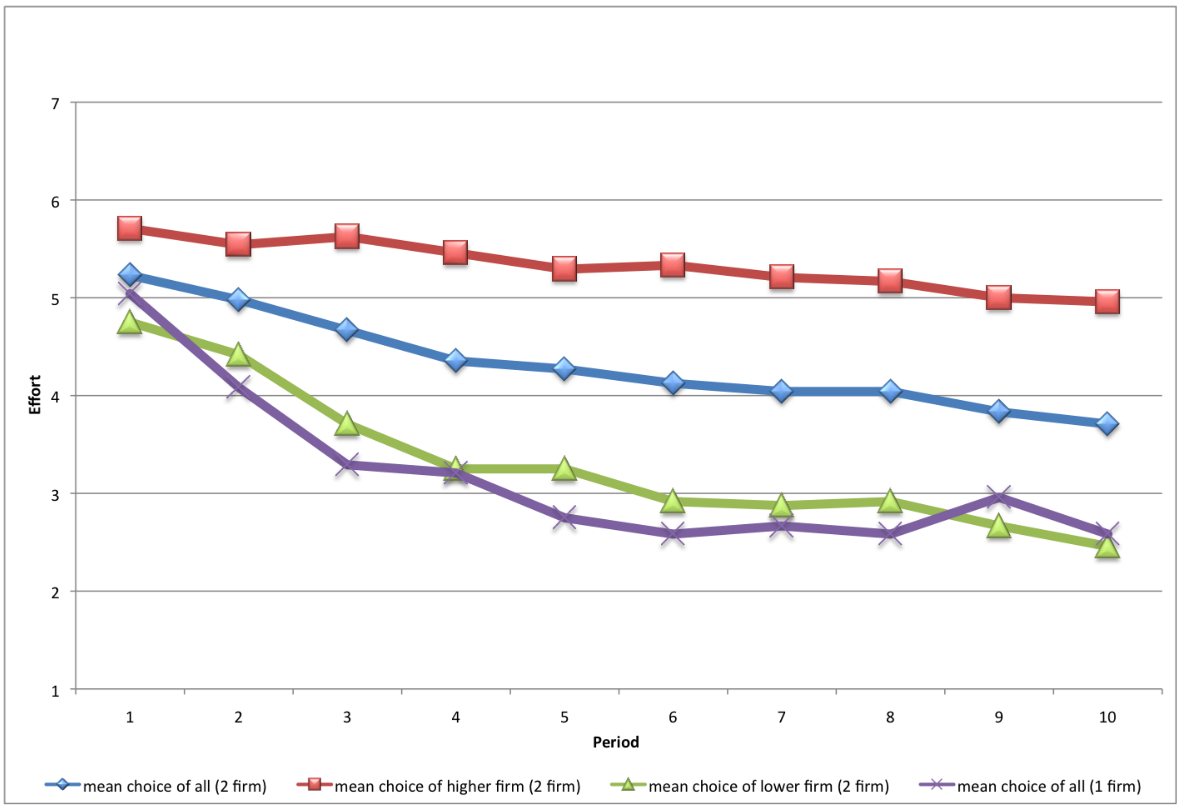

Figure 7: Mean Choice of Effort: One-Firm Treatment vs Two-Firm Treatment

4.4 Wasted Effort

So far we have only considered having a higher minimum effort as an indicator of better coordination. Table 11 and Figure 8 present the average wasted effort per period by each individual. Comparing various combinations of two-firm treatment and one-firm treatment, and just the high performer of two firm and low performer of two-firm treatment, we do not get any statistically significant differences between the average wasted effort. At best, the p-value is 0.372 and at worst, it is 0.9 in a two-tailed t-test. The average wasted effort across both the one-firm and two-firm treatment is 1.033 per period with standard error of 0.087. Therefore, we conclude that amount of effort wasted does not vary much between treatments.

	Mean	SE	Num of Obs		P-value
(A) 2 firm setting	1.063	0.120	48	(A) & (B)	0.640
(B) 1 firm setting	0.975	0.109	24	(B) & (C)	0.9
(C) 2 firm setting (higher only)	0.954	0.124	24	(B) & (D)	0.404
(D) 2 firm setting (lower only)	1.171	0.206	24	(C) & (D)	0.372
everyone	1.033	0.087	72		
Ho: mean(X) - mean(Y) = diff = 0. Ha: diff != 0					

Table 11: T-Test: Average Wasted Effort Per Period

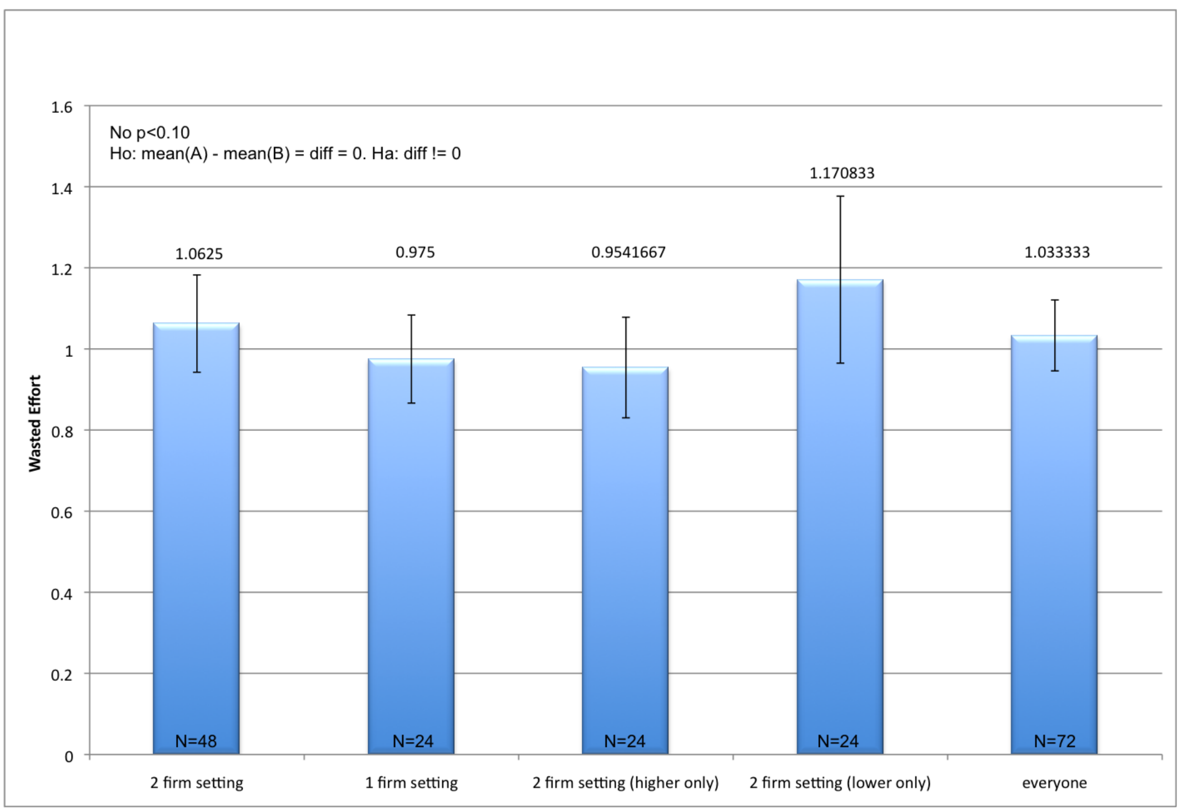

Figure 8: Average Wasted Effort Per Period

4.5 Convergence

Another method in measuring coordination is the rate of convergence speed to an equilibrium. Figure 9 presents the average number of best responses per period. For example, if the average rate of best response is 3, this means that on average, 3 agents are best responding in that period. As the graph depicts, there are no major differences between one-firm or two-firm treatment or between higher or lower performing firm. In all cases, the average rate of best response starts out low, between 1-1.5, and converges to 3.5-4 by the end of the experiment. Therefore, we conclude that the rate of convergence speed does not vary much between treatments.

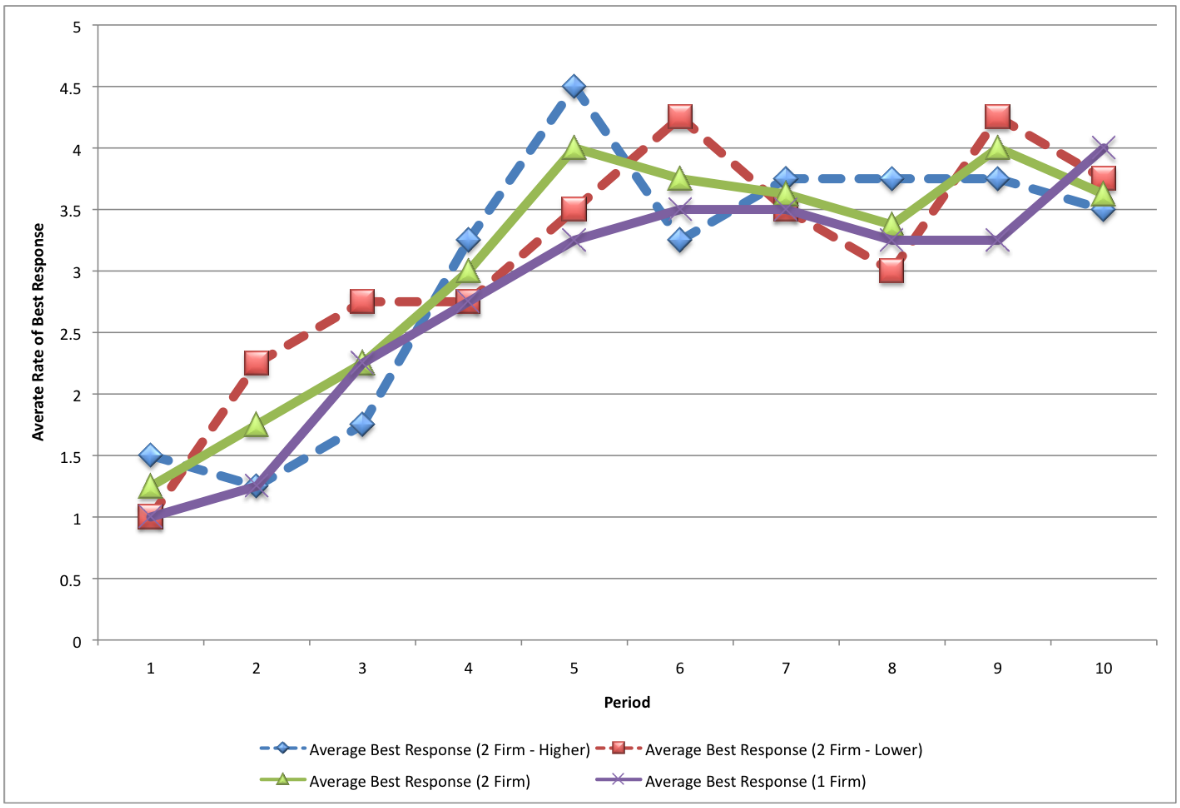

Figure 9: Average Rate of Best Response

4.6 Cooperation

Here, we address the relationship between the likelihood of cooperation conditioned on a firm's coordination outcome. Table 12 is the correlation matrix of our explanatory variables. While one may think that the last period's minimum effort from the coordination game would have the most significant relationship on cooperation, the first period's minimum effort decision had the strongest relationship ($\rho = 0.296$ and p-value of 0.018). This may be the case because when the cooperation treatment was induced by pairing the subjects randomly within the firm, the subjects are conditioning their expectation on the how others behaved at the beginning of the coordination treatment. Not surprisingly, the correlation between firm's minimum effort at period 1 has correlation of 0.77 with firm's minimum effort at period 10.

	pd	gpmin1	gpmin10	gender	exptype	p1	p10
pd	1						
gpmin1	0.296**	1					
gpmin10	0.227*	0.772***	1				
gender	0.244*	-0.196	-0.238*	1			
exptype	0.143	0.346***	0	-0.011	1		
p1	0.037	0.556***	0.422***	-0.144	0.168	1	
p10	0.197	0.726***	0.916***	-0.262**	0.022	0.409***	1
*p < 0.1, **p < 0.05, ***p < 0.01. (Two-tailed test); n=64							

Table 12: Correlation Relationship

By running a logit regression of cooperation (1 if cooperated and 0 otherwise, Table 13) we are able to make the following conclusions. When looking at the sole effect of individual effort choice, this has no significant effects to the likelihood of cooperation. However, when looking at the sole effect of firm's minimum on the first period, this has a positive significant effect (coefficient: 0.398) on the likelihood of cooperation. This may suggest that the individual's likelihood of cooperation is not based on whether the individual is likely to put in high effort in the first period but whether he comes from a firm that coordinated well. When looking at the multivariable logit regression, we can make the following conclusions. First, the three significant variables are individual choice in period 1 (coefficient: 0.723), firm's minimum in period 1 (coefficient: 2.88), and the interaction effect of firm's minimum in period 1 with individual effort in period 1 (coefficient: -0.424). This result suggests that people who chose higher effort levels in first period are also more likely to choose to cooperate. Furthermore, when a firm has a higher minimum effort, workers in that firm are more likely to choose to cooperate. Therefore, it is not that the subjects are trying to take advantage of fellow subjects who seem to be more trusting, but instead are choosing to cooperate. However, when looking at the interaction effect which has a negative coefficient, this suggests that a person who initially chose a high effort and was damaged by low firm's minimum effort is more likely to choose to defect.[11] The variables relating to period 10's efforts are not significant.

[11]Recall that $p1 \geq gpmin1$. Therefore, this does not state the converse which suggests that people

Ind. Variable	Dependent Variable: PD = 1 if cooperate and PD = 0 if defect				
Constant	-0.725	-1.215**	-1.809***	-1.291**	-5.217**
	(0.777)	(0.534)	(0.647)	(0.520)	(2.289)
p1	0.041				0.723*
	(0.140)				(0.408)
p10		0.228			-0.532
		(0.147)			(0.443)
gpmin1			0.398**		2.880***
			(0.173)		(0.935)
gpmin10				0.302*	0.003
				(0.169)	(1.248)
gpmin1xp1					-0.434***
					(0.160)
gpmin1xgpmin10					0.126
					(0.233)
Number of Obs	64	64	64	64	64
Pseudo R2	0.001	0.030	0.068	0.039	0.205

*p < 0.1, **p < 0.05, ***p < 0.01. (Two-tailed test).
numbers in parentheses are standard errors

Table 13: Logit Regression: Cooperation

We further subdivide the population to different groups based on effort levels to determine the types and proportion of the subgroup who cooperate in Figure 10 and 11 and Table 14 and 15 to supplement the result from the logit regression on Table 13. The results from Figure 10 and Table 14 support the idea that people who come from firms with higher minimum efforts are more likely to cooperate than those from lower minimum efforts. This occurs in two ways. First, when comparing between groups, for example min $< j$ to min $\geq j$, there generally is a statistically significant effect that min $\geq j$ has higher proportion of cooperation. Secondly, when comparing within groups, for example min $< j$ to min $< j+1$, although the effects are not statistically significant, we do observe the the proportion of cooperation is higher for min $< j+1$. In terms of individual choices, the results from Figure 11 and Table 15 supports that individual effort choices are a poor predictor of the proportion of cooperation.

who initially chosen low effort and realized that $gpmin1$ was higher than his effort are more likely to take advantage of fellow workers in the cooperation treatment.

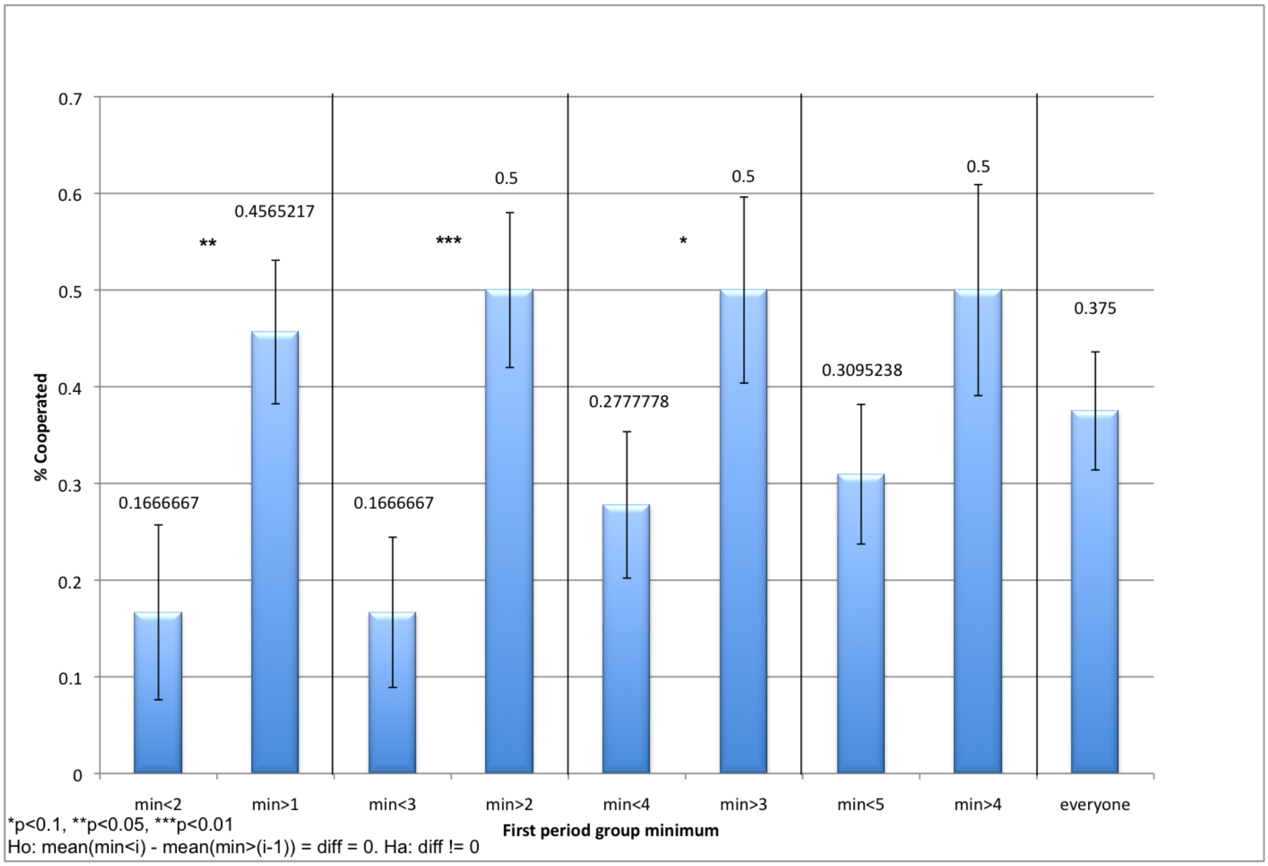

Figure 10: T-Test: Average Cooperation Conditional on First Period Firm's Minimum

First Period Firm Min	% Cooperated	SE	Num of Obs	P-value
min<2	0.1667	0.0904	18	0.0315
min>1	0.4565	0.0743	46	
min<3	0.1667	0.0777	24	0.0071
min>2	0.5000	0.0801	40	
min<4	0.2778	0.0757	36	0.0704
min>3	0.5000	0.0962	28	
min<5	0.3095	0.0722	42	0.1393
min>4	0.5000	0.1091	22	
everyone	0.3750	0.0610	64	
Ho: mean(min<i) - mean(min>(i-1)) = diff = 0. Ha: diff != 0				

Table 14: T-Test: Average Cooperation Conditional on First Period Firm's Minimum

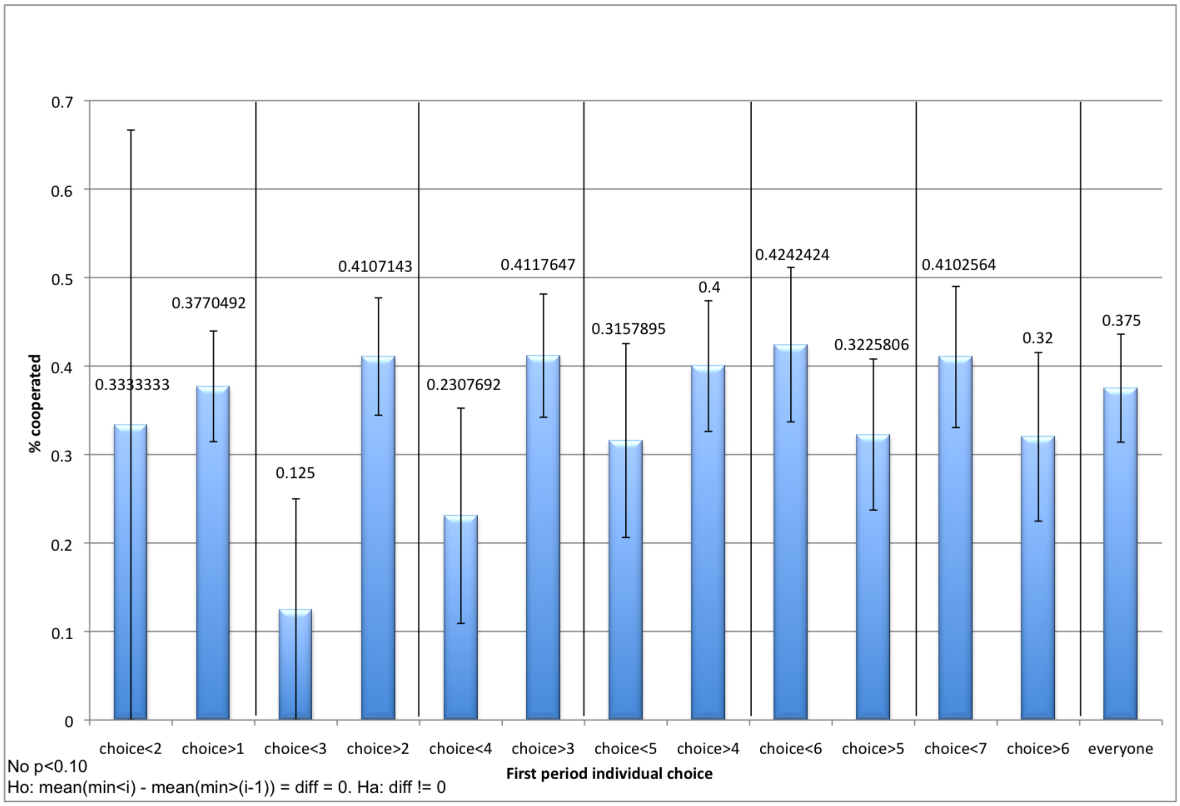

Figure 11: T-Test: Average Cooperation Conditional on First Period's Individual Choice

First Period Individual Choice	% Cooperated	SE	Num of Obs	P-value
choice<2	0.3333	0.3333	3	0.8810
choice>1	0.3770	0.0626	61	
choice<3	0.1250	0.1250	8	0.1222
choice>2	0.4107	0.0663	56	
choice<4	0.2308	0.1216	13	0.2355
choice>3	0.4118	0.0696	51	
choice<5	0.3158	0.1096	19	0.5325
choice>4	0.4000	0.0739	45	
choice<6	0.4242	0.0874	33	0.4092
choice>5	0.3226	0.0853	31	
choice<7	0.4103	0.0798	39	0.4747
choice>6	0.3200	0.0952	25	
everyone	0.3750	0.0610	64	

Ho: mean(min<i) - mean(min>(i-1)) = diff = 0. Ha: diff != 0

Table 15: T-Test: Average Cooperation Conditional on First Period's Choice

5 Conclusion

We set out to study the relationship of persistent performance differences among seemingly similar enterprises and used corporate culture as part of the explanation. We defined corporate culture as the ability to coordinate and cooperate. Our contributions are twofold: The experimental results support that competition significantly improves coordination which pareto improves everyone's payoff. Furthermore, this increase in coordination also improves the likelihood of cooperating even when defecting is individually beneficial. That is also a pareto improvement in everyone's payoff. An organizational culture of coordinating to an efficient outcome determines the ability to cooperate even when there is no monitoring by the principal. We conclude that the results provided in our experiment supports the theory that the endogenous features of culture developed from coordination and cooperation can help explain the persistent performance differences.

As economists, not only are we concerned with existence of equilibrium and its selection but also efficiency. We have shown that in the coordination game we have studied, higher levels of coordination lead to higher social surplus. Hence the natural question to ask is how to improve coordination and we have provided one way in doing so. In the prisoner's dilemma game, the pareto-efficient outcome is not an equilibrium, but an organization was better able to achieve such outcome for greater social surplus due to the institutional design and corporate culture.

There are many open questions left in this field of study. For example, one can start focusing on different types of contracts for coordination. Furthermore, unlike our design, it would be interesting to see how well the firms in one-firm treatment will coordinate if the investors are not allowed to invest until the 5th period. Of course, the idea of studying coordination and cooperation in organization can be extended to different games as well, such as, the battle of the sexes and the trust game in different organizational structure.

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