Improving Coordination and Cooperation Through Competition

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Abstract: Understanding how to improve coordination in a coordination game and why people cooperate in a prisoner's dilemma game are important aspects for both game theory and management. We design an experiment that shows that a competitive environment provides for improved coordination in the minimum-effort coordination game. Furthermore, agents are more likely to cooperate in the one-shot prisoner's dilemma game if they originate from a group with higher levels of coordination. The cooperation level depends on the coordination level of the group itself and not on the individual agent's strategy from the coordination game. Our experimental design provides an endogenous development of culture, defined by coordination and cooperation, and can help to explain widely studied questions such as the persistent performance differences among seemingly similar enterprises.

Keywords: competition, coordination game, corporate culture, equilibrium selection, experiment, organization, prisoner's dilemma.

JEL classification: C72, C91, C92, D02, D23

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1 Introduction

One question that often gets attention in organizational economics is the persistent performance differences (PDD) among seemingly similar enterprises (SSE) (Gibbons, Henderson, Repenning, and Sterman In Press). Many empirical studies have demonstrated that performance differences do exist, whether measured in productivity or profit in various sectors of industry (Brush, Bromiley, and Hendrickx 1999, Roquebert, Phillips, and Westfall 1996, Macher and Mowery 2003). For example, Disney, Haskel, and Heden (2003) have shown that there is a 156% difference in productivity between the top 10 and bottom 10 decile in UK manufacturing industries. These results are prevalent even at the more narrow levels of five-digit industries.

Because an organization is in essence a repeated game, the folk theorem may suggest that any outcome we observe is just a different equilibrium reached by the organization. While that may be true, we still desire to address the question of equilibrium selection and Pareto improvement. One set of arguments for performance differences can be addressed with management skill (Bloom and van Reenen 2007). Management skill is just another form of labor input, however. Something that is more general and endogenous to the firm is corporate culture.

Economists have emphasized the importance of corporate culture as an integral part of studying the theory of firm. Kreps (1990) argued that culture is a focal point (Schelling 1960), Cremer (1986) and Cremer (1993) viewed culture as an investment, and Hermalin (2001) argued that culture is an efficiency improving mechanism. Although a corporate culture might be seen as a firm-specific technology, it cannot be easily transferred nor purchased, even in similar industries. Cultures can even hinder mergers between similar firms (Weber and Camerer 2003). These literatures all pointed to the crucial role of culture in affecting corporate performance. Corporate culture is important because it can be a cheap way of increasing performance and reducing agency cost. Second, corporate culture also provides researchers with an equilibrium prediction.

Consider the following thought exercise. When an organization is first formed, it often faces many coordination problems, whether they are due to social culture, experiences, ethics, linguistics, or educational background. After an organization matures, individuals can choose to cooperate or to defect for self-benefit. Our experimental design and time line were structured to replicate a similar time line of how an organization may evolve. And this evolution of corporate culture can have long-lasting effects on performance. As a simplified representation of these situations, we focus on the following two games: the minimum-effort coordination game (MECG) and the prisoner's dilemma game. Coordination games are a class of games with at least two pure-strategy Nash equilibria. In particular, MECGs are games with Pareto-ranked Nash equilibria, which places a dichotomy between strategic uncertainty and high payoff. Therefore, equilibrium selection and improving coordination become important issues to address. The prisoner's dilemma game, unlike the MECG, has a unique Nash equilibrium that is dominant solvable. The equilibrium to the prisoner's dilemma game is not Pareto efficient, and it is worth investigating how and why agents would choose a non-equilibrium strategy.[1]

We design two environments for our analysis. The first phase focuses on the coordination problem and is divided into a competitive setting and a non-competitive setting. In the competitive treatment, there are two firms that each independently play the MECG. There is only one firm for the non-competitive treatment. In both treatments, there are external investors whose individual task is to decide how much to invest in each firm. The investor's payoff increases with the minimum effort of the firm. The workers in the firm know the exact investments made and the payoff structure prior to making any decisions, and the investments linearly increase the payoffs to the workers in the firm. This procedure is done to control for risk dominance. Competition has been known to help with production in an organization (Nalbantian and Schotter 1997, Fatas, Neugebauer, and Perote 2006) and our design of competition is an extension of Bornstein, Gneezy, and Nagel (2002)'s (BGN) experiment that supported the idea that competition can improve coordination. Some major differences between our work and BGN are that we control for risk dominance in the competition setting[2] and we remove the uncertainty of not knowing the payoff matrix for the players in the MECG. Unlike the previous works cited, the investment to the form is constructed endogenously and is more aligned with the principal-agent framework in an organization. Lastly, both competitive and non-competitive settings have investors in our design, which allows us to compare the two treatments.

Others have examined the relationship between effort choices and exogenous, one-time changes to the payoff function (Brandts and Cooper 2006, Hamman, Rick, and Weber 2007). These exogenous changes are changes that are not controlled by anyone participating in the experiment. Brandts and Cooper (2006) and Hamman, Rick, and Weber (2007) showed that after observing coordination failure, periodic and exogenous changes of the payoff function in a non-affine manner[3] improve coordination. Adapted from their studies, our experiment deals with endogenous changes and affine transformations to the payoff function in order to maintain the same risk dominance structure. We show that the effort levels from the competitive setting stochastically dominate the non-competitive setting, on average a 36.22% improvement. 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 two-firm setting. Furthermore, even though the experiment is designed so that the investors cannot lose any of their investments in the non-competitive setting, we observe that the investors do not fully invest their endowment to a poorly performing firm. This punishment mechanism does not increase the effort levels.

The second phase is where we deal with cooperation in the prisoner's dilemma game. Specifically, we explore the likelihood of cooperation after having endogenously developed a

[1]The choice of using the MECG follows from the literature cited in this paper. MECG are often used as a representation of coordination problems in an organization. The choice of prisoner's dilemma game follows from the literature cited as well as from management literature (Bettenhausen and Murnighan 1985, Bettenhausen and Murnighan 1991).

[2]For example, the losing group received a payoff of zero in BGN.

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

culture of different coordination levels. Cooperation is approximately 30% more likely in the prisoner's dilemma game when the subject is randomly matched with a person with high levels of coordination from the previous group. Previous studies have dealt with spillovers from one game to another (Devetag 2005, Charness, Frechette, and Qin 2007), and the most closely related experiment was by Knez and Camerer (2000). Knez and Camerer tried to establish a link between a coordination game of two players and a repeated prisoner's dilemma game. Players are much more likely to cooperate in the repeated prisoner's dilemma game compared to a one-shot game. Furthermore, having only two players reduced anonymity and produced little variation in the level of coordination for comparison.

The following results summarize our main findings. From the experimental game theory perspective, first, we show that competition leads to better coordination in the MECG. Better coordination refers to higher minimum effort, which leads to a Pareto-superior equilibrium. Furthermore, we show that stronger coordination also leads to a higher rate of cooperation in the one-shot prisoner's dilemma game. We also find that the likelihood of an agent's cooperation is driven by the minimum effort of the group and not by the individual agent's choice of effort level in the MECG. These results introduce a way to think about how to improve coordination in the MECG and the spillover effects from the MECG to the PD game. From an organizational economics perspective, these results can be seen as the high-efficiency culture we endogenously developed in the coordination game acting as a focal point for the outcome of a subsequent prisoner's dilemma game. These results lead to a higher performance outcome in an organization.

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 follow with a detailed analysis of the exerpiment in the results section. We then provide a conclusion.

2 General Discussion of the Minimum-Effort Coordination Game

The minimum-effort coordination game (MECG, 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

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

The best response in this game is for agent i to match the lowest effort of everyone else:

$$e_i = \min_{j \in N \setminus i} \{e_j\} \tag{2}$$

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 where $M = 7, \alpha = 400, \beta = 200$, and $\delta = 1100$. The game can then be 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, it has seven pure-strategy Nash equilibria: $e_i = 1\ \forall i \in N$, $e_i = 2\ \forall i \in N$, ..., $e_i = 7\ \forall i \in N$. However, given this particular game structure with strict Nash equilibria, many of the standard notions of refinements, such as the trembling hand perfection, will not help in reducing any equilibria. We are able to focus on two particularly interesting equilibria (Harsanyi and Selten 1988): the payoff-dominant equilibrium and the risk-dominant equilibrium. Every agent choosing an effort level of 7 is the payoff-dominant equilibrium since this equilibrium Pareto-dominates all other equilibria. Choosing an effort level of 1 is the least efficient equilibrium but also the risk-dominant equilibrium. Notice that this strategy secures a specific payoff, regardless of the actions of other agents. Harsanyi and Selten (1988) further argued that payoff dominance should be the first criterion applied when selecting between these two equilibira. However, in a tacit environment, experiments have shown that people converge to the risk-dominant equilibrium (van Huyck, Battalio, and Beil 1990) due to strategic uncertainty. One way to understand this behavior is by using the adaptive learning framework (Crawford 1995).

Many variations of the MECG have shown to improve the effort levels. In addition to the papers previously mentioned, for example, Cooper, DeJong, Forsythe, and Ross (1992) and Blume and Ortmann (2007) showed that having a non-binding pre-game communication or costless communication can improve coordination. Even without communication, Weber (2006) provided an experimental result where one slowly grows the organization to improve coordination. Schmidt, Shupp, Walker, and Ostrom (2003) provided experimental data showing that 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). Even having nonmonetary sanctions can improve coordination (Dugar 2010). Refer to Camerer (2003) for a survey of coordination games.

3 Experimental Design

Our experiments were conducted at the Social Science Experimental Laboratory (SSEL) at the California Institute of Technology (Caltech) and the California Social Science Laboratory (CASSEL) at the University of California, Los Angeles (UCLA). A total of 128 subjects participated in the experiments and were recruited by electronic announcements. The average performance-based payment was 19 US dollars.

The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher 2007). Instructions for the experiment were available both in print as well as on screen for the subjects. The experimenter read the instructions out loud. Subjects were also given a brief quiz after instruction to ensure proper understanding of the game and the software.

The subjects were randomly assigned to their roles and did not change their roles for the duration of the 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. The experiment used fictitious currency called francs, and the expected payment for the different roles was comparable.

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 within this paper, we will refer to groups as *firms* and *investors* henceforth. The members in a firm will be called *workers*. Lastly, we will refer to the number chosen by the subject as *effort level* throughout the paper.

3.1 Two-Firm (Competitive) Treatment

Following 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 to their firm.
3. The workers privately select an effort level between 1 – 7.
4. The minimum effort for each firm is shown to the investors along with their current period payoff and total payoff.
5. The workers are only shown the minimum effort selected from their 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. The experiment concludes at a period undisclosed to the subjects.

We conducted four sessions of the two-firm treatment (three at UCLA and one at Caltech). Subjects in the two-firm treatment were divided into three groups: Firm 1, Firm 2, and Investors. Each firm had six workers, and there was a total of four 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 was $I_1^i \geq 0$, investment to Firm 2 was $I_2^i \geq 0$, 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

$$R\left(\min_{i \in firm1}\{e_i\}\right) \times I_1^i + R\left(\min_{j \in firm2}\{e_j\}\right) \times I_2^i \tag{3}$$

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: Multipliers for $R(min\{e_i\})$ for Both Firms

These multipliers are standard in economics experiments, such as the trust game and the centipede game. Notice that the investors cannot lose money from the investment. The worst-case scenario will result in the return of the initial investment.

Workers: Each firm consisted of six workers, and the composition of the firm did not change for the entire experiment. The workers played the MECG with the following variation. Worker i in Firm j chose an effort level $e_i \in \{1, 2, ..., 7\}$ with his payoff determined by

$$p_i = 400 \min_{i \in N} e_i - 200e_i + 1100 + I_j \tag{4}$$

where $I_j = \sum_{k \in investors} I_j^k$, the sum of the investments made to 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 for any single period.[4] In particular, risk dominance is invariant with respect to isomorphisms (Harsanyi and Selten 1988). The workers' payoff matrix is 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. Insuring 100 francs 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 (Nalbantian and Schotter 1997). 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 parameter was again chosen for simplicity of computation during the experiment, as well as to not change the risk dominance of the game.

[4] The repeated game effect is important but is outside the scope of this paper.

	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: The 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 four sessions of the one-firm treatment (three at UCLA and one at Caltech). Again, the equilibrium structure does not change for any single period. The comparison between the two treatments is summarized by 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
Investor's downside risk	None	None

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

3.3 Standard Treatment

We ran two sessions at UCLA and two at Caltech of the standard MECG 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 (see Table 5).[5]

The subjects were not aware beforehand that they would be playing the prisoner's dilemma game. The subjects were randomly and anonymously matched to one other person from the same previous group during the coordination game. For example, someone from

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

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

Table 5: The Prisoner's Dilemma Game

Firm 1 was paired with another person from Firm 1. Subjects were clearly told that the prisoner's dilemma game was being played only once. We chose the prisoner's dilemma game because this game has one pure-strategy Nash equilibrium that is dominant solvable. In addition, the equilibrium is not Pareto efficient. 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 a one-shot prisoner's dilemma provides a strong result.

3.5 Hypothesis

For the coordination phase, we test whether the workers in the two-firm treatment coordinate 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. We focus on the higher minimum effort levels as a better coordination for consistency with the previous literatures. However, we also address the wasted effort and the rate of convergence in the results section. For the cooperation phase, we test whether workers from a better-coordinating firm are also more likely to cooperate.

Hypothesis 1. Higher Minimum Effort: Workers in the two-firm treatment will choose a higher minimum effort level than workers in the one-firm treatment.

Hypothesis 2. Likelihood of Cooperation: Workers 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 Treatment

Figure 1 shows the summary results aggregated over all four sessions of the two-firm treatment. For the analysis, we have subdivided the sample into two sets. The first set, denoted as the *higher performing firms*, consists of firms that had a higher minimum effort in a given session. The second set, denoted as the *lower performing firms*, consists of firms that had a lower minimum effort in a given session. Of the two firms per session, we define a firm as higher performing if it achieved 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 Periods 5 to 10 (10 being the last period).

The mean choice of effort was between 3 – 6 for all firms combined, while the mean choice of effort was between 4 – 6 and 2 – 5 for the higher and lower performing firm, respectively. Results from the two-sample Kolmogorov-Smirnov (K-S) test and the kernel estimated cumulative distribution from Figure 2 show that the higher performing firms have higher effort levels – on average of two effort levels, or 66.67% higher per period – compared to the lower performing firms ($p<0.01$).[6]

Table 6 is a cross-sectional time series FGLS regression for the average effort level. The average effort level for Period t is predominately determined by a firm's previous period's minimum effort (coefficient: 0.699 for the higher performing firm and 0.91 for the lower performing firm) and, minimally but statistically significant, determined by the percentage of wealth invested in the firm. The effect of investment for the higher performing firm is negative (coefficient: -0.016) while for the lower performing firm it is positive (coefficient: 0.0145). The difference is due to an upper and lower bound of the possible effort and investment. The investors can only contribute 100% of their wealth to the higher performing firm, so the decrease in average effort in time will show up as a negative effect. Yet, the investors have no reason to shift their investment from the higher performing to the lower performing firm. Also, as the average effort approaches 1 for the lower performing firm, even a modest investment shows up as a positive effect.

Tables 7 and 8 focus on the investor's behavior. Although investors start out by investing approximately equally between the two firms, Table 7 shows that by the last period, over 98% of the wealth is invested to the higher performing firm ($p<0.01$). Investors invest their entire endowments by the last period, which is not necessarily the case in the one-firm treatment. Table 8 suggests that the investment behavior at Period t is not driven by the firm's minimum effort level in Period $t-1$, ($n.s.$) but instead driven by the difference between the higher performing firm's and the lower performing firm's minimum effort level in Period $t-1$, ($p<0.01$). A difference in one unit of minimum effort shifts on average by 16.587% of total wealth invested ($p<0.01$). In other words, the investment gravitates towards the higher performing firm and the larger differences in the minimum effort level cause larger differences in the investment level.

[6] The CDF of the higher performing firm stochastically dominates the CDF of the lower performing firm.

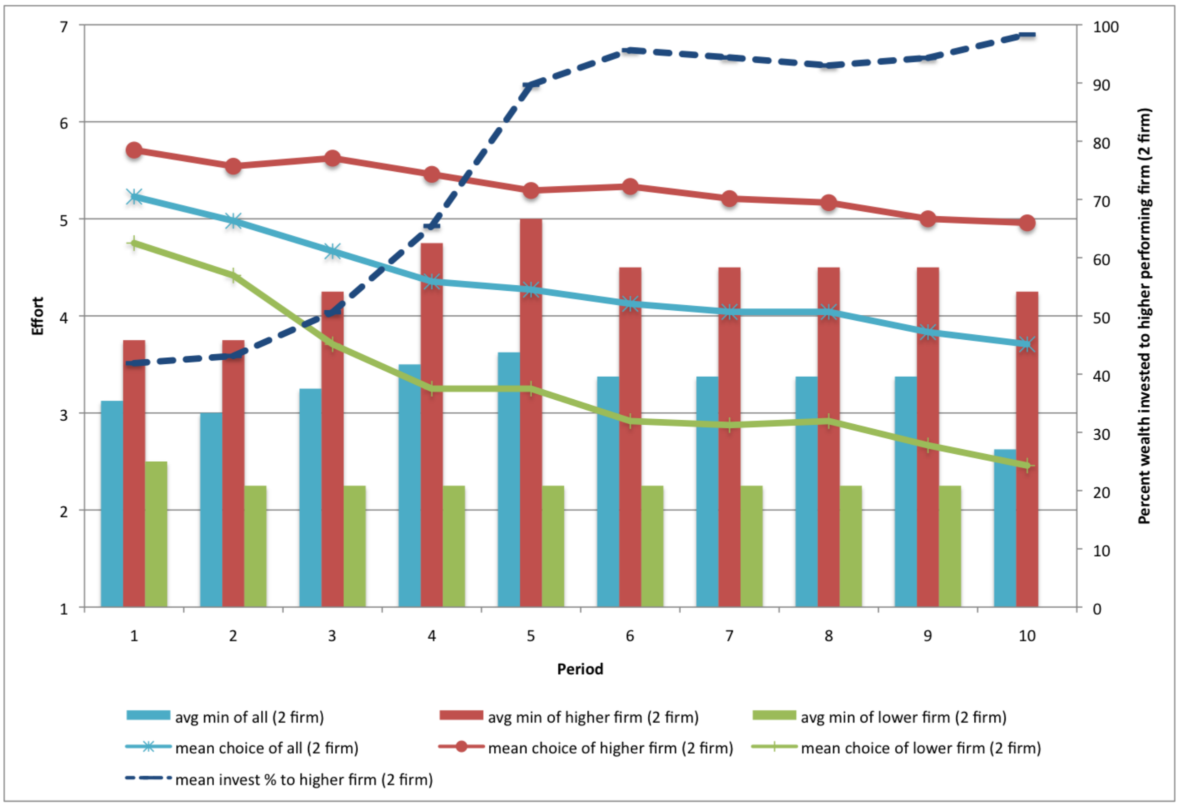

Figure 1: Mean Choice and Average Minimum Effort for the Two-Firm Treatment

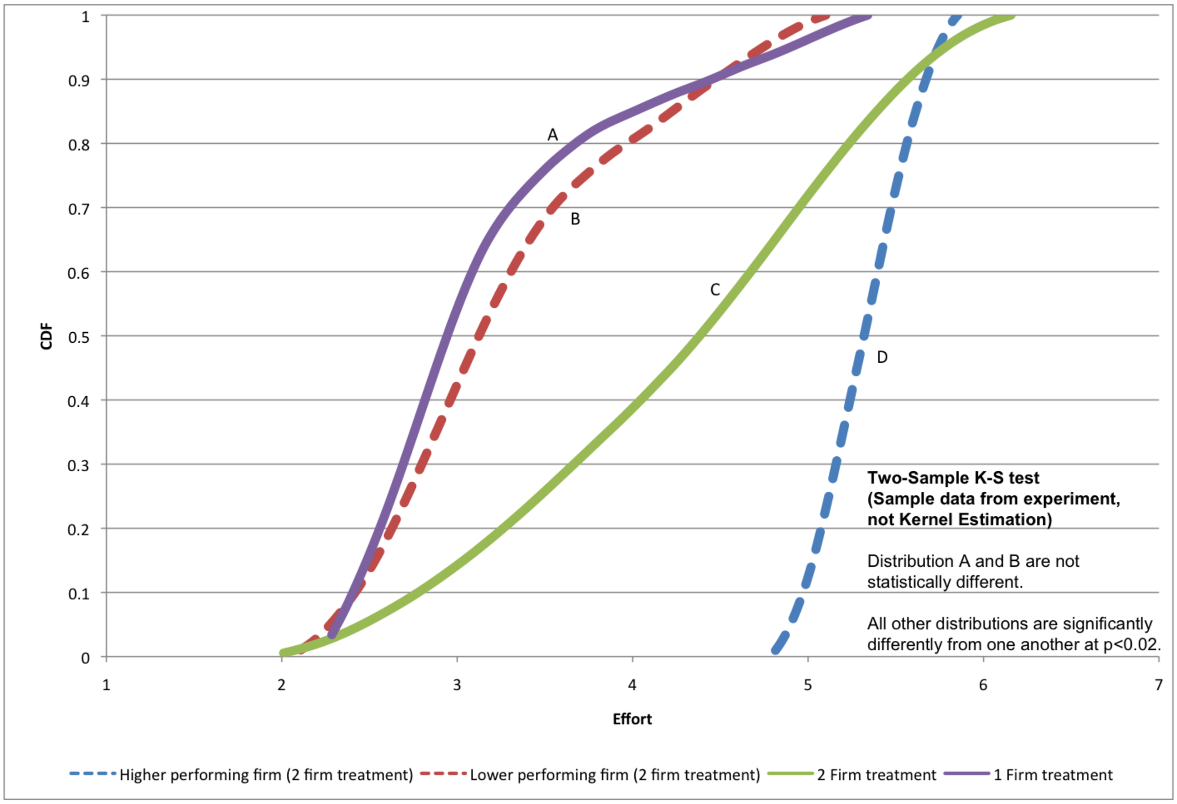

Figure 2: Kernel Estimated CDF of the Average Effort Choice and Two-Sample K-S Test Results

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 (t-1)	0.917***	0.699***	0.909***	
	(0.085)	(0.052)	(0.061)	
Percent of wealth invested	0.013***	-0.016***	0.014***	
	(0.005)	(0.003)	(0.005)	
Minimum difference (t-1)				0.864***
				(0.100)
Investment difference				-0.002
				(0.003)
Common AR(1), 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 6: Cross-Sectional Time Series FGLS Regression for the Average Effort Level
Difference: higher performing firm - lower performing firm
t-1: lagged 1 period

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 7: Percentage of Wealth Invested in the Two-Firm Treatment at the 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 (t-1)	11.475***	2.219	-2.24	
	(2.468)	(2.983)	(2.712)	
Minimum difference (t-1)		7.068**	-10.122***	16.587***
		(2.818)	(2.983)	(5.051)
Common AR(1), 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 8: Cross-Sectional Time Series FGLS Regression for Investment
Difference: higher performing firm - lower performing firm
t-1: lagged 1 period

4.2 One-Firm Treatment

Figure 3 shows the summary results aggregated over all four sessions of the one-firm treatment. The mean choice of effort ranged from 2 – 5. The average minimum effort level was between 2 – 3. Similar to the two-firm treatment, according to the FGLS in Table 6, the average effort level is predominately determined by the firm's minimum in the previous period (coefficient: 0.917). The percentage of wealth invested only has a small but still statistically significant effect (coefficient: 0.013).

Recall that there is no downside risk to investment. Investors are guaranteed at least their initial investment, even when the firm's minimum effort level is 1. Investors do start by investing over 90% of their wealth in the first period but invest even smaller percentages of their wealth in later periods. Referring to Table 9, by the last period, the investors only invested an average of 66% of their wealth. If we subdivide the sample into two groups – firms with a minimum-effort level higher than 1 and firms with a minimum-effort level equal to 1 – we observe that the average investment to the firm with a minimum-effort level of 1 is only 37.75%. However, over 95% of the wealth is invested whenever the firm's minimum-effort level is greater than 1. In other words, there is a 57.25 percentage point higher investment when the minimum-effort level is higher than 1 ($p<0.05$). In addition, according to the FGLS in Table 8, investment is positively and significantly driven by the firm's minimum-effort level in the previous period (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 do observe that there are lower investments to poorly performing firms. However, withholding investment does not accomplish an increase in the effort level. By Table 6, the investment variable actually has a positive coefficient of 0.013, which suggests that lowering the investment may decrease the average effort level.

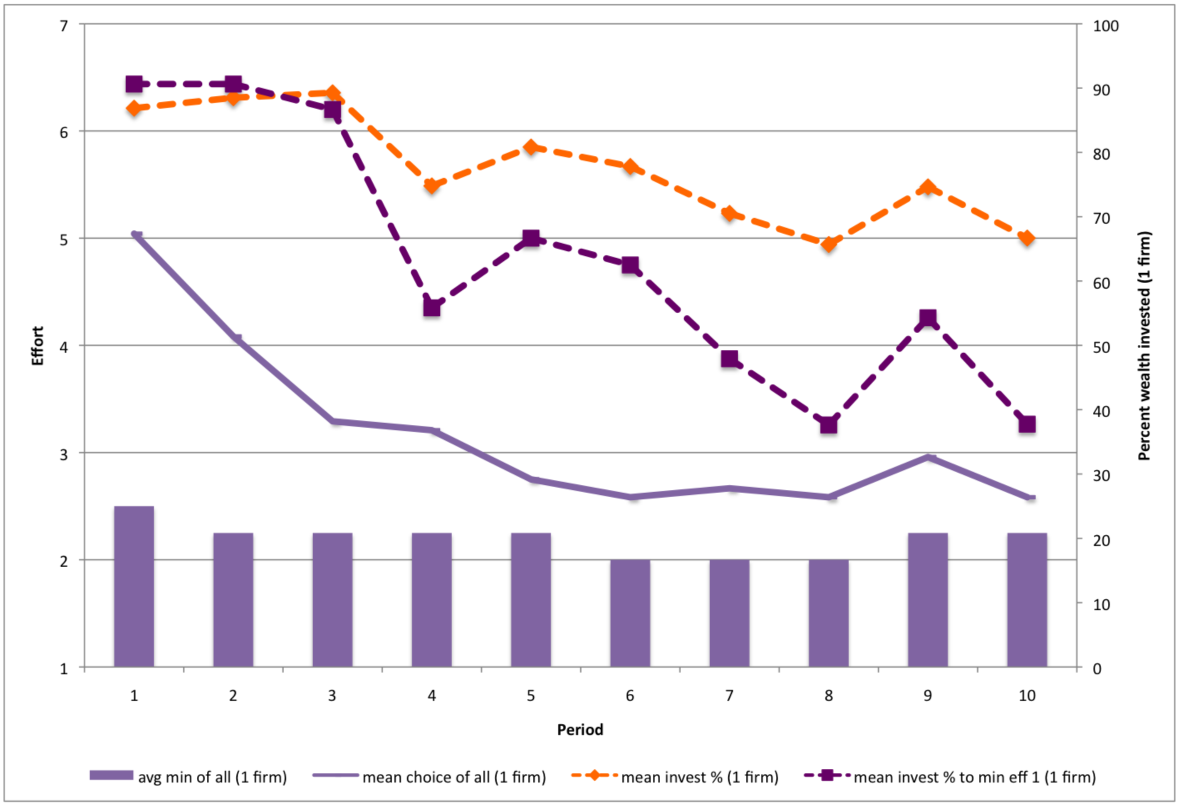

Figure 3: Mean Choice and Average Minimum Effort for the One-Firm Treatment

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 9: Percentage of Wealth Invested in the One-Firm Treatment at the Last Period

4.3 Two-Firm Treatment vs One-Firm Treatment

Recall that the difference between the one-firm treatment and the two-firm treatment is on the investor's outside option (depicted by Table 4). Figure 4 compares the mean choice and the average minimum-effort level between the one-firm treatment to that of the two-firm treatment. The mean choice and the average minimum-effort of the one-firm treatment is not statistically different from the lower performing firm in the two-firm treatment. If there were no effects by having two firms, we would expect the performance of the one-firm treatment to be statistically no different compared to the performance of the higher and lower performing firms of the two-firm treatment combined. Referring back to the two-sample K-S test comparing the distribution of average effort choices and Figure 2 (the CDF of average choices), we can draw the following conclusions regarding the comparison between the one-firm treatment and the two-firm treatment. First, addressing Hypothesis 1, we can reject the null that the distributions from the one-firm treatment and the two-firm treatment are not different ($p<0.05$). The two-firm treatment outperforms the one-firm treatment by an average of 1.15 effort levels, or 36.22%. 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 firm of the two-firm treatment to the one-firm treatment, we can reject the null ($p<0.01$) that the firms have the same distribution. The higher performing firm outperforms the one-firm treatment by an average of 2.15 effort levels, or 67.85%. In addition, we conclude that the higher performing firm of the two-firm treatment also stochastically 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 1) the distributions are the same (p-value of 0.418), 2) neither the one-firm treatment nor the lower performer in the two-firm treatment dominates the other (p-value of 0.407 and 0.905, respectively). In sum, our data supports Hypothesis 1. The subjects in the two-firm treatment choose a higher minimum-effort level than those in 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 from the two-firm treatment.

One reason why we might observe such a difference between the two treatments is that workers start out with only half of the wealth invested in the two-firm treatment. Therefore, they work "harder" to earn the rest of the investment, unlike in the one-firm treatment. Workers in the one-firm treatment are offered almost the entire investment from the begin-

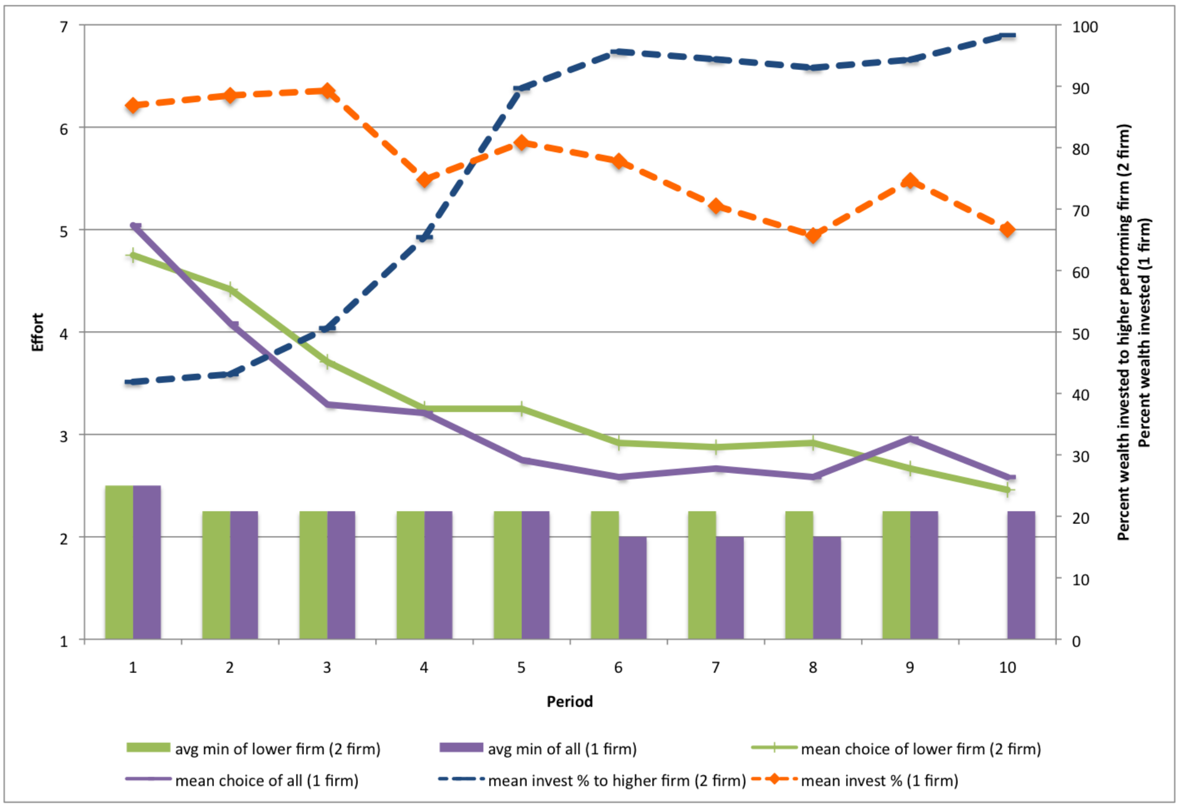

Figure 4: Mean Choice and Average Minimum Effort: One-Firm Treatment vs. Two-Firm Treatment

ning. It does not change the fact, however, that everyone exerting a higher effort level, and in turn getting a higher minimum effort, is Pareto improvement regardless of the treatment. We test 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 an individual's initial effort level. By regressing Period 1's individual effort level on the first period's investment[7], we obtain a negative but statistically insignificant coefficient of -0.0235 with an SE of 0.04737. This actually is an argument against the idea that the workers will exert higher efforts in order to attract additional investment when they observe a lower investment level in the first period.

4.4 Wasted Effort

So far, we have only considered having a higher minimum effort as an indicator of a better coordination. Figure 5 presents the average wasted effort per period by each worker. Comparing various subsets of the two-firm treatment and the one-firm treatment, there are no statistically significant differences between the average wasted effort. The average wasted effort across both the one-firm treatment and the two-firm treatment is 1.033 per period (SE = 0.087). The amount of effort wasted does not vary much between and within treatments.

[7]Recall that investment decisions are made and shown to the workers before the workers choke an effort level.

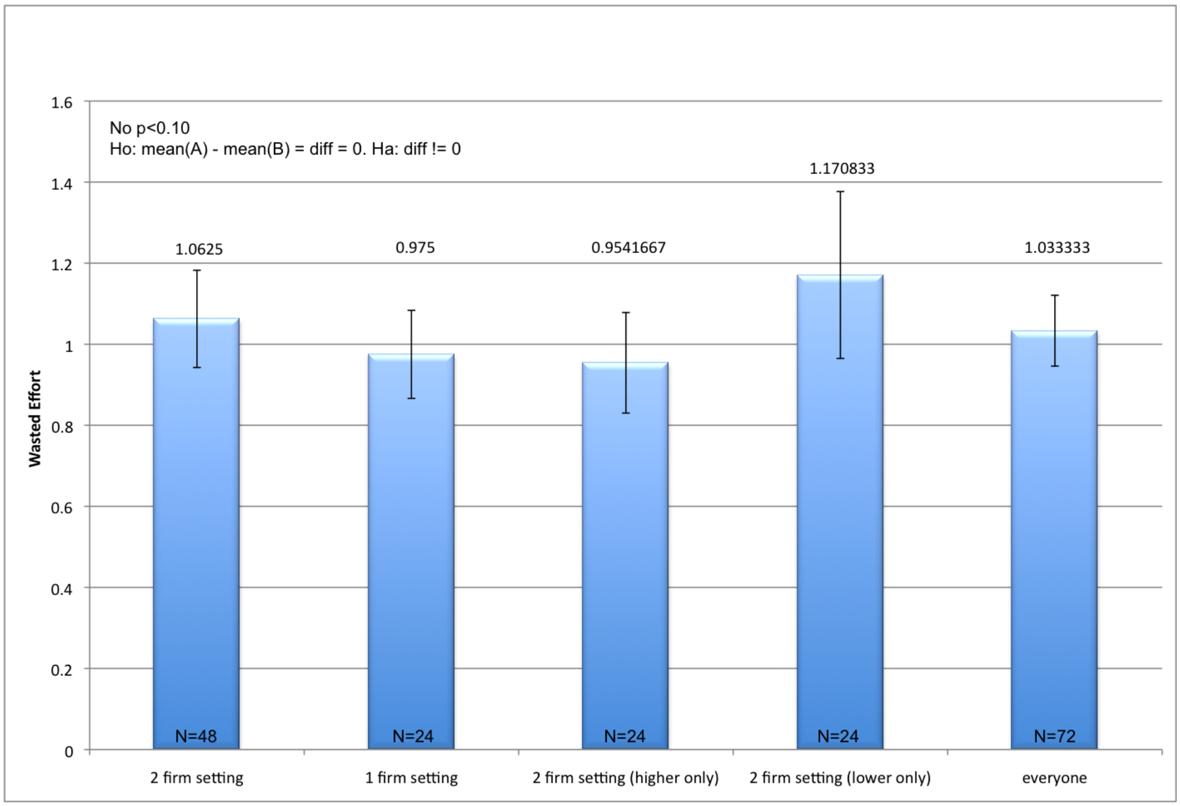

Figure 5: Average Wasted Effort per Period

4.5 Convergence

Another method of measuring coordination is the convergence speed to an equilibrium. Figure 6 presents the average number of best responses per period. For example, if the average rate of best response is 3, this implies that on average, three agents are best responding in that period. As the graph depicts, there are no major differences between the two treatments or their subsets. 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. This result is not surprising since there is a close relationship between wasted effort and convergence speed.

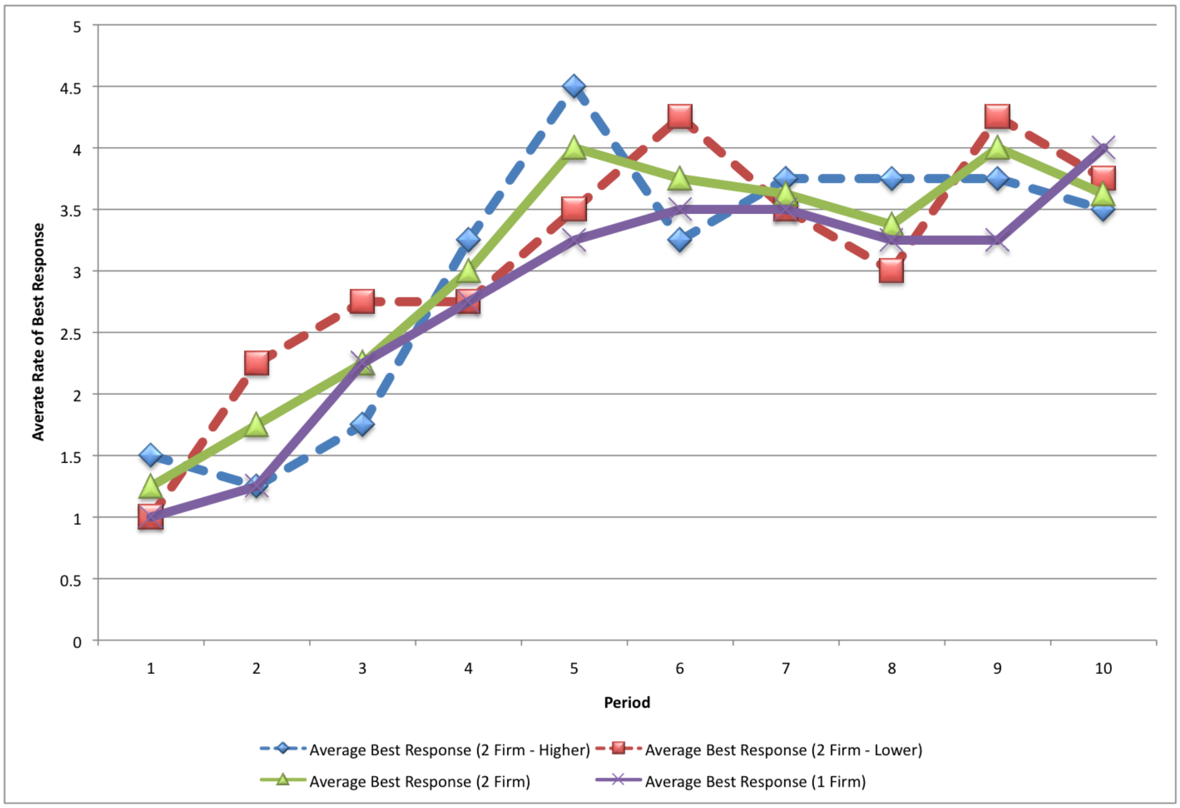

Figure 6: Average Rate of Best Response

4.6 Cooperation

Thus far, we have endogenously created different cultures by coordination levels. Now we address the relationship between the likelihood of cooperation and the firm's coordination outcome.

Overall, 37.5% of participants chose to cooperate. Figure 7 subdivides samples by the minimum effort of the group in the first period. The results from Figure 7 support the idea that workers 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, min $< j$ to min $\geq j$, there is generally a statistically significant effect that min $\geq j$ has a higher proportion of cooperation. For example, individuals coming from a group with the first period's minimum effort of ≥ 3 are one-third more likely (p<0.01) to cooperate than individuals coming from a group with a minimum effort of < 3. Secondly, when comparing within groups – for example, min $< j$ to min $< j + 1$ – although the effects are not statistically significant, we do observe that the proportion of cooperation is higher for min $< j + 1$. For example, individuals coming from a group with the first period's minimum effort of < 4 are one-ninth more likely (*n.s.*) to cooperate than individuals coming from a group with a minimum effort of < 3. Figure 8 subdivides the sample by the choice of individual effort levels in the first period. Individual effort choices are a poor predictor of cooperation, and we do not find any significant comparisons.

Furthermore, by running a logit regression of cooperation (1 if the individual cooperated, and 0 otherwise; see Table 10), we are able to draw the following conclusions. When looking at the sole effect of the individual effort choices, this has no significant effect on the likelihood of cooperation. However, when looking at the sole effect of the firm's minimum effort on the first period, this has a positive significant effect on the likelihood of cooperation. For each unit of higher minimum effort observed, the individual's log odds ratio of cooperating in the prisoner's dilemma game increases by 0.398 (p<0.05). These results may suggest that the individual's likelihood of cooperation is not based on whether the individual exerted a high effort in the first period of the coordination game but whether he came from a firm that coordinated well in the first period. When analyzing the multivariable logit regression (see Table 10), we can make the following conclusions. First, the three significant variables are individual choice in Period 1 (coefficient: 0.723, p<0.10), a firm's minimum effort in Period 1 (coefficient: 2.88, p<0.01), and the interaction effect of a firm's minimum effort in Period 1 with individual effort in period 1 (coefficient: -0.424, p<0.01). These results suggest that workers who choose higher effort levels in the 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, the subjects are not trying to take advantage of fellow subjects who seem to be more trusting. Workers are simply 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 the firm's low minimum effort is more likely to choose to defect.[8] The variables relating to Period 10's

[8]Recall that individual effort in Period 1 $\geq$ firm's minimum effort in Period 1. Therefore, this does not state the converse: workers who have initially chosen a low effort level and realized that the group's

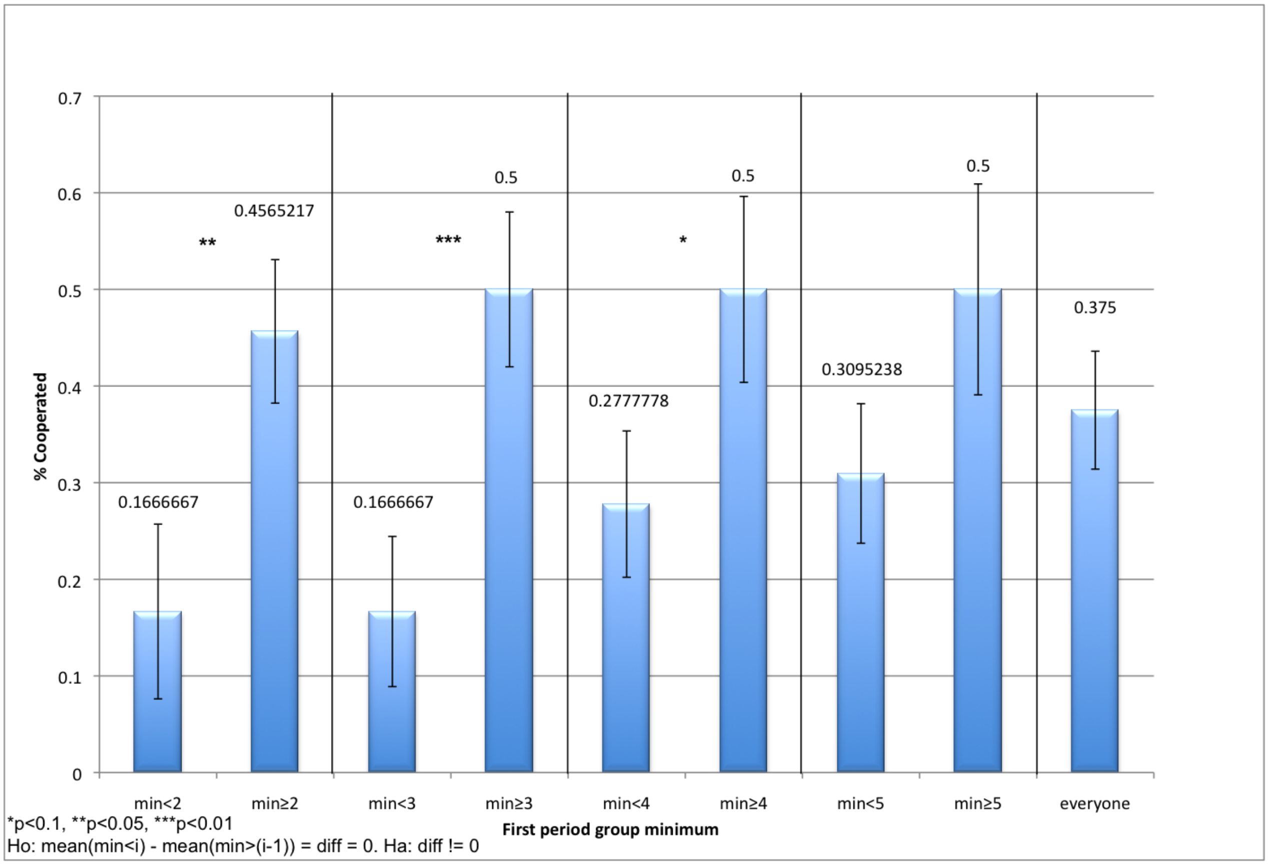

Figure 7: Comparing Average Cooperation Conditional on a Firm's Minimum Effort in the First Period

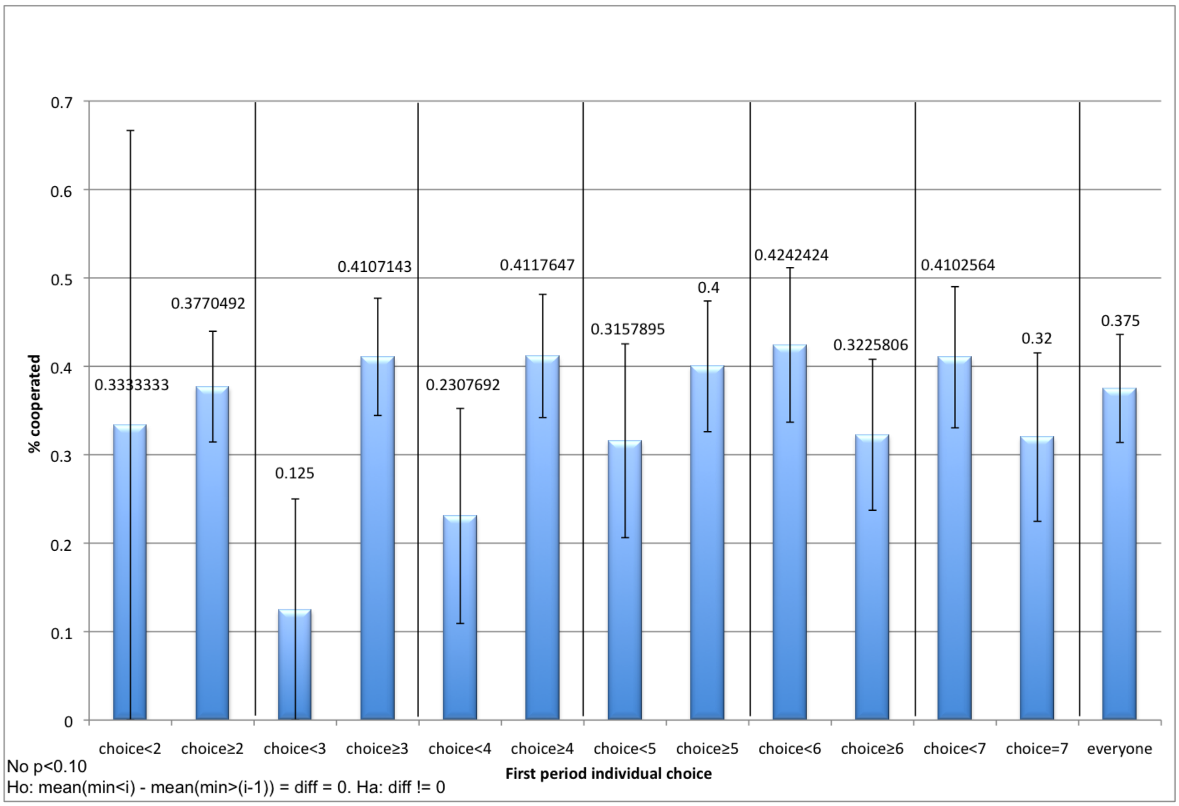

Figure 8: Comparing Average Cooperation Conditional on an Individual's Choice of Effort in the First Period

efforts are not significant, which suggests that the starting point is more important.

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)
Period 1 choice	0.041				0.723*
	(0.140)				(0.408)
Period 10 choice		0.228			-0.532
		(0.147)			(0.443)
Group min per 1			0.398**		2.880***
			(0.173)		(0.935)
Group min per 10				0.302*	0.003
				(0.169)	(1.248)
Group min per 1 x Per 1 choice					-0.434***
					(0.160)
Group min per 1 x Group min per 10					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 10: Logit Regression: Cooperation

In support of Hypothesis 2, we conclude that the subjects are more likely to cooperate in the prisoner's dilemma game if they were part of a group that had coordinated well in the coordination game.

5 Conclusion

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. These results are a Pareto improvement in everyone's payoff. Our results have many applications, in particular to organizational economics. An organizational culture of coordinating to an efficient outcome may help to promote cooperation even when there is no monitoring by the principal.

minimum effort level was higher than his effort level are more likely to take advantage of fellow workers in the cooperation treatment.

We also utilize and analyze the endogenous investment behavior. Investors invest most of their wealth to the higher performing firm in the competitive setting. But the investors provide low levels of investment when the firm converges to the lowest level of effort, even though the investors have no downside risk in the non-competitive setting.

We are concerned not only with the existence of an equilibrium or equilibrium selection but also the overall efficiency. We have shown that in our coordination game, 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 to do so. In the prisoner's dilemma game, the Pareto-efficient outcome is not an equilibrium, but an organization was able to achieve such an outcome more frequently for a greater social surplus due to its 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. We utilized a simple fixed-payment contract between the investors and firms, but a contract may indeed be state contingent or performance based. Different contracts may help to improve coordination. Furthermore, unlike our design, it would be interesting to see how well the firms in the one-firm treatment will coordinate if the investors are not allowed to invest until a later period. Of course, the idea of studying coordination and cooperation in different organizational structures can also be extended to different games as well, such as the battle of the sexes and the trust game.

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6 Appendix - not for publication

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

	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

	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 13: T-Test: Average Wasted Effort Per Period

First Period Firm Min	% Cooperated	SE	Num of Obs	P-value
min<2	0.1667	0.0904	18	0.0315
min≥2	0.4565	0.0743	46	
min<3	0.1667	0.0777	24	0.0071
min≥3	0.5000	0.0801	40	
min<4	0.2778	0.0757	36	0.0704
min≥ 4	0.5000	0.0962	28	
min<5	0.3095	0.0722	42	0.1393
min≥ 5	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: Comparing Average Cooperation Conditional on First Period Firm's Minimum

First Period Individual Choice	% Cooperated	SE	Num of Obs	P-value
choice<2	0.3333	0.3333	3	0.8810
choice≥2	0.3770	0.0626	61	
choice<3	0.1250	0.1250	8	0.1222
choice≥3	0.4107	0.0663	56	
choice<4	0.2308	0.1216	13	0.2355
choice≥4	0.4118	0.0696	51	
choice<5	0.3158	0.1096	19	0.5325
choice≥5	0.4000	0.0739	45	
choice<6	0.4242	0.0874	33	0.4092
choice≥6	0.3226	0.0853	31	
choice<7	0.4103	0.0798	39	0.4747
choice=7	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: Comparing Average Cooperation Conditional on First Period's Choice