# Incentive Contracts for Teams: Experimental Evidence*

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**Abstract**

This paper reports the results of an experiment on incentive contracts for teams. The agents, whose efforts are complementary, are rewarded according to a sharing rule chosen by the principal. Depending on the sharing rule, the agents confront endogenous prisoner's dilemma or stag-hunt strategic environments. Our main findings are as follows. First, when the agents cannot communicate, long-term or ongoing teams increase the likelihood of team cooperation. Long-term teams also raise the likelihood of a high payoff for the principal, suggesting that team cooperation is achieved at a lower cost when the agents are assigned to long-term teams. Second, in short-term team settings, communication between the agents increases the likelihood of team cooperation. Third, in long-term team settings and the lowest sharing rule, the endogeneity of the strategic environment – where a human principal chooses the sharing rule – decreases the likelihood of team cooperation, indicating the presence of negative reciprocity. (JEL Categories: C72, C90, D86, K10, L23.)

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# 1 Introduction

Group-based incentives are pervasive. In labor environments, workers are often organized as teams and rewarded according to their joint performance. As noted by Lazear and Shaw (2007), between 1987 and 1999, the percentage of firms with employees working in self-managed work teams increased from 27 percent to 72 percent. Over the same time period, the use of gain-sharing and other forms of group-based incentive schemes in large firms grew from 26 percent to 53 percent. Similarly, many professional service organizations, including law firms, accounting firms, and medical practices, operate as partnerships where net revenues are divided among the members (Kandel and Lazear, 1992; Gaynor and Pauly, 1990; Gilson and Mnookin, 1985; Leibowitz and Tollison, 1980).[1]

Incentive schemes that rely on collective rewards are susceptible to free riding. When each individual agent bears a private cost of effort but shares the benefits of her effort with others, there is a natural incentive to underinvest in effort or "shirk" (Alchian and Demsetz, 1972).[2] Early theoretical work on moral hazard in teams studied static environments in which the agents interact just once (see for instance, Hölmstrom, 1982).[3] Real-world settings often involve long-term or ongoing interaction among team members, however. Ongoing interaction can create implicit incentives by facilitating peer monitoring, since the threat of peer sanctions may render shirking unprofitable. As a result, cooperation (hard work) among team members may arise (Roth, 1975; Aumann and Shapley, 1976, 1994; Rubinstein, 1979; Axelrod, 1984; Abreu, 1988).[4]

[1] See also Ribstein (2010) and Galanter and Henderson (2008).

[2] See Gaynor and Pauly (1990) and Leibowitz and Tollison (1980) for empirical studies of free riding in medical practices and law-firm partnerships, respectively.

[3] See also Hart and Hölmstrom (1987), Radner (1986), Hölmstrom and Milgrom (1990), Varian (1990), Kandel and Lazear (1992), and Itoh (1993, 1992).

[4] In team contexts,"cooperation" corresponds to hard work by all team members. Referring to prisoner's dilemma games, Axelrod (1984, p.11) notes, "With an indefinite number of interactions, cooperation can emerge." (See also Axelrod, 1980a, 1980b, and Axelrod and Hamilton, 1981.) Roth (1975), Aumann and Shapley (1976), and Rubinstein (1979) provide seminal theoretical analyses of infinitely-repeated games without discounting; Abreu (1988) presents a general analytical framework for infinitely-repeated games with discounting; Friedman (1971) studies repeated games with discounting focused on paths supportable by Cournot-Nash punishments; Radner (1986) analyzes repeated partnership games with imperfect monitoring; Rayo (2007) investigates team incentives in a repeated-interaction framework with transfers among agents.

Building upon the insights from the literature on infinitely-repeated games, Che and Yoo (2001) demonstrate how principals can harness the power of long-term teams when agents are rewarded for their joint performance. Their framework involves three players, a principal and two identical agents with complementary efforts. The agents, who work as a team, are rewarded according to a sharing rule chosen by the principal. The sharing rule endogenously determines the strategic environment confronted by the agents and the agents' payoffs. Specifically, in this *effort-complementarity setting*, low-powered and high-powered sharing rules generate prisoner's dilemma and stag hunt environments, respectively. The framework involves multiple equilibria.[5] Imposing the Pareto-dominance refinement, Che and Yoo (2001) show that low-powered incentive contracts, coupled with long-term team interaction, allow the principal to successfully induce agents' cooperation at the minimum cost. Equilibrium selection is largely an empirical question, however.

We extend this literature by experimentally studying the factors that affect the likelihood that agents cooperate when rewarded for joint performance, and the principal's cost of achieving team cooperation. We first construct a simple framework that captures Che and Yoo's (2001) insights regarding the effects of long-term teams on agents' cooperation and principal's choice of sharing rules.[6] We then replicate this framework in the lab.

Our experimental design includes two team treatments, short-term teams (characterized by a one-shot interaction between the agents) and long-term teams (characterized by an ongoing interaction between the agents). We also study two communication treatments, no communication between the agents, and two-way agent-agent communication where the agents state their intentions (immediately after receiving the sharing offers from the principal, and before deciding whether to cooperate and work hard). Finally, we investigate two strategic-environment treatments, endogenous and exogenous. For the endogenous strategic environment, an actual subject (representing the principal) chooses the sharing rule. For the exogenous strategic environment, we take these very same sharing rules and administer them to a sepa-

[5]The prisoner's dilemma game has multiple equilibria in infinitely-repeated settings. The stag-hunt game has multiple equilibria in both one-shot and infinitely-repeated settings.

[6]In Che and Yoo's (2001) framework, the agents' efforts affected the probability of a project's success. The probabilistic feature of Che and Yoo's (2001) model was not essential for the purpose of our paper. Then, we decided to adopt a deterministic framework, where strictly positive revenues are determined by agents' effort with certainty.

rate set of subjects in an exogenous fashion (through the computer). A combination of these treatments generates eight experimental conditions. The subjects, a pool of undergraduate and graduate students from Harvard University, were paid according to their performance.

The rationale for adopting these experimental treatments is as follows. First, in theory, *long-term (ongoing) interaction* among agents should enhance the principal's ability to induce team cooperation, and to achieve this goal at the minimum cost. No experimental test has been conducted to assess these theoretical predictions. Second, the theoretical framework is characterized by effort complementarity. Depending on the sharing rule chosen by the principal, the agents confront either an *endogenous* prisoner's dilemma or a stag-hunt game. The patterns of cooperation observed in previous experimental studies of exogenous prisoner's dilemma and stag-hunt games (Dal Bó and Fréchette, 2011; Duffy and Feltovich, 2002) might be different when agents play endogenously-constructed games. In fact, previous experimental work on stag-hunt games with endogenous payoffs suggest the presence of *reciprocity* (Landeo and Spier, 2012, 2009). Ours is the first experimental study of the effects of the endogeneity of the strategic environment on team cooperation.[7]

Third, the theoretical framework involves multiple equilibria. The experimental literature on one-shot prisoner's dilemma and stag hunt games with exogenous payoffs (Duffy and Feltovich, 2002; Cooper et al., 1992) emphasizes the role of non-binding pre-play *communication* as a coordination device. However, the effects of communication between the agents on the cost of achieving team cooperation (and hence, on the principal's choice of sharing rules) and team cooperation in ongoing-interaction environments have not been previously explored, theoretically or empirically. Importantly, ongoing team interaction, endogenous design of agents' payoffs, and agents' communication are empirically-relevant features of teams.

Our results yield important insights regarding incentive contracts for teams and organizational design. First, as predicted by the theory, we show that ongoing interaction among team members positively affects the principal's payoff. The principal receives a direct benefit from greater team cooperation, since the agents' hard

[7] Charness et al. (2007) experimentally investigate one-shot prisoner's dilemma games with endogenous transfers made in the first period by the *same* players who move in the second period; Schneider and Weber (2013) experimental study finitely-repeated prisoner's dilemma games with endogenous partners' interaction duration decided in the first period by the *same* players who move in later periods.

work raises the value of the principal's residual claim. The principal also obtains an additional indirect benefit, since team cooperation may be successfully induced with a less generous sharing rule. Second, our analysis suggests that, in short-term team settings, better communication among the agents leads to higher levels of team cooperation. Although fostering communication among team members does not significantly increase the principal's payoff (i.e., communication among agents is an imperfect substitute for long-term team interaction), our findings do indicate that communication among agents helps the principal induce cooperation. Finally, agents were particularly uncooperative when the principal, played by a human subject, proposed a low sharing rule. This finding suggests that when the principal's behavior is perceived as unkind by the agents, negative reciprocity is triggered.

Our paper is motivated by workers with complementary efforts organized as teams. However, our insights might also apply to contexts in which agents face joint liability for the harms that their activities cause. Joint liability is prevalent in a variety of situations including the violation of emission standards and the infringement of antitrust regulations by group of manufacturers (Kornhauser and Revesz, 1994, 1989; Segerson, 1988; Feess and Walzl, 2004; Spagnolo, 2003). As with group rewards for team production, the design of group punishment schemes affects the strategic environment faced by the agents. Our results might also contribute to the understanding of group borrowing environments (Varian, 1990; Che, 2002).[8]

The rest of the paper is organized as follows. Section 2 discusses previous experimental literature. Section 3 outlines the theoretical model and predictions. Section 4 discusses the qualitative hypotheses. Section 5 presents the experimental design. Section 6 examines the results from the experimental sessions. Section 7 provides concluding remarks.

# 2 Related Literature

Nalbantian and Schotter (1997) provide seminal work on exogenously-administered group-incentive schemes in one-shot environments. Consistent with Hölmstrom (1982), free-riding occurs under revenue-sharing schemes.[9] Although production

[8] See Che (2002) for additional applications.

[9] Meidinger et al. (2003, 2000) extend this literature by incorporating the role of the principal in Nalbantian and Schotter's (1997) environment, and allowing for ability heterogeneity among team members. Their findings indicate the presence of free-riding, and that free-riding is exacerbated

complementarity among team members is the main reason for adopting team work (Lazear and Shaw, 2007), most experimental studies on teams involve production technologies in which the agents' efforts are perfect substitutes (Charness, 2011). An exception is Brandts and Cooper (2007). They investigate the effects of communication between the principal and team members using finitely-repeated games and Leontief production, and find that communication raises group performance. Goerg et al.'s (2009) work also involves production complementarity. In one-shot environments, they find that higher efficiency is achieved under an exogenously-administered discriminatory reward mechanism than under a cost-equivalent symmetric compensation scheme.[10] Our work extends this literature by studying team cooperation and the cost of achieving team cooperation in an environment that allows for the interplay of three empirically-relevant features of teams: Ongoing team interaction, agents' communication, and endogenous design of agents' payoffs.

Our paper is also related to the work on infinitely-repeated games and the literature on communication. There is a small experimental literature on infinitely-repeated prisoner's dilemma games with exogenous payoffs. Dal Bó (2005) and Dal Bó and Fréchette (2011) provide evidence on the positive effects of ongoing interaction and subjects' experience on cooperation. (See also Normann and Wallace, 2012; Blonski et al., 2011; Duffy and Ochs, 2009; Camera and Casari, 2009.)[11] Ex-

by inequitable offers. Importantly, given that a treatment with exogenously-administered offers is not included, a causality effect of payoff endogeneity (i.e., principal's intentionality as a trigger of agents' reciprocity) cannot be evaluated.

[10]Note that these findings might not hold in an environment in which the principal is an active player. Discriminatory offers might be perceived as "unkind" by the agents, and hence, might trigger negative reciprocity. (See the discussion on social preferences below.) Field experiments on teams include Bandiera et al.'s (2012) work on the effects of group incentives on workers' effort and team composition; and, Hossain and List (2012) and Fryer et al.'s (2012) study on the effects of contract frames on workers' effort in individual and team settings. (See List and Rasul, 2010, for a survey on field experiments in labor settings.) Empirical studies include Ichniowski et al.'s (1997) work on the effects of groups of employment practices (use of teams, provision of employment security, among others) on productivity using steel finishing processes data. Public goods experiments with voluntary contribution mechanisms (Isaac and Walker, 1988) and our settings share some common elements: Group output might be interpreted as a public good (nonexcludable and shared equally according to a sharing rule determined by the principal). In contrast to our experimental environments, these public-goods settings do not involve endogenous prisoner's dilemma and stag-hunt games. (See Palfrey and Rosenthal, 1994, for an experimental study of infinitely-repeated public good environments.)

[11]Stag-hunt games have not been previously studied in infinitely-repeated settings.

perimental work on one-shot coordination and prisoner's dilemma games (see for instance, Cooper et al., 1992; Duffy and Feltovich, 2002) provide evidence of the role of communication as a coordination device. Cason and Mui's (2014) work on coordinated-resistance games is the only study involving infinitely-repeated games and communication. Their environment involves endogenous coordination games with Pareto-rankable N.E. and games in which the unique N.E. is Pareto-dominant or dominated. Their results suggest that infinitely-repeated interaction and communication increase coordination on the Pareto-efficient outcome. We extend this literature by studying the interaction between infinite repetitions and communication in prisoner's dilemma and stag-hunt games.

Finally, our work is connected with the literature on social preferences and reciprocity. Findings from experimental economics and social psychology suggest the presence of "regard for others" (interdependent preferences). Perceived unkindness or unfairness may trigger negative reciprocity (Sobel, 2005).[12] Moreover, reciprocity considerations tend to be strongly elicited when the other player is a human subject who has a stake in the game, i.e., when the other player's actions reflect intentionality (Blount, 1995). In principal-agent settings, Fehr et al.'s (1998) findings suggest the presence of reciprocity on agents' responses to the principal's offers.[13] In contractual environments, Landeo and Spier's (2009) results indicate that reciprocity influences the seller's contract design and the buyers' coordination on the Pareto-efficient equilibrium. Our paper extends this literature by studying the effects of agents' reciprocity considerations in infinitely-repeated team environments.

# 3 Theoretical Framework

This section describes the theoretical framework and numerical examination used in our experimental design.[14]

[12] Sobel (2005) defines reciprocity as "the tendency to respond to perceived kindness with kindness and perceived meanness with meanness and to expect this behavior from others."

[13] See also Berg, et al. (1995) and Gächter and Fehr (2001) for a survey on work on fairness in labor settings.

[14] See the Appendix for a formal analysis.

## 3.1 General Setup

The framework involves three risk-neutral players, a principal and two identical agents (agents 1 and 2) who work together and are rewarded for their joint performance. The model has two stages. In Stage 1, the principal chooses the sharing rule $x$, i.e., the percentage of future revenues allocated to each agent. The sharing rule is observed by both agents. In Stage 2, the agents play an "Effort Stage-Game," i.e., they choose how hard to work, and revenues are realized. Specifically, the agents simultaneously make binary effort decisions whether to work hard or shirk. For each agent, the cost of working hard is $e > 0$. (The cost of shirking is normalized to zero.) Letting $k \in \{0, 1\}$ be the effort of agent 1 and $l \in \{0, 1\}$ be the effort of agent 2, the revenues in each round are denoted by $R_{kl}$ and satisfy $R_{11} > R_{10} = R_{01} \geq R_{00}$. Importantly, we assume that agents' efforts are complementary. Specifically, agent $i$'s hard work (weakly) increases agent $j$'s productivity gain from working hard: $R_{11} + R_{00} \geq R_{10} + R_{01}$.[15] The revenues are realized and divided among the principal and the agents as specified by the sharing rule; each agent receives $xR_{kl}$ and the principal receives $(1 - 2x)R_{kl}$.[16] We assume that working hard is socially efficient, and refer to the situation in which both agents decide to work hard as "agents' cooperation."

We study short-term and long-term team settings. In the short-term team setting, Stage 2 involves a one-shot interaction between the agents (i.e., the Effort Stage-Game is played once). In the long-term team setting, Stage 2 involves an ongoing interaction between the agents (i.e., the Effort Stage-Game is played for infinitely-many rounds). In each round, the agents simultaneously choose their effort levels. They subsequently observe the effort that was chosen by the other agent. So, in the long-term team setting, the agents can mutually monitor each other over time.[17] In the long-term team setting, at the conclusion of each round, a random

[15] In Che and Yoo (2001), the agents' efforts influence the probability of project's success. In the optimal contract, the agents are paid nothing if the project fails and a positive wage if it succeeds. Our model is a deterministic version of theirs. To see why, suppose that $R$ is the revenue from a successful project, and let the probability of success be $p_{kl} = R_{kl}/R$. Our sharing rule is equivalent to paying workers a wage $xR$ if the project succeeds and nothing if the project fails.

[16] Implicitly, we are assuming that the principal observes the revenues generated by the team but does not observe the agents' individual effort decisions (or this information is not verifiable).

[17] Mutual monitoring is an empirically-relevant feature of team production. Given mutual observability, the principal could require the agents to report their observations. We abstract from this possibility by assuming that any communication between the principal and the agents is extremely

Table 1: Agents' Payoffs Matrix for the Effort Stage-Game[a]

| | Work Hard (W) | Shirk (S) |
|---|---|---|
| Work Hard (W) | $344x - 38, 344x - 38$ | $200x - 38, 200x$ |
| Shirk (S) | $200x, 200x - 38$ | $100x, 100x$ |

*Notes*: [a]This stage game is played once in the short-term team settings, and is infinitely repeated in the long-term team settings.

process determines whether the interaction ends or continues for another round. Specifically, the game continues with probability $\delta \in (0, 1)$ in each round. Hence, $\delta$ might be interpreted as a measure of the (expected) duration of team interaction.[18] Finally, in the long-term team setting, we restrict the sharing rule to be time invariant (or memoryless), i.e., the sharing rule $x$ chosen by the principal in Stage 1 applies to all rounds of the Effort Stage-Game in Stage 2. This assumption makes the Stage 2 for the short-term and long-term team settings comparable, and allows us to isolate the effect of long-term teams on agents' cooperation.[19]

## 3.2 Numerical Examination

We now describe the numerical examination adopted in our experimental design.[20] The revenues are $R_{11} = 344$, $R_{01} = R_{10} = 200$, and $R_{00} = 100$. The agent's cost of effort is $e = 38$ if he works hard and 0 if he shirks. In the long-term team setting, the probability that the agents' interaction will continue to the next round is $\delta = .75$. Table 1 shows the agents' payoff matrix for the Effort Stage-Game under a sharing rule $x$. This stage-game is played just once in the short-term team setting, and is played repeatedly in the long-term team setting.

Due to effort complementarity, depending on the sharing rule chosen by the

costly.

[18]The probability $\delta$ can also be interpreted as a common discount factor for the two agents.

[19]A similar assumption was adopted by Che and Yoo (2001).

[20]Our numerical examination satisfies all of the model's assumptions and, therefore, the predictions derived from these assumptions hold. From a behavioral point of view, however, a numerical examination different from the one presented here might affect the results.

principal, the Effort Stage-Game in Table 1 has either a prisoner's dilemma or a stag-hunt structure.[21] Specifically, when the sharing rule $x \in \left(\frac{38}{244}, \frac{38}{144}\right) \approxeq (.16, .26)$, the Effort Stage-Game is a prisoner's dilemma game. Although the agents would be jointly better off cooperating with each other and working hard, shirking is a strictly dominant strategy for each agent.[22] When the sharing rule is in a higher range, $x \in \left(\frac{38}{144}, \frac{38}{100}\right) \approxeq (.26, .38)$, the Effort Stage-Game is a stag-hunt game with two pure-strategy Nash equilibria, (Work Hard, Work Hard) and (Shirk, Shirk). In this "assurance game," an agent would choose to work hard only if he is sufficiently confident or "assured" that the other agent will work hard as well. The two Nash equilibria are Pareto rankable from the agents' perspective: The (Work Hard, Work Hard) equilibrium is better for both agents than the (Shirk, Shirk) equilibrium.[23] Sharing rules greater than $x = .31$ (but lower than .38) generate (Work Hard, Work Hard) as the risk-dominant Nash equilibrium (Harsanyi and Selten, 1988).[24]

To reduce subjects' computational efforts, we restrict the sharing rules to $x \in \{.20, .25, .30, .35\}$. The four different Effort Stage-Game matrices associated with these sharing rules represent the four different choices available for the principal in our experimental environment.[25] This sharing rule set exhibits several important features. First, when the sharing rule is equal to .20 or .25, the Effort Stage-Game has a prisoner's dilemma structure; when the sharing rule is equal to .30 or .35, the Effort Stage-Game has a stag-hunt structure. Second, sharing rules equal to .30 and .35 generate (Work Hard, Work Hard) as risk-dominated and risk-dominant Nash equilibria, respectively. Third, a sharing rule equal to .25 yields a payoff matrix identical to that used in Dal Bó and Fréchette's (2011) experimental study of the infinitely-repeated prisoner's dilemma in environments with exogenous payoffs,

[21] In the absence of effort complementarity, only the prisoner's dilemma will be present.

[22] When $x < \frac{38}{244}$ the game is not a prisoner's dilemma. Although shirking is a strictly dominant strategy, it *jointly optimal* for the agents to shirk.

[23] So-called "strategic uncertainty" arises from the conflict between the players' common motive to coordinate on (Work Hard, Work Hard) and earn $(344x - 38)$ each and the private motive to avoid the "risk" of getting $(200x - 38)$ if the other person shirks.

[24] A sharing rule $x > .38$ creates an environment where working hard is a strictly dominant strategy for the agents.

[25] Each matrix displays the players' payoffs associated with the specific value of $x$ and $e = 38$. The principal's task is to choose one of the four possible matrices. This experimental design allows us to reduce subjects' computational requirements, and to minimize the presence of unnecessary noise in the data due to computational errors. See the Experimental Design section for more details, and the sample instructions provided in the Appendix.

Table 2: Game Structure and Equilibria for Stage 2 (For Each Sharing Rule)

| | Sharing Rule | Game Structure[a] | Equilibria |
|---|---|---|---|
| Short-Term Team Setting | | | N.E. |
| | .20 | P.D. | $(S, S)$ |
| | .25 | P.D. | $(S, S)$ |
| | .30 | Stag-Hunt | $(S, S)$, $(W, W)$ |
| | .35 | Stag-Hunt | $(S, S)$, $(W, W)$ |
| Long-Term Team Setting | | | S.P.N.E.[b] |
| | .20 | P.D. | $(S, S)$, $(W, W)$ |
| | .25 | P.D. | $(S, S)$, $(W, W)$ |
| | .30 | Stag-Hunt | $(S, S)$, $(W, W)$ |
| | .35 | Stag-Hunt | $(S, S)$, $(W, W)$ |

*Notes*: [a]P.D. stands for prisoner's dilemma; [b]S.P.N.E. stands for subgame-perfect Nash equilibrium; with sharing rules equal to .20 and .25, $(W, W)$ are the equilibrium actions sustained by grim-trigger strategies in the long-term team settings.

and allows us to compare our findings to theirs. Fourth, in the long-term team setting, sharing rules equal to .20 and .25 generate (Work Hard, Work Hard) as risk-dominant actions (see Blonski and Spagnolo, 2001; Blonski et al., 2011)[26] at two different levels of cooperation payoffs (Dal Bó and Fréchette, 2011).[27] Finally, from a behavioral point of view, these sharing rules generate payoffs for the three players that are large enough to trigger subjects' attention and effort, and simple enough to minimize subjects' cognitive costs.

Table 2 summarizes the equilibria of Stage 2. When the sharing rule is equal to

[26]Consider a prisoner's dilemma game. Let (r, s, t, p) be the payoffs for player 1 from (player 1's action, player 2's action) equal to (W, W), (W, S), (S, W), and (S, S), respectively. Following Blonski and Spagnolo (2001) and Blonski et al. (2011), the critical value of $\delta$ over which cooperation is risk dominant is determined by $\delta\frac{r-p}{1-\delta} \geq t - r + p - s$, i.e., it is obtained by incorporating the short-run disincentive to cooperate $(p - s)$ to the short-run incentive to defect including in the standard approach to assess sustainability of cooperation. When sharing rules are equal to .20 and .25, the critical values are .71 and .39, respectively. Given that our numerical examination uses $\delta = .75$, cooperation is a risk-dominant action under sharing rules equal to .20 and .25.

[27]In our setting, cooperation payoffs refer to the agents' payoffs under (Work Hard, Work Hard). Dal Bó and Fréchette (2011) find that cooperation payoffs influence the likelihood of agents' cooperation.

.20 and .25, the short-term team setting (one-shot Effort Stage-Game) has a unique equilibrium where both agents shirk.[28] In the long-term team setting (infinitely-repeated Effort Stage-Game), however, cooperation – (Work Hard, Work Hard) – can be sustained in equilibrium by grim trigger strategies. When, the sharing rules are equal to .30 and .35, on the other hand, both cooperation – (Work Hard, Work Hard) – and (Shirk, Shirk) are equilibria in the short-term and long-term team settings.

The next two propositions characterize the equilibria for the entire game in short-term and long-term team settings.

PROPOSITION 1. *In short-term team settings, there are multiple subgame-perfect Nash equilibria. In some equilibria the agents work hard (cooperate) and in other equilibria the agents shirk. In the cooperation equilibria, the principal chooses a sharing rule* $x \in \{.30, .35\}$ *and both agents decide to work hard. In the shirking equilibrium, the principal chooses a sharing rule* $x = .20$ *and both agents decide to shirk.*

There are multiple subgame-perfect Nash equilibria in the short-term team setting. If the Pareto-dominance refinement holds in Stage 2, i.e., if the agents coordinate on the equilibrium that is in their joint interest in every subgame, then the principal can successfully induce agents' high performance by choosing a sharing rule equal to .30. If, on the other hand, the agents play only risk dominant equilibria in Stage 2, or if the agents rationally decide to"punish" the principal for choosing low sharing rules by playing the (shirk, shirk) equilibrium in Stage 2, then the principal would rationally choose a sharing rule of .35. There is also a shirking equilibrium where the principal chooses the lowest possible sharing rule, .20.[29] The preferred

[28] There are also mixed-strategy equilibria and equilibria with asymmetric strategies in Stage 2. We restrict attention to pure-strategy equilibria.

[29] Note that a sharing rule equal to .30 induces shirk and work-hard Nash equilibria in Stage 2, but only the work-hard equilibrium can be part of a subgame-perfect Nash equilibrium. The reason is that a sharing rule equal to .20 generates a payoff for the principal equal to 60, a sharing rule equal to .30 and shirking by the agents will generate a payoff for the principal equal to 40, which is strictly lower than 60. Hence, this play cannot be part of a subgame-perfect Nash equilibrium. Similar logic applies to a sharing rule equal to .35. A sharing rule equal to .25 is a strictly dominated strategy for the principal. Since the agents will shirk in Stage 2 with sharing rules equal to .20 and .25, the principal is better off choosing a sharing rule equal to .20.

equilibrium for the principal involves a sharing rule equal to .30 and .35, under the Pareto- and risk-dominance refinements, respectively.

PROPOSITION 2. *In long-term team settings, there are multiple subgame-perfect Nash equilibria. In some equilibria the agents work hard (cooperate) and in other equilibria the agents shirk. In the cooperation equilibria, the principal chooses a sharing rule* $x \in \{.20, .25, .30, .35\}$ *and both agents decide to work hard. In the shirking equilibrium, the principal chooses a sharing rule* $x = .20$ *and both agents decide to shirk.*

There are multiple subgame-perfect Nash equilibria in the long-term team setting. If the agents could coordinate on shirking when offered a sharing rule equal to .20, then they might induce the principal to choose a sharing rule equal to .25. Similarly, if the agents could coordinate on shirking for all sharing rules below .35, then they might succeed in getting the principal to choose the highest sharing rule, .35.[30] There is also a shirking equilibrium where the principal chooses the lowest sharing rule, .20. The preferred equilibrium for the principal involves a sharing rule equal to .20, under the Pareto- and risk-dominance refinements.

Table 3 summarizes the results of Propositions 1 and 2.

# 4 Qualitative Hypotheses

HYPOTHESIS 1. *Long-term team settings will increase the likelihood of team cooperation (hard work) and will reduce the principal's cost of achieving team cooperation.*

In short-term team settings, non-cooperation (shirking) is the unique equilibrium outcome when the sharing rule equals .20 and .25. In contrast, cooperation (hard work) and non-cooperation (shirking) are both equilibrium outcomes when the sharing rule equals .30 and .35. Cooper et al.'s (1990) work on one-shot coordination games with exogenous payoffs suggests that risk-dominance is generally the equilibrium selection criterion chosen by subjects when there are multiple equilibria. In our settings, the cooperation equilibrium is risk-dominant only when the sharing rule is .35. Then, we might expect that cooperation will be obtained when the sharing

[30]While shirking is Pareto dominated, shirking is also an equilibrium in Stage 2. There is also a working hard equilibrium where the principal chooses a sharing rule equal to .30.

Table 3: Equilibria for the Entire Game
(Principal's Sharing Rules and Agents' Responses)

| | Principal's Sharing Rule | Agents' Responses |
|---|---|---|
| Short-Term Team Setting | | N.E. |
| | .20 | $(S, S)$ |
| | .30 | $(W, W)$ |
| | .35 | $(W, W)$ |
| Long-Term Team Setting | | S.P.N.E.[a] |
| | .20 | $(S, S)$, $(W, W)$ |
| | .25 | $(W, W)$ |
| | .30 | $(W, W)$ |
| | .35 | $(W, W)$ |

*Notes*: [a]S.P.N.E. stands for subgame-perfect Nash equilibrium; with sharing rules equal to .20 and .25, $(W, W)$ are the equilibrium actions sustained by grim-trigger strategies in the long-term team setting.

rule equals .35 but not when it equals .20, .25, or .30. In long-term team settings, both cooperation and non-cooperation are equilibrium outcomes for all four sharing rules. Cason and Mui's (2014) work on infinitely-repeated coordinated-resistance games with endogenous payoffs suggests that ongoing interaction increases the likelihood of the efficient outcome. In our settings, the cooperation equilibrium is Pareto-dominant for all four sharing rules. Then, we might expect that cooperation will be obtained across sharing rules.[31]

Hence, long-term team settings will increase the likelihood of cooperation in both prisoner's dilemma and stag-hunt strategic environments. Anticipating this effect, the strategic principal will lower his sharing rule. As a result, the cost of achieving team cooperation will be lower in long-term team settings.[32] It is worth noting that

[31]Dal Bó and Fréchette's (2011) work on infinitely-repeated prisoner's dilemma with exogenous payoffs suggests that high levels of cooperation arise when this outcome is risk dominant, and the probability of continuation and payoffs from cooperation are high enough. In our prisoner's dilemma settings, although the cooperation equilibrium is risk-dominant under sharing rules equal to .20 and .25, the agents' payoffs from cooperation are higher under a sharing rule equal to .25. Then, the likelihood of cooperation might be higher when the sharing rule equals .25.

[32]If the principal believes that low sharing rules might reduce the likelihood of team cooperation

previous experimental work on the effects of communication in one-shot prisoner's dilemma and stag-hunt games suggests that cooperation will be more frequent in communication environments (Duffy and Feltovich, 2000).[33] Then, the effects of long-term teams on team cooperation and on the cost of achieving cooperation might be stronger when the agents cannot communicate.

HYPOTHESIS 2. *Two-sided non-binding pre-play communication between the agents will increase the likelihood of team cooperation (hard work) and will reduce the principal's cost of achieving team cooperation.*

Experimental evidence on one-shot stag-hunt and prisoner's dilemma games suggests that coordination on the efficient outcome is facilitated by communication.[34] For instance, Cooper et al. (1992) study one-sided and two-sided pre-play communication in one-shot stag-hunt games, and find that two-way communication has a stronger effect.[35] In fact, two-sided communication practically guarantees that subjects coordinate on Pareto-dominant equilibria.[36] The robustness of these findings is confirmed by Landeo and Spier's (2009) work on one-shot stag-hunt games with endogenous payoffs.[37] Duffy and Feltovich (2002) investigate the effect of communication in one-shot stag-hunt and prisoner's dilemma games. They find that, although communication induces coordination in both games, it is more effective in stag-hunt games for which the Pareto-dominant outcome is also an equilibrium outcome. Cason and Mui (2014) study infinitely-repeated coordinated-resistance games with endogenous payoffs, and find that communication induces the players to coordinate on the efficient outcome.

In short-term team settings, cooperation is the efficient outcome across sharing rules but is the equilibrium outcome only under sharing rules equal to .30 and .35.

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due to negative reciprocity (Sobel, 2005) or weaker salience of the cooperation payoffs (Schelling, 1960), long-term team settings might not affect the sharing rule or the cost of achieving team cooperation.

[33] See Hypothesis 2 for a discussion of the effects of communication.

[34] See Farrell (1987), Aumann (1990), Farrell and Rabin (1996), Charness (2000), Crawford (1998).

[35] See Ochs (1995) for a survey of seminal experimental work on coordination games.

[36] Charness (2000) experimentally assesses Aumann's conjecture, and finds that communication does affect cooperation in stag-hunt games.

[37] Blume and Ortmann (2007) study coordination games with multiple players, and find that communication facilitates coordination.

Given the previous experimental findings in one-shot environments, we might expect that communication will increase the likelihood of team cooperation across sharing rules. Anticipating this effect, the strategic principal will lower his sharing rule. As a result, the cost of achieving team cooperation will be lower under communication.[38] In long-term team settings, cooperation is the Pareto-dominant equilibrium outcome across sharing rules. Given the previous experimental findings on infinitely-repeated settings, we might expect higher likelihood of cooperation under communication for all four sharing rules. Anticipating this effect, the strategic principal will lower his sharing rule. As a result, the principal's cost of achieving cooperation will be lower when agents can communicate.[39] Given that cooperation might be more frequent in long-term team settings (see Hypothesis 1), the effects of communication on team cooperation might be stronger in short-term team settings.

HYPOTHESIS 3. *In long-term team settings with prisoner's dilemma games generated by the lowest sharing rule, endogeneity will decrease the likelihood of team cooperation (hard work).*

In our experiment, the role of the principal is played by a human subject only in the endogenous strategic-environment conditions. If the agents perceive that the principal has been unkind, they may retaliate and punish the principal by "shirking" (Sobel, 1995).[40] A sharing rule equal to .20 represents the lowest possible sharing rule a principal can propose. As a result, this sharing rule might trigger negative reciprocity.[41] Given that the elicitation of agents' reciprocity considerations will

[38]Note that the principals might believe that low sharing rules will reduce the likelihood of team cooperation (due to negative reciprocity or payoff-salience issues). It is also plausible that the effects of communication on cooperation might be too weak under sharing rules equal to .20 and .25 (the sharing rules for which cooperation is not an equilibrium outcome). In those cases, the choice of a sharing rule by the principal and the cost of achieving team cooperation might not be affected by communication.

[39]If the principal believes that low sharing rules might reduce the likelihood of team cooperation due to negative reciprocity or payoff-salience issues, communication might not affect the sharing rule or the cost of achieving team cooperation.

[40]In our framework, the interests of the principal and the agents are aligned so retaliation by shirking is also costly for the agents.

[41]Note also that if the normative expectation about fairness is reflected by a 50-50 split of the pie between the principal and the team (a sharing rule equal to .25), then a 60-40 split of the pie (a sharing rule equal to .20) might be perceived by the agents as "unkind." It is also possible that "fairness" might be reflected by a sharing rule equal to .33 instead, i.e., a 33-33-33 split of the pie

be stronger in the presence of a human principal (Blount, 1995), we might expect that the likelihood of agents' cooperation will be lower in endogenously-generated prisoner's dilemma games. It is worth noting that the previous analysis primarily applies to long-term team settings for which a sharing rule equal to .20 and team cooperation under that sharing rule are equilibrium outcomes.

# 5 Experimental Design

We analyze the effect of long-term teams, non-binding pre-play communication between the agents, and strategic-environment endogeneity on team cooperation and the cost of achieving team cooperation. We specify the experimental setting in a way that satisfies the assumptions of the theory. To ensure control and replicability, a free-context environment is constructed.[42] Human subjects paid according to their performance are used in this study. A concern with our study, a concern that is common to all experimental research, is its external validity. Although our experiment cannot predict the effects of incentive contracts in richer environments, the experiment provides evidence regarding whether long-term team settings, non-binding pre-play communication and strategic-environment endogeneity in an environment such as the one we have structured here will have the predicted qualitative effects.[43]

The experimental design consists of two team treatments, two communication treatments, and two strategic-environment treatments. The team treatments are: Short-term teams (ST), where the agents play a one-shot game (one-shot interaction at Stage 2); and, long-term teams (LT), where the agents play an infinitely-repeated game (ongoing interaction at Stage 2). The communication treatments are: No-Communication (NC), where communication between the agents is not allowed; and, two-way agent-agent communication (C), where the agents state their inten-

between the principal, agent 1, and agent 2, respectively. In this case, only a sharing rule equal to .35 will be perceived by the agents as "fair." Hence, sharing rules lower than .35 will trigger agents' negative reciprocity in the presence of a human principal, and lower agents' cooperation will be observed in endogenous strategic-environments.

[42] If our findings in this simple environment do not conform to the theory, there is little hope that this theory can explain subjects' behavior in more complex settings (see Davis and Holt, 1993). Hence, our experiment might provide useful feedback to improve the theory.

[43] There is a trade-off between control and external validity. Experimental methods are complementary techniques to field data analysis.

Table 4: Experimental Conditions

| | Endogenous Strategic-Environment | Exogenous Strategic-Environment[a] |
|---|---|---|
| Short-Term Teams/No-Communication | EN/ST/NC | EX/ST/NC |
| | $[33, 99]$ | $[22, 99]$ |
| Short-Term Teams/Communication | EN/ST/C | EX/ST/C |
| | $[33, 99]$ | $[22, 99]$ |
| Long-Term Teams/No-Communication | EN/LT/NC | EX/LT/NC |
| | $[36, 432]$ | $[24, 432]$ |
| Long-Term teams/Communication | EN/LT/C | EX/LT/C |
| | $[36, 432]$ | $[24, 432]$ |

*Notes*: [a]In the exogenous conditions, each group includes 2 human subjects; number of subjects and total number of groups are in brackets (short-term and long-term team settings involve 1 round per match and 4 rounds per match on average, respectively; each setting includes 9 matches).

tions after learning the principal's decision and before making their own choices).[44] The strategic-environment treatments are exogenous (EX) and endogenous strategic-environments (EN). As described in Table 4, a combination of these treatments generates eight experimental conditions.

## 5.1 The Games

Procedural regularity is accomplished by developing a software program that permits subjects to play the game by using networked personal computers.[45] The experiment is a three-player, two-stage game. Subjects play the role of principal, agent 1, or agent 2.[46]

The benchmark game corresponds to the EN/ST/NC condition. Each match involves two stages. In the first stage, the principal chooses an Effort Stage-Game matrix among four possible matrices (corresponding to the four sharing rules). In

[44]A specific communication structure was imposed to provide useful feedback to game theorists. The only message that an agent can send to the other agent is about her *intended* choice.

[45]The software consists of 8 versions of the game, reflecting the eight experimental conditions. Software screenshots and a complete set of instructions are available upon request.

[46]The roles of agent 1 and agent 2 are similar.

the second stage, after observing the principal's decision, the agents play the Effort Stage-Game once (i.e., each agent chooses whether to work hard or shirk only once). We use neutral labels to denote the subjects' roles:[47] Player Gray, for the principal; and, Players Red and Blue, for agents 1 and 2, respectively. The players' choices are also labeled in a neutral way: Proposal 1, 2, 3, or 4 (referring to the Effort Stage-Game matrix for a sharing rule equal to .20, .25, .30., or .35, respectively) for the principal; and, Option A or C (referring to work hard or shirk, respectively) for the agents.[48] We use a laboratory currency called the "token" (90 tokens = 1 US dollar).[49]

Variations of the benchmark game satisfy the other experimental conditions:

(i) In the long-term team conditions, the agents play the Effort Stage-Game repeatedly. Following the experimental literature,[50] the infinitely-repeated game is implemented in the lab by using a random termination rule with $\delta = .75$. To maximize control over match length effects across sessions and long-term team conditions, the realization of the random variable "game continuation" per match is randomly pre-determined by the computer using $\delta = .75$ before the actual implementation of experimental sessions, and applied across sessions and long-term team conditions.

(ii) In the communication conditions, pre-play communication between the agents (through computer terminals) is allowed. Each agent has the option to inform her choice *intention* to the other agent. Communication occurs immediately after the information about the principal's proposal is provided to the agents, and before each agent reports her *actual* decision to the computer. The principal is not informed about the content of this communication;

(iii) In the exogenous strategic-environment conditions, the computer provides the

[47]Given the simplicity of the experimental environment, more realistic labels (for instance, employer and employees) are not necessary to improve subjects' understanding. Importantly, more realistic labels might generate unnecessary noise in the subjects' responses due to the degree of identification with the role described by the label.

[48]To facilitate subjects' understanding of the strategic environment, the instructions and software screens display the payoffs for Players Gray, Red, and Blue in colors gray, red, and blue, respectively. See the sample instructions in the Appendix for details.

[49]The use of tokens allows us to create a fine payoff grid that underlines the payoff differences among actions (see Davis and Holt, 1993).

[50]See Roth and Murnighan (1978) and Murnighan and Roth (1983) for seminal implementation; and, Dal Bó's (2005), Duffy and Ochs (2009), and Fréchette and Dal Bó's (2011) for recent implementations.

proposal in Stage 1. Subjects are informed that the proposal is provided by the computer. Each exogenous session is matched with a previously-run endogenous session, and the computer is programmed to follow the pattern of proposals made by the human principals in the corresponding endogenous session.[51] Finally note that both the exogenous and endogenous conditions include two stages.

## 5.2 The Experimental Sessions

We ran twenty-two 70- to 120-minute sessions[52] of 6 to 18 subjects each (two or three sessions per condition, 230 subjects in total)[53] at experimental laboratories of Harvard University.[54] The subject pool was recruited from undergraduate and graduate classes at Harvard University, by posting advertisements on public boards and on an electronic bulletin board.[55]

[51] To make the endogenous and exogenous conditions comparable, (i) for each exogenous session, the formation of groups (pair of agents in this case) replicated the randomization process of forming groups followed by the corresponding endogenous session; (ii) to ensure that the sequence of proposals received by each individual agent in the exogenous and endogenous conditions followed the same pattern, each agent in the exogenous conditions was matched with an agent in the corresponding endogenous condition and followed the same pattern of sharing rules (and matching process with other agents).

[52] Note that the exogenous strategic-environment treatments did not involve a human principal, the short-term team treatment involved only one-round Stage 2 per match, and the no-communication treatment did not involve intention decisions. Then, the sessions run on condition EX/ST/NC lasted 70 minutes.

[53] The endogenous strategic-environment sessions (three-player group sessions) involved 9 to 18 subjects; the exogenous strategic-environment sessions (two-player group sessions) involved 6 to 12 subjects. Only the EN/ST/C and EX/ST/C conditions involved two sessions.

[54] A criticism to our lab implementation of infinitely-repeated games might be related to the potential contagion effects (Kandori, 1992) due to the number of subjects per session and the random-matching protocol for group formation (see Dal Bó, 2005). Note, however, that contrary to Kandori (1992), Duffy and Ochs's (2009) experimental findings on infinitely-repeated prisoner's dilemma games with exogenous payoffs do not suggest the presence of contagion effects in treatments where players are matched randomly. Importantly, in contrast to exogenous-payoff implementations of infinitely-repeated games, our implementation is characterized by endogenously-generated strategic environments. We believe that the diversity of game structures and payoff matrices that subjects confront in each match (due to the heterogeneity of the principal's sharing rule) reduces even further any potential contagion effects.

[55] The pool of subjects encompasses graduate and undergraduate students from a wide variety of fields of study.

At the beginning of each session, written instructions were provided to the subjects (see the appendix for a sample of instructions for the EN/LT/C condition). The instructions about the game and the software used were verbally presented by the experimenter to create common knowledge. Subjects were informed about the random process of allocating roles and about the randomness and anonymity of the process of forming groups. In the long-term team conditions, subjects were also informed about the random process of match continuation. Specifically, subjects were informed that the likelihood of continuation of the match to the next round was equal to .75,[56] that the computer randomly determined the realization of the random variable, and that this realization was common across groups within a match. Game structure, possible choices, and payoffs were common information among subjects.

Subjects were informed only about the game version that they were assigned to play and allowed to participate in one experimental session only. Subjects were also instructed that they would receive the dollar equivalent of the tokens they held at the end of the experiment, and they were informed about the token/dollar equivalence. Finally, subjects were required to fill out a short questionnaire to ensure their ability to read the information tables (see the appendix for a sample questionnaire for the EN/LT/C condition). The rest of the session was entirely played using computer terminals and the software designed for this experiment. Communication between players was done through a computer terminal, and therefore, players were completely anonymous to one another. Hence, this experimental environment did not permit the formation of reputations across rounds.

The experimental sessions included one practice match with one round and four rounds, for the short-term and long-term team settings, respectively.[57] Nine actual matches were included in the short-term and long-term team sessions. The number of rounds per match in the long-term team environments were randomly pre-determined using $\delta = .75$, and applied across sessions and long-term team conditions. Specifically, the round number per match was as follows: 4 rounds for the practice match; and, 7, 3, 4, 6, 4, 5, 2, 4, 1 rounds for matches 1, 2, ..., 9, re-

[56]This information allows us to control for subjects' beliefs about the likelihood of future interaction. See Dal Bó (2005).

[57]Note that the outcomes from the practice match were not considered in the computation of players' payoffs. Hence, during these practice matches, subjects had an incentive to experiment with the different options and hence, learn about the consequence of their choices.

spectively. Hence, long-term team sessions involve four rounds, on average, and a total number of rounds equal to 36. Note that theoretically, the expected number of rounds per match is equal to four (for $\delta = .75$). The average number of rounds per match, and the total number of matches is aligned with Dal Bó (2005). In that study, the average number of rounds (for the environments with $\delta = .75$) was 3.73 and the total number of matches was 10.

Before the practice match, every participant was randomly assigned a role. The roles remained the same during the entire session. At the beginning of each match, new three-subject groups were randomly and anonymously formed. In the long-term team sessions, the groups remained the same during all the rounds of a match.[58] The history of agents' actions and payoffs was provided to the agents during each round of a match corresponding to a long-term team session. At the end of each round, subjects received information only about their own group results and payoffs.[59] The average payoff was \$56, for an average time commitment of 90 minutes.[60] At the end of each experimental session, subjects received their monetary payoffs in cash.

# 6 Results

The main findings are reported in a series of results. Given that the data suggest learning across matches, only the last five matches are included in our analysis (see Tables A1–A6 in the Appendix for descriptive statics involving the complete data set). In addition, given that the matches in long-term team environments involve different number of rounds, and the frequency of team cooperation might be different across rounds, it is important to look separately at first rounds (Dal Bó and Fréchette, 2011). For brevity, we only report the analysis involving the first rounds of the last five matches. The qualitative results hold when all rounds of the last five matches are considered (see Tables A7–A11 in the Appendix). Observations correspond to the number of three-player and two-player groups, in endogenous and

[58]The computer was programmed to form groups taking into account this restriction and the maximization of the number of different groups per match in a nine-match session.

[59]Given the randomization process used to form groups, and the diversity of strategic environments and payoff matrices that subjects confronted due to the heterogeneity of the principal's sharing rule), it might be expected that the subjects would consider each actual match as an independent game.

[60]The participation fee was \$17 per hour.

Table 5: Descriptive Statistics

| Conditions | Princ.'s Sharing Rules | Agents' Actions | | Payoffs[b] | |
|---|---|---|---|---|---|
| | Mean/Mode[a] | (W, W) | (S, S) | Principal | Both Agents |
| **EN/ST/NC** | .28/.30 | .33 | .31 | 89.85 | 87.67 |
| [55] | (.04/.60) | | | (34.09) | (38.41) |
| **EN/LT/NC** | .28/.30 | .75 | .07 | 128.47 | 108.90 |
| [60] | (.04/.47) | | | (34.23) | (35.40) |
| **EN/ST/C** | .28/.30 | .55 | .07 | 116.91 | 98.40 |
| [55] | (.05/.53) | | | (31.73) | (40.12) |
| **EN/LT/C** | .27/.20 | .77 | .10 | 136.63 | 100.43 |
| [60] | (.06/.33) | | | (47.82) | (45.28) |
| **EX/ST/NC** | .28/.30 | .27 | .36 | 84.87 | 83.49 |
| [55] | (.04/.60) | | | (39.94) | (37.03) |
| **EX/LT/NC** | .28/.30 | .75 | .00 | 134.10 | 107.40 |
| [60] | (.04/.47) | | | (36.41) | (33.57) |
| **EX/ST/C** | .28/.30 | .53 | .20 | 107.93 | 97.56 |
| [55 | (.05/.53) | | | (33.64) | (42.51) |
| **EX/LT/C** | .27/.20 | .90 | .02 | 151.77 | 104.60 |
| [60] | (.06/.33) | | | (42.64) | (42.46) |

*Notes*: [a]The sharing rules provided by the computer in the exogenous sessions replicated the patterns of the endogenous sessions; standard deviations and mode frequencies are in parentheses; [b]standard deviations are in parentheses; sample sizes (total number of groups) are in brackets.

exogenous conditions, respectively.

## 6.1 Data Summary

Table 5 provides descriptive statistics (first rounds of last five matches). Regarding the endogenous conditions, the data suggest that long-term team settings increased team cooperation (the (W, W) rate), with a stronger effect in no-communication environments. Long-term team settings also raised the principal's payoff. Our findings also indicate that communication increased team cooperation, especially in short-term team settings, and raised the principal's payoff. The mode sharing rule chosen

Table 6: Frequencies of Principal's Sharing Rules and Agents' Actions

| Condition | Prisoner's Dilemma | | Stag-Hunt Game | | Total Sharing-Rule |
|---|---|---|---|---|---|
| | .20 | .25 | .30 | .35 | Decisions |
| **ST/NC** | .16 | .16 | .60 | .07 | 55 |
| EN | [.00, .89] | [.11, .89] | [.39, .03] | [1.00, .00] | |
| EX | [.00, .89] | [.00, .67] | [.36, .18] | [.75, .00] | |
| **LT/NC** | .10 | .30 | .47 | .13 | 60 |
| EN | [.00, .67] | [.78, .00] | [.86, .00] | [.88, .00] | |
| EX | [.67, .00] | [.72, .00] | [.75, .00] | [.88, .00] | |
| **ST/C** | .18 | .20 | .53 | .09 | 55 |
| EN | [.10, .30] | [.27, .09] | [.72, .00] | [1.00, .00] | |
| EX | [.00, .60] | [.09, .45] | [.79, .00] | [1.00, .00] | |
| **LT/C** | .33 | .27 | .13 | .27 | 60 |
| EN | [.55, .25] | [.81, .06] | [.88, .00] | [.94, .00] | |
| EX | [.75, .05] | [1.00, .00] | [1.00, .00] | [.94, .00] | |

*Notes*: Agents' actions rates are in brackets ((W, W) and (S, S) rates, respectively).

by the principal was equal to .30 across conditions, except for the long-term settings with communication for which the mode sharing rule was equal to .20. The patterns of cooperation frequencies and (implied) principal's payoffs[61] were similar in the exogenous conditions with one notable exception. In the long-term team setting with communication, the cooperation rate and the principal's payoff were higher in the exogenous condition.

Table 6 presents a more detailed description of the agents' actions and principal's sharing rule (first rounds of last five matches). For example, in the EN/LT/NC condition, principals chose a sharing rule equal to .25 in thirty percent of the total cases. In seventy-eight percent of the cases, both agents decided to work hard (team cooperation); and, in zero percent of the cases, both agents decided to shirk.

The data indicate that long-term team settings increased the frequency of team cooperation, especially in prisoner's dilemma games generated by a sharing rule equal to .25. Communication also raised the frequency of team cooperation in

[61] Remember that the role of the principal was played by a subject only in the endogenous conditions.

short-term team settings with stag-hunt games generated by a sharing rule equal to .30, and in long-term team settings with prisoner's dilemma games. These results suggest that communication has stronger effects when cooperation is an equilibrium outcome. Interestingly, when the strategic environment was endogenously constructed, the rate of agents' cooperation experienced an important reduction in long-term team settings with prisoner's dilemma games generated by a sharing rule equal to .20. The decline was especially strong in no-communication environments. These findings might indicate that offering the lowest possible sharing rule was perceived as unkind behavior, and hence, triggered agents' negative reciprocity. Regarding the sharing rules chosen by the principals, the data indicate that long-term team settings raised the frequency of prisoner's dilemma games (.32 vs. .40 and .38 vs. .60, short-term vs. long-term team settings, no-communication and communication, respectively). Communication also increased the frequency of prisoner's dilemma games, especially in long-term team settings for which cooperation is sustained in equilibrium (.32 vs. .38 and .40 vs. .60, no-communication vs. communication, short-term and long-term team settings, respectively).

## 6.2 Analysis

The analysis presented in this section corresponds to the first rounds of the last five matches. Our probit analysis involves standard errors that are robust to general forms of heteroskedasticity and, hence, account for the possible dependence of observations within session.[62] Marginal effects, which are more easily interpreted, are reported.[63]

## Team Cooperation

Table 7 presents the effects of long-term teams and agents' communication on the likelihood of team cooperation (hard work by both agents). We take pair of conditions and estimate probit models. Each probit model includes a treatment dummy and match as its regressors. The treatment dummy variable is constructed as follows. For example, for the probit model that assesses the effects of long-term teams in no-communication environments, the dummy variable takes a value equal to one

[62]Note that each person plays in nine matches and interacts with other players during the session. Then, sessions are used as clusters.

[63]Coefficients for all probit estimations are available upon request.

Table 7: Effects of Treatments on the Likelihood of Team Cooperation
(Probit Tests of Differences across Conditions)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Marginal Effects | Conditions | Marginal Effects |
| EN/ST/NC vs. | .42*** | EN/ST/NC vs. | .23** |
| EN/LT/NC | (.09) | EN/ST/C | (.11) |
| Observations | 115 | Observations | 110 |
| | | | |
| EN/ST/C vs. | .22 | EN/LT/NC vs. | .02 |
| EN/LT/C | (.18) | EN/LT/C | (.17) |
| Observations | 115 | Observations | 120 |
| | | | |
| EX/ST/NC vs. | .48*** | EX/ST/NC vs. | .26*** |
| EX/LT/NC | (.11) | EX/ST/C | (.07) |
| Observations | 115 | Observations | 110 |
| | | | |
| EX/ST/C vs. | .37*** | EX/LT/NC vs. | .15 |
| EX/LT/C | (.06) | EX/LT/C | (.10) |
| Observations | 115 | Observations | 120 |

*Notes:* Robust standard errors (using sessions as clusters) are in parentheses; *** and ** denote significance at the 1% and 5% levels, respectively; observations correspond to number of groups.

if the observation pertains to the EN/LT/NC condition, and a value equal zero if the observation pertains to the EN/ST/NC condition. Pooled data on these two conditions are used in the probit estimation.[64]

The effects of long-term teams on the probability of team cooperation are reported in the second column. Regarding the endogenous strategic environments, long-term teams significantly increase the likelihood of team cooperation when communication is not present ($p$-value $< .01$). In fact, as a result of long-term teams, a higher team cooperation rate is observed: 75 versus 33 percent for the EN/LT/NC and EN/ST/NC conditions, respectively.[65] The findings under exogenous strategic-

[64]The probit models reported in Tables 8–11 are constructed in similar way.
[65]The variable match was not significant for any probit model.

environments indicate significant effects of long-term teams on the likelihood of team cooperation in no-communication and communication settings ($p$-value $< .01$ in both communication settings). The relevant comparisons are 90 vs. 53 percent, and 75 vs. 27 percent, for the long-term and short-term team settings, no-communication and communication, respectively. These results provide support to Hypothesis 1.

RESULT 1: *When the agents cannot communicate with each other, long-term team settings significantly increase the likelihood of team cooperation. When the agents can communicate with each other and the strategic environment is exogenous, long-term team settings significantly increase the likelihood of team cooperation.*

The effects of communication on the probability of team cooperation are reported in the fourth column of Table 7. Regarding the endogenous strategic-environments, communication significantly increases the likelihood of team cooperation when short-term team settings are present ($p$-value $= .03$). The comparisons are 33 percent versus 55 for the EN/ST/NC and EN/ST/C conditions, respectively.[66] The exogenous strategic environments follow similar patterns ($p$-value $< .01$). Hence, our findings support Hypothesis 2 in short-term team settings.

RESULT 2: *In short-term team settings, communication between the agents significantly increases the likelihood of team cooperation.*

Note that our settings involve endogenously-generated prisoner's dilemma (under sharing rules equal to .20 and .25) and stag-hunt (under sharing rules equal to .30 and .35) strategic environments. The effects of long-term teams and agents' communication might differ across strategic environments. We will now strengthen our understanding of the effects of long-term teams and agents' communication on team cooperation by studying prisoner's dilemma and stag-hunt environments separately.

Table 8 summarizes the probit estimations. The effects of long-term team settings are reported in the second and third columns. Regarding the endogenously-generated prisoner's dilemma games, our findings suggest a significant effect of long-term teams on cooperation, across communication settings ($p$-value $< .01$ and $p$-value $= .04$, no-communication and communication, respectively). The patterns

[66] The variable match was significant for EN/ST/NC vs. EN/ST/C and EN/LT/NC vs. EN/LT/C; coefficient, standard error, and $p$-value ($-.08$ , .02, $< .01$) and (.04, .02, .02), respectively.

Table 8: Effects of Treatments on the Likelihood of Team Cooperation in Prisoner's Dilemma and Stag-Hunt Environments
(Probit Tests of Differences across Conditions)

| Effects of Long-Term Teams | | | Effects of Communication | | |
|---|---|---|---|---|---|
| | P.D. | S.-H. | | P.D. | S.-H. |
| Conditions | Mg. Eff. | Mg. Eff. | Conditions | Mg. Eff. | Mg. Eff. |
| EN/ST/NC vs. | .53*** | .41** | EN/ST/NC vs. | .14 | .31* |
| EN/LT/NC | (.15) | (.14) | EN/ST/C | (.09) | (.14) |
| Observations | 42 | 73 | Observations | 39 | 71 |
| | | | | | |
| EN/ST/C vs. | .48** | .15 | EN/LT/NC vs. | .09 | .06 |
| EN/LT/C | (.22) | (.15) | EN/LT/C | (.25) | (.15) |
| Observations | 57 | 58 | Observations | 60 | 60 |
| | | | | | |
| EX/ST/NC vs. | n.a.[a] | .38** | EX/ST/NC vs. | n.a.[a] | .42*** |
| EX/LT/NC | | (.14) | EX/ST/C | | (.12) |
| Observations | | 73 | Observations | | 71 |
| | | | | | |
| EX/ST/C vs. | .81*** | .14 | EX/LT/NC vs. | .15 | .18* |
| EX/LT/C | (.07) | (.08) | EX/LT/C | (.09) | (.10) |
| Observations | 57 | 58 | Observations | 60 | 60 |

*Notes:* [a]Probit estimations were not possible because the frequency of team cooperation in the EX/ST/NC condition was zero (the frequencies of team cooperation in the EX/LT/NC and EX/ST/C conditions were equal to .71 and .05, respectively); P.D. and S.-H. stand for prisoner's dilemma and stag-hunt games, respectively; robust standard errors (using sessions as clusters) are in parentheses; *** , **, and * denote significance at the 1%, 5%, and 10% levels, respectively; observations correspond to number of groups.

observed in exogenous environments are similar ($p$- value $< .01$, EX/ST/C vs. EX/LT/C).[67] Regarding the endogenously-generated stag-hunt games, long-term teams also significantly influence cooperation, under no-communication ($p$-value $= .05$). A similar effect is observed in case of exogenous environments ($p$-value $= .01$).[68] These last results suggest that the principals benefit from the use of ongoing teams even under more generous sharing rules when agents' communication is not present. Our findings provide further support to Hypothesis 1.

RESULT 3: *In prisoner's dilemma games, long-term team settings significantly increase the likelihood of team cooperation.*

RESULT 4: *In stag-hunt games, long-term team settings significantly increase the likelihood of team cooperation when the agents cannot communicate with each other.*

This previous analysis helps us understand why the effect of long-terms teams on cooperation across sharing rules is not significant when communication is present. When communication and short-term teams are present, cooperation is already very high under sharing rules equal to .30 or .35 (i.e., in stag-hunt environments). Then, although long-term teams significantly increase cooperation under sharing rules equal to .20 or .25, the effect of long-term teams across sharing rules is not significant.[69]

The effects of communication are reported in the fifth and sixth columns of Table 8. The probit analysis of the effect of communication on the likelihood of cooperation in prisoner's dilemma environments across team settings does not indicate a significant effect.[70] The results in short-term team settings, for which cooperation

[67]In the case of EX/ST/NC vs. EX/LT/NC, a probit estimation was not possible because the frequency of team cooperation in the EX/ST/NC condition was zero. The frequency of team cooperation in the EX/LT/NC condition was .71.

[68]The match covariates were significant for EN/ST/NC vs. EN/LT/NC; coefficient, standard error, and $p$-value equal to (.07, .02, .02) and (−.05, .03, .05), prisoner's dilemma and stag-hunt games, respectively. The match covariate was also significant for EX/ST/NC vs. EX/LT/NC; coefficient, standard error, and $p$-value equal to (.04, .02, .02), stag-hunt game.

[69]In case of exogenous settings and communication, the stronger effect of long-term teams on cooperation in prisoner's dilemma environments might help explain the significant effect of long-terms across sharing rules.

[70]The variable match was significant in EN/ST/NC vs. EN/ST/C; coefficient, standard error, and $p$-value equal to (−.04, .02, .03). Although the effect of communication on cooperation under sharing rules equal to .20 and .25 was not strong enough to generate significance, it contributed to

is not an equilibrium outcome, are not surprising. The results in long-term team settings might be explained as follows. Although communication strongly increased cooperation under a sharing rule equal to .20, the frequency of this sharing rule was not high enough to trigger a significant effect of communication on cooperation across prisoner's dilemma environments (i.e., across environments generated by a sharing rule equal to .20 or .25). Regarding the endogenously-generated stag-hunt games, the probit analysis of the effect of communication on the likelihood of cooperation suggests a significant effect in short-term team settings only ($p$-value = .06).[71] In the exogenous environments, communication significantly increases cooperation across team settings ($p$-value < .01 and $p$-value = .06, short-term and long-term teams, respectively).[72] Our findings provide further support to Hypothesis 2.

RESULT 5: *In short-term team settings with stag-hunt games, communication between the agents significantly increases the likelihood of team cooperation. In long-term team settings and exogeneity, communication also significantly raises the likelihood of team cooperation.*

This previous analysis might explain why the effect of communication on cooperation across sharing rules is not significant when long-term teams are present. Under long-term team settings and no-communication, cooperation is already very high under sharing rules greater than .20. Then, although communication strongly influences cooperation under a sharing rule equal to .20, its effect across sharing rules is not significant.[73]

Finally, we assess the effects of endogeneity in long-term team settings under each sharing rule. Table 9 reports our findings. Each probit model includes a

overall effect of communication across sharing rules when short-term teams were present.

[71]The variable match was significant; coefficient, standard error, and $p$-value (−.08, .02, < .01).

[72]The variable match was significant for EX/LT/NC vs. EX/LT/C; coefficient, standard error, and $p$-value (.05, .02, < .01), stag-hunt game. Although Duffy and Feltovich (2002) find that communication induces cooperation in both one-shot prisoner's dilemma and stag-hunt games, the effects of communication are stronger in stag-hunt games. In a coordinated-resistance game environment under a divide-and-conquer strategy from the designer (which generates a stage game with a unique N.E that is not the efficient outcome), Cason and Mui (2014) find that responders' coordination on the efficient outcome is increased by communication even in the presence of repetitions.

[73]In exogenous settings and long-term teams, the weak effect of communication in stag-hunt strategic environments might explain the lack of significance across sharing rules.

Table 9: Effects of Endogeneity on the Likelihood of Long-Term Team Cooperation under Sharing Rules Equal to .20, .25, .30, and .35 (Probit Tests of Differences between Conditions)

| | Effects of Endogeneity | | | |
|---|---|---|---|---|
| | .20 | .25 | .30 | .35 |
| | Marginal Effect | Marginal Effect | Marginal Effect | Marginal Effect |
| EX/LT vs. | $-.31^{**}$ | $-.06$ | .05 | $-.00$ |
| EN/LT | (.15) | (.14) | (.14) | (.06) |
| Observations | 52 | 68 | 72 | 48 |

*Notes*: Robust standard errors (using sessions as clusters) are in parentheses; ** denotes significance at the 5% level, respectively; observations correspond to number of groups.

treatment dummy variable and match as its regressors.[74] Our analysis suggests that endogeneity significantly decreases the likelihood of cooperation ($p$-value = .05) only under a sharing rule equal to .20.[75] These results can be explained as follows. Reciprocity considerations are strongly elicited by the endogeneity of the strategic environment due to the intentionality of the principal. A sharing rule equal to .20, the lowest possible sharing rule, might be perceived by the agents as unkind behavior from the principal. As a result, negative reciprocity is elicited: The agents will be less willing to cooperate as a way of punishing the principal. In fact, lower team cooperation rates are observed under endogeneity (0 versus 67 percent for the EN/LT/NC and EX/LT/NC conditions, respectively; and, 55 versus 75 percent for the EN/LT/C and EX/LT/C conditions, respectively). Importantly, given that punishment actions (shirking) also reduce the agents' payoffs, negative reciprocity seems to be very strong.[76] Our findings provide support for Hypothesis 3.[77]

[74]The data for the EN/LT/NC, EN/LT/C, EX/LT/NC, and EX/LT/C conditions are pooled to estimate each probit model.

[75]The stronger effect of endogeneity occurred in no-communication environments. The effect of the variable match was not significant in any probit model.

[76]Landeo and Spier (2009) provide seminal evidence regarding the effects of reciprocity on contract design and contract recipients' choices. In contrast to our current study, in Landeo and Spier (2009) setting, the interests of the seller (contract designer) and the buyers (contract recipients) were not aligned. Then, the punishment to the seller actually increased the buyers' payoffs.

[77]The effects of endogeneity in short-term team settings under sharing rules equal to .25 and .30 were not significant. Probit estimations were not possible under sharing rules equal to .20

Table 10: Effects of Treatments on the Likelihood of Sharing Rules Equal to .20 or .25 in Cooperation Cases (Probit Tests of Differences across Conditions)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Marginal Effects | Conditions | Marginal Effects |
| EN/ST/NC vs. | .25** | EN/ST/NC vs. | .08 |
| EN/LT/NC | (.12) | EN/ST/C | (.06) |
| Observations | 63 | Observations | 48 |
| | | | |
| EN/ST/C vs. | .39** | EN/LT/NC vs. | .21 |
| EN/LT/C | (.22) | EN/LT/C | (.24) |
| Observations | 76 | Observations | 91 |

*Notes:* Robust standard errors are in parentheses (sessions used as clusters); *** and ** denote significance at the 1 and 5% levels, respectively; observations correspond to number of groups.

RESULT 6: *In long-term team settings with prisoner's dilemma games generated by a sharing rule equal to .20, endogeneity significantly decreases the likelihood of team cooperation.*

## Cost of Achieving Team Cooperation

Our previous findings suggest that the principals can induce team cooperation by assigning agents to long-term teams or by enhancing agents' communication. The next important question is whether cooperation can be achieved at a low cost in these environments, i.e., with sharing rules equal to .20 or .25.

We start our analysis of the sharing rules used by principals to induce team cooperation by investigating whether long-term teams and agents' communication increase the likelihood of sharing rules equal to .20 or .25 in team cooperation cases. Our findings are reported in Table 10. Each probit model includes a treatment dummy variable and match as its regressors.

The effects of long-term team settings are reported in the second column. Our findings suggest that long-term teams significantly increase the likelihood of a shar-

and .35 because in three of the conditions the team cooperation rates were equal to zero and one, respectively.

ing rule equal to .20 or .25 in team cooperation cases ($p$- value = .05 and $p$-value = .04, for EN/ST/NC vs. EN/LT/NC and EN/ST/C vs. EN/LT/C, respectively).[78] In fact, as a result of long-term team settings, the frequency of a sharing rule equal to .20 or .25 in cooperation cases increased from 6 to 31 percent and from 13 to 52 percent (EN/ST/NC vs. EN/LT/NC and EN/ST/C vs. EN/LT/C, respectively). These results might be explained by the principal's anticipation of higher likelihood of cooperation under low sharing rules in long-term team settings.

RESULT 7: *Long-term team settings significantly increase the likelihood of a sharing rule equal to .20 or .25 in team cooperation cases.*

The effects of communication on the likelihood of low sharing rules are reported in the fourth column of Table 10. Our probit estimations do not suggest significant effects. The findings in short-term team settings might reflect the fact that cooperation is not an equilibrium outcome under sharing rules equal to .20 or .25. The results in long-term settings might be explained as follows. Under long-term team settings and no-communication, the frequency of a sharing rule equal to .25 and the frequency of cooperation under this sharing rule were already relatively high. Then, despite the more frequent choice of a sharing rule equal to .20 (and higher cooperation under this sharing rule) under communication, this effect was not strong enough to generate a significant effect across prisoner's dilemma environments.

We deepen our understanding of the cost of achieving team cooperation by assessing the effects of long-term team settings and agents' communication on the likelihood of a high payoff for the principal. We define a high payoff for the principal as a payoff greater than 138. The rationale is as follows. Under our numerical examination, the principal can get a payoff greater than 138 only under team cooperation and prisoner's dilemma strategic environments (i.e., under a sharing rule equal to .20 or .25). Hence, a principal's payoff greater than 138 represents achieving team cooperation at a low cost.

Table 11 presents the effects of long-term team settings and agents' communication on the likelihood of a high payoff for the principal. We take pair of conditions and estimate probit models. Each probit model includes a treatment dummy variable and match as its regressors.

[78] The variable match was significant only in the case of EN/ST/NC vs. EN/LT/NC; coefficient, standard error, and $p$-value equal to (.04, .01, .01).

Table 11: Effects of Treatments on the Likelihood of High Payoff for the Principal (Probit Tests of Differences across Conditions)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Marginal Effects | Conditions | Marginal Effects |
| EN/ST/NC vs. | .21*** | EN/ST/NC vs. | .05 |
| EN/LT/NC | (.10) | EN/ST/C | (.04) |
| Observations | 115 | Observations | 110 |
| | | | |
| EN/ST/C vs. | .33** | EN/LT/NC vs. | .17 |
| EN/LT/C | (.19) | EN/LT/C | (.21) |
| Observations | 115 | Observations | 120 |

*Notes:* Robust standard errors (using sessions as clusters) are in parentheses; * and ** denote significance at the 1% and 5% levels, respectively; observations correspond to number of groups.

The effects of long-term teams are reported in the second column. Long-term teams significantly increase the likelihood of high payoff for the principal across communication environments ($p$-value $< .01$ and $p$-value $= .02$, no-communication and communication, respectively). In fact, as a result of long-term teams, a higher frequency of a high payoff for the principal is observed across communication environments: 23 versus 2 percent, for the EN/LT/NC and EN/ST/NC conditions, respectively; and, and 40 versus 7 percent, for the EN/LT/C and EN/ST/C conditions, respectively. The effects in no-communication environments might be explained by the increase in team cooperation under sharing rules equal to .25 and .30, and the higher frequency of a sharing rule equal to .25 and lower frequency of a sharing rule equal to .30. The effects in communication settings might be explained by the increase in cooperation under sharing rules equal to .20 and .25, and the higher frequency of a sharing rule equal to .20 and lower frequency of a sharing rule equal to .30. Importantly, these findings suggest that team cooperation is achieved at a lower cost when the agents are assigned to long-term teams.

RESULT 8: *Long-term team settings significantly increase the likelihood of a high payoff for the principal.*

The fourth column of Table 11 reports the results of the effects of communication. Our probit analysis suggests that communication does not significantly affect the

Table 12: Evolution of Team Cooperation in Prisoner's Dilemma Environments

| Match Group | Sharing Rules | | (W, W) - First Round | | (W, W) - All Rounds | |
|---|---|---|---|---|---|---|
| | .20 | .25 | .20 | .25 | .20 | .25 |
| **LT/NC** | | | | | | |
| M1-3 | .39 | .11 | [.00, .27] | [.25, .50] | [.00, .18] | [.50, .44] |
| M4-6 | .17 | .26 | [.00, .83] | [.67, .78] | [.00, .87] | [.85, .78] |
| M7-9 | .04 | .38 | [.00, .50] | [.85, .69] | [.00, .67] | [.91, .75] |
| All Matches | .21 | .24 | [.00, .43] | [.69, .69] | [.00, .41] | [.80, .71] |

*Notes*: Cooperation rates are in brackets (endogenous and exogenous conditions, respectively).

likelihood of high payoff for the principal.[79] Although communication significantly increases cooperation in short-term team settings, our findings regarding the effects of communication on the likelihood of a high payoff for the principal do not suggest that team cooperation is achieved at a lower cost when agents' communication is enhanced. These results are aligned with our previous findings regarding the effects of agents' communication on the likelihood of team cooperation and the likelihood of low sharing rules in cooperation cases.

## 6.3 Evolution of Team Cooperation: An Extension

We first describe the evolution of team cooperation in our endogenously-generated prisoner's dilemma game structures, i.e., under sharing rules equal to .20 and .25. Then, we compare our results with Dal Bó and Fréchette's (2011) findings.

Table 12 provides a summary of the evolution of the frequency of sharing rules equal to .20 and .25, and the evolution of team cooperation rates in prisoner's dilemma game structures.[80] Information about sharing rules is presented in the second and third columns. Columns four and five show cooperation rates for the first round and all rounds of the first match; and, columns six and seven indicate

[79]The variable match was significant only in EN/ST/NC vs. EN/LT/NC and EN/ST/NC vs. EN/ST/C; coefficient, standard error, and $p$-value equal to (.03, .01, .02) and (−.01, .00, .02), respectively.

[80]Given that the purpose of this section is to compare our findings with Dal Bó and Fréchette's (2011) work on exogenous prisoner's dilemma games, only sharing rules equal to .20 and .25. are considered here.

cooperation rates for the first rounds and all rounds of all matches.

Our data suggest that, as the principals gain more experience, the frequency of a sharing rule equal to .20 goes down, and the frequency of a sharing rule equal to .25 goes up. These findings might be explained by the higher frequency of (W, W) for a sharing rule equal to .25 (with respect to a sharing rule equal to .20), and its increasing trend with experience. Specifically, under a sharing rule equal to .25, the frequency of (W, W) was .25 and .50 in the first three matches (first round and all rounds rates, respectively). In the last three matches, however, these rates were .85 and .91 (first round and all rounds rates, respectively). Importantly, payoff endogeneity decreases the frequency of cooperation under a sharing rule equal to .20, across matches and rounds. These findings suggest that a sharing rule equal to .20 was perceived by the agents as an unkind behavior from the principal, and hence, triggered agents' negative reciprocity.

Dal Bó and Fréchette (2011) study the evolution of cooperation using eight infinitely-repeated prisoner's dilemma games and exogenous payoffs. The sharing rule equal to .25 and the discount factor $\delta = .75$ used in our study endogenously replicate one of their environments. Dal Bó and Fréchette (2011) find cooperation rates equal to .57 and .56, for the first round and all rounds of the first match; and, .85 and .76, for the first round and all rounds of all matches. The patterns of their data across matches suggest that cooperation increases with experience. In our endogenous prisoner's dilemma environment generated by a sharing rule equal to .25, we find cooperation rates equal to zero and .43, for the first round and all rounds of the first match; and, .69 and .80, for the first round and all rounds of all matches. Our data across rounds (within a match) indicate an adjustment of agents' actions towards cooperation. In addition, the patterns of our data across matches suggest that cooperation increases with experience. In contrast, in our endogenous prisoner's dilemma environment generated by a sharing rule equal to .20, we find zero cooperation across rounds and matches. These findings suggest that the emergence of cooperation in prisoner's dilemma games might be affected by the endogeneity of the strategic environment. In particular, the presence of more generous sharing rules might exacerbate the elicitation of agents' negative reciprocity when confronting prisoner's dilemma games generated by the least-generous sharing rule.

## 7 Summary and Conclusions

This paper explores the classic problem faced by a principal when agents work as a team and are rewarded for their group performance rather than their individual contributions. Our framework is characterized by effort complementary: Hard work by one agent raises the raises the overall return of hard work by the other agent. Depending on the sharing rule chosen by the principal, the strategic environment faced by the agents may be either a prisoner's dilemma or a stag hunt game. Using experimental economics methods, we provide evidence of how ongoing interaction among team members, better communication channels, and the endogeneity of the strategic environment affect the likelihood of team cooperation and the cost of achieving team cooperation.

Our work provides important contributions to the literature on incentive contracts for teams. (1) When the agents cannot communicate, we find that long-term or ongoing teams increase the likelihood of team cooperation. Long-term teams also raise the likelihood of a high payoff for the principal, suggesting that team cooperation is achieved at a lower cost when the agents are assigned to long-term teams. (2) In short-term team settings, communication between the agents increases the likelihood of team cooperation. (3) In long-term team settings and the lowest sharing rule, the endogeneity of the strategic environment – where a human principal chooses the sharing rule – decreases the likelihood of team cooperation. This last result indicates that a particularly aggressive behavior from the principal might trigger agents' negative reciprocity.

Our paper also extends the experimental literature on infinitely-repeated games and communication by studying the interaction between infinite repetitions and communication in prisoner's dilemma and stag-hunt games. Our findings in prisoner's dilemma environments suggest that the positive effects of infinite repetitions on cooperation are robust to communication protocols. Finally, we extend the literature on social preferences and reciprocity by assessing the effects of reciprocity in infinitely-repeated team environments. Although our findings for more generous sharing rules are aligned with the patterns of cooperation found in previous studies of exogenous infinitely-repeated prisoner's dilemma games, our results also suggest the presence of agents' negative reciprocity when confronting prisoner's dilemma games generated by the least-generous sharing rule.

Possible extensions might include endogenizing the principal's decision regarding the duration of team interaction and the communication channels available to team members. It might be also interesting to introduce risk into the production function, and imperfect monitoring among the agents. These, and other topics, are fruitful venues for future research.

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# Appendix

This section presents the results for the more general theoretical framework. We first introduce the basic notation. We then characterize the equilibria of the effort stage-game, the equilibria of the entire game in short-term team settings under Pareto and Risk-Dominance refinements, and the equilibria of the entire game in long-term team settings.

## Basic Notation

Define the following thresholds:

$$\underline{x} = \frac{e}{R_{11} - R_{00}}; x^* = \frac{e}{R_{11} - R_{01}}; \bar{x} = \frac{e}{R_{01} - R_{00}};$$

$$x^{RD} = \frac{2e}{R_{11} - R_{00}}; x^*(\delta) = \frac{e}{R_{11} - (1-\delta)R_{00} - \delta R_{01}}.$$

Using the (weak) supermodularity assumption, $R_{00} + R_{11} \geq 2R_{01}$, it is straightforward to verify that

$$\underline{x} < x^*(\delta) < x^* < x^{RD} < \bar{x}.$$

Finally, we assume that $(1 - 2\bar{x})R_{11} > R_{00}$ where $\bar{x}$ is defined above. This ensures that the principal wants to implement high effort, and will choose to do so at the lowest possible cost.

## Equilibria Characterization

*Effort Stage-Game*

**LEMMA A1:** *The equilibria of the effort stage-game are as follows:*

*(i)If $x \leq \underline{x}$ then shirking is a dominant strategy and is jointly efficient for the agents;*

*(ii) If $x \in (\underline{x}, x^*)$ then the Effort Stage-Game is a prisoner's dilemma game and (shirk, shirk) is the unique Nash equilibrium and (work, work) is jointly efficient for the agents;*

*(iii) If $x \in (x^*, \bar{x}]$ then the Effort Stage-Game is a stag-hunt game and (shirk, shirk) and (work, work) are both Nash equilibria and (work, work) is jointly efficient for the agents;*

*(iv)If $x \geq \bar{x}$ then working hard is a dominant strategy and is jointly efficient for the agents.*

**PROOF.** Suppose agent $i$ works hard. Agent $j$ will work hard as well when $xR_{11} - e > xR_{10}$, or $x > x^*$, and will shirk when $x < x^*$ where $x^*$ is defined above. Suppose instead that agent $i$ shirks. Agent j will work hard when $xR_{01} - e > xR_{00}$, or $x > \bar{x}$, and will shirk when $x < \bar{x}$ where $\bar{x}$ is defined above. Note that it is jointly optimal for the two agents to work hard when $2xR_{11} - 2e > 2xR_{00}$, or $x > \underline{x}$. In case (i) where $x \leq \underline{x}$, it is a dominant strategy for both agents to shirk and, since shirking is jointly optimal for the agents. In case (ii), it is jointly optimal for the agents to work hard (since $x > \underline{x}$) but they have dominant strategies to shirk (since $x < x^*$). In case (iii), neither player has a dominant strategy. ■

*Entire Game – Short-Term Team Setting*

Consider first the Pareto-dominance refinement. This refinement serves the interest of the principal by guaranteeing that the agents will work hard for all sharing rules above $x^*$. Without this refinement, the agents might succeed in extracting higher sharing rules from the principal. Hence, this refinement prevents the agents from "punishing" the principal for low share offers by threatening to play the Pareto-dominated shirk equilibrium in Stage 2 subgame.

**PROPOSITION A1(i):** *Suppose that the agents interact only once, and that they play Pareto optimal continuation equilibria in Stage 2 subgame. In the unique subgame-perfect Nash equilibrium, the principal chooses a sharing rule $x^*$ and both agents work hard.*

**PROOF.** From Lemma, 1 we have that shirking is a dominant strategy for all $x < x^*$. So the principal cannot implement (work, work) in cases (i) and (ii). In case (iii), the stage game is a stag-hunt game with two Nash equilibria, (shirk, shirk) and (work, work). The work equilibrium Pareto dominates the shirking equilibrium, and so the refinement selects for (work, work). It follows that the principal can implement high effort for shares $x \geq x^*$. To minimize the cost of labor, the principal offers $x = x^*$. ■

Consider now Harsanyi and Selten's (1988) risk dominance refinement. This refinement implies that the workers would shirk when the share is in the range $[x^*, x^{RD})$. To induce hard work under the risk dominance refinement, the principal would need to raise the sharing rule to at least the level $x^{RD}$.

**PROPOSITION A1(ii):** *Suppose that the agents interact only once, and that they play the risk dominant continuation equilibria in Stage 2 subgame. In the unique subgame-perfect Nash equilibrium, the principal choose a sharing rule $x^{RD}$ and both agents work hard.*

**PROOF.** Suppose that agent $i$ places equal likelihood on agent $j$ choosing work and shirk. If agent $i$ chooses to work, his expected payoff is $.5(xR_{11} - e) + .5(xR_{01} - e)$. If agent $i$ chooses to shirk, his expected payoff is $.5xR_{01} + .5xR_{00}$. Setting these expressions equal and rearranging terms gives $x^{RD}$. ■

The agents can do better still if they can condition their strategies on the principal's sharing rules, essentially threatening the principal with shirking if they do not get a high enough sharing rule. Note that this threat is in fact credible for all offers below $\bar{x}$ since Lemma 1 establishes that there are (shirk, shirk) equilibria of the associated subgames. The threat would not be credible for share offers above $\bar{x}$, however, since working hard is a dominant strategy for the agents in this case and hence (work, work) is the unique equilibrium. We have the following result.

**PROPOSITION A1(iii)** *Suppose that the agents interact only once, and that they play the (shirk, shirk) continuation equilibrium in the Stage 2 subgame for all offers below $\bar{x}$. In the subgame-perfect Nash equilibrium, the principal chooses a sharing rule $\bar{x}$ and both agents work hard.*

**PROOF.** Follows immediately from the assumption that $(1 - 2\bar{x})R_{11} > R_{00}$. ■

*Entire Game – Long-Term Team Setting*

When the agents interact with each other infinitely-repeated times after receiving the principal's sharing rule, then the principal may be able to induce the agents to work hard with lower sharing rules than before. Specifically, when $x \in (x^*(\delta), x^*)$, which is a subset of the range in case (ii), then although work hard is not an equilibrium of the one-shot Stage 2 subgame, it may be an equilibrium of the infinitely-repeated effort stage-game. Although the folk theorem tells us that there is a continuum of subgame-perfect Nash equilibria of this infinitely-repeated game when the discount factor is sufficiently high,[81] only work hard constitutes the equilibrium outcome of the entire game if the agents coordinate on the Pareto optimal equilibrium of the continuation subgame.

**PROPOSITION A2(i):** *Suppose that the agents interact infinitely-repeated times, and that they play Pareto optimal continuation equilibria in the Stage 2 subgame. In the unique subgame-perfect Nash equilibrium, the principal chooses a sharing rule $x = x^*(\delta)$ and both agents work hard in each period thereafter.*

**PROOF.** Consider the range of sharing rules in case (ii). We first show how and when (work, work) can be sustained in a subgame-perfect Nash equilibrium under a grim trigger strategy. Imagine an equilibrium where the agents work hard in each and every period. The payoff to each agent is $(xR_{11} - e) + \delta(xR_{11} - e) + (\delta)^2(xR_{11} - e) + ... = (\frac{1}{1-\delta})(xR_{11} - e)$. The payoff to an agent from unilaterally deviating from the equilibrium path is $xR_{01} + \delta xR_{00} + (\delta)^2 xR_{00} + ... = xR_{01} + (\frac{\delta}{1-\delta})xR_{00}$. Comparing these two expressions verifies that hard work is sustainable when $x \geq x^*(\delta)$. It follows that the principal can implement high effort at the lowest cost by offering $x = x^*(\delta)$. ■

As discussed in the context of the one-shot setting, the Pareto refinement also serves the interest of the principal in the infinitely-repeated setting. The principal can exploit the *ex post* eagerness of the agents to play Pareto-dominant hard work equilibria, even when the share is relatively small. Without this refinement, there

[81] Specifically, the folk theorem states that any feasible payoff profile that strictly dominates the minmax profile of the effort stage-game (given by the shirking N.E.) can be realized as a Nash equilibrium payoff profile with a sufficiently large discount factor.

are many other equilibria. In fact, since shirk is an equilibrium of the effort stage-game for all offers below $\bar{x}$ (albeit a Pareto dominated one), there are also equilibria where the principal chooses sharing rules that are far above the level suggested by the last proposition. The next proposition characterizes the subgame-perfect Nash equilibrium that is most favorable to the agents.

**PROPOSITION A2(ii):** *Suppose that the agents interact infinitely-repeated times, and that they play the (shirk, shirk) continuation equilibrium in the effort stage-game for all offers below $\bar{x}$. In the unique subgame-perfect Nash equilibrium, the principal choose a sharing rule $\bar{x}$ and both agents work hard in each period thereafter.*

**PROOF.** Follows immediately from the assumption that $(1 - 2\bar{x})R_{11} > R_{00}$. ■

Table A1: Descriptive Statistics
(All Rounds, All Matches; Endogenous Strategic-Environments)

| Conditions | Princ.'s Sharing Rules | Agents' Actions | | Payoffs$^{(b)}$ | |
|---|---|---|---|---|---|
| | Mean/Mode$^{(a)}$ | (W, W) | (S, S) | Principal | Both Agents |
| **EN/ST/NC** | | | | | |
| M1–M4 | .26/.30 | .20 | .23 | 93.00 | 76.59 |
| [44, 44] | (.05/.36) | | | (32.73) | (34.97) |
| M5–M9 | .28/.30 | .33 | .31 | 89.85 | 87.67 |
| [55, 55] | (.04/.60) | | | (34.09) | (38.41) |
| **EN/LT/NC** | | | | | |
| M1–M4 | .26/.30 | .39 | .34 | 100.63 | 81.08 |
| [48, 240] | (.05/.45) | | | (42.36) | (39.13) |
| M5–M9 | .28/.30 | .79 | .10 | 128.44 | 110.47 |
| [60, 192] | (.04/.47) | | | (36.82) | (35.84) |
| **EN/ST/C** | | | | | |
| M1–M4 | .27/.30 | .64 | .16 | 121.59 | 98.00 |
| [44, 44] | (.05/.50) | | | (38.32) | (41.85) |
| M5–M9 | .28/.30 | .55 | .07 | 116.91 | 98.40 |
| [55, 55] | (.05/.53) | | | (31.73) | (40.12) |
| **EN/LT/C** | | | | | |
| M1–M4 | .26/.20 | .70 | .20 | 129.87 | 93.68 |
| [48, 240] | (.06/.37) | | | (51.31) | (44.22) |
| M5–M9 | .27/.20 | .74 | .15 | 132.41 | 98.63 |
| [60, 192] | (.06/.33) | | | (50.14) | (45.67) |

*Note*: $^{(a)}$Standard deviations and mode frequencies are in parentheses; $^{(b)}$standard deviations are in parentheses; sample sizes (first four matches and last five matches) are in brackets, [number of sharing rule decisions, total number of teams].

Table A2: Descriptive Statistics
(All Rounds, All Matches; Exogenous Strategic-Environments)

| Conditions | Princ.'s Sharing Rules | Agents' Actions | | Payoffs[(b)] | |
|---|---|---|---|---|---|
| | Mean/Mode[(a)] | (W, W) | (S, S) | Principal | Both Agents |
| **EX/ST/NC** | | | | | |
| M1–M4 | .26/.30 | .14 | .52 | 83.55 | 71.77 |
| [44, 44] | (.05/.36) | | | (34.86) | (30.67) |
| M5–M9 | .28/.30 | .27 | .37 | 84.87 | 83.49 |
| [55, 55] | (.04/.60) | | | (39.94) | (37.03) |
| **EX/LT/NC** | | | | | |
| M1–M4 | .26/.30 | .63 | .14 | 123.16 | 90.88 |
| [48, 240] | .05/.45) | | | (47.82) | (38.98) |
| M5–M9 | .28/.30 | .75 | .12 | 129.43 | 105.52 |
| [60, 192] | (.04/.47) | | | (45.98) | (35.29) |
| **EX/ST/C** | | | | | |
| M1–M4 | .27/.30 | .57 | .29 | 117.59 | 96.18 |
| [44, 44] | (.05/.50) | | | (33.82) | (41.97) |
| M5–M9 | .28/.30 | .53 | .20 | 107.93 | 97.56 |
| [55, 55] | (.05/.53) | | | (33.64) | (42.51) |
| **EX/LT/C** | | | | | |
| M1–M4 | .26/.20 | .84 | .05 | 145.53 | 98.72 |
| [48, 240] | (.06/.37) | | | (48.72) | (42.91) |
| M5–M9 | .27/.20 | .90 | .04 | 150.05 | 104.88 |
| [60, 192] | (.06/.33) | | | (43.88) | (43.38) |

*Notes*: [(a)]The sharing rules provided by the computer in the exogenous sessions replicated the patterns of the endogenous sessions; standard deviations and mode frequencies are in parentheses; [(b)]standard deviations are in parentheses; sample sizes (first four matches and last five matches) are in brackets, [number of sharing rule decisions, total number of teams].

Table A3: Frequencies of Principal's Sharing Rules and Agents' Actions
(All Rounds, All Matches; Endogenous Strategic-Environments)

| Cond. | P.D. Game Structure | | Stag-Hunt Game Structure | | Total Sharing-Rule |
|---|---|---|---|---|---|
| | .20 | .25 | .30 | .35 | Decisions |
| **EN/ST/NC** | | | | | |
| M1–M4 | .34 | .16 | .36 | .14 | 44 |
| | [.00, .53] | [.14, .14] | [.44, .06] | [.17, ..00] | |
| M5–M9 | .16 | .16 | .60 | .07 | 55 |
| | [.00, .89] | [.11, .89] | [.39, .03] | [1.00, .00] | |
| **EN/LT/NC** | | | | | |
| M1–M4 | .35 | .17 | .44 | .04 | 48 |
| | [.00, .62] | [.67, .12] | [.48, .27] | [1.00, .00] | |
| M5–M9 | .10 | .30 | .47 | .13 | 60 |
| | [.00, .76] | [.91, .00] | [.86, .05] | [.90, .00] | |
| **EN/ST/C** | | | | | |
| M1–M4 | .25 | .18 | .50 | .07 | 44 |
| | [.18, .36] | [.38, .38] | [.91, .00] | [1.00, .00] | |
| M5–M9 | .18 | .20 | .53 | .09 | 55 |
| | [.10, .30] | [.27, .09] | [.72, .00] | [1.00, .00] | |
| **EN/LT/C** | | | | | |
| M1–M4 | .38 | .23 | .19 | .21 | 48 |
| | [.45, .36] | [.69, .22] | [1.00, .00] | [.87, .04] | |
| M5–M9 | .33 | .27 | .13 | .27 | 60 |
| | [.48, .30] | [.86, .08] | [.84, .12] | [.90, .04] | |

*Notes*: Agents' actions rates are in brackets [(W, W) rate, (S, S) rate].

Table A4: Frequencies of Principal's Sharing Rules and Agents' Actions
(All Rounds, All Matches; Exogenous Strategic-Environments)

| Cond. | P.D. Game Structure | | Stag-Hunt Game Structure | | Total Sharing-Rule |
|---|---|---|---|---|---|
| | .20 | .25 | .30 | .35 | Decisions |
| **EX/ST/NC** | | | | | |
| M1–M4 | .34 | .16 | .36 | .14 | 44 |
| | [.06, .73] | [.14, .29] | [.19, .13] | [.17, .00] | |
| M5–M9 | .16 | .16 | .60 | .07 | 55 |
| | [.00, .89] | [.00, .67] | [.36, .18] | [.75, .00] | |
| **EX/LT/NC** | | | | | |
| M1–M4 | .35 | .17 | .44 | .04 | 48 |
| | [.31, .47] | [.62, .17] | [.86, .06] | [.54, .38] | |
| M5–M9 | .10 | .30 | .47 | .13 | 60 |
| | [.76, .14] | [.78, .09] | [.72, .13] | [.83, .10] | |
| **EX/ST/C** | | | | | |
| M1–M4 | .25 | .18 | .50 | .07 | 44 |
| | [.09, .45] | [.25, .13] | [.86, .00] | [1.00, .00] | |
| M5–M9 | .18 | .20 | .53 | .09 | 55 |
| | [.00, .60] | [.09, .45] | [.79, .00] | [1.00, .00] | |
| **EX/LT/C** | | | | | |
| M1–M4 | .38 | .23 | .19 | .21 | 48 |
| | [.70, .19] | [.80, .17] | [1.00, .00] | [1.00, .00] | |
| M5–M9 | .33 | .27 | .13 | .27 | 60 |
| | [.73, .12] | [1.0, .00] | [1.00, .00] | [.98, .00] | |

*Notes*: Agents' actions rates are in brackets, [(W, W) rate, (S, S) rate].

Table A5: Descriptive Statistics (All Rounds, Last Five Matches)

| Conditions | Princ.'s Sharing Rules | Agents' Actions | | Payoffs[b] | |
|---|---|---|---|---|---|
| | Mean/Mode[a] | (W, W) | (S, S) | Principal | Both Agents |
| **EN/ST/NC** | .28/.30 | .33 | .31 | 89.85 | 87.67 |
| [55, 55] | (.04/.60) | | | (34.09) | (38.41) |
| **EN/LT/NC** | .28/.30 | .79 | .10 | 128.44 | 110.47 |
| [60, 192] | (.04/.47) | | | (36.82) | (35.84) |
| **EN/ST/C** | .28/.30 | .55 | .07 | 116.91 | 98.40 |
| [55, 55] | (.05/.53) | | | (31.73) | (40.12) |
| **EN/LT/C** | .27/.20 | .74 | .15 | 132.41 | 98.63 |
| [60, 192] | (.06/.33) | | | (50.14) | (45.67) |
| **EX/ST/NC** | .28/.30 | .27 | .37 | 84.87 | 83.49 |
| [55, 55] | (.04/.60) | | | (39.94) | (37.03) |
| **EX/LT/NC** | .28/.30 | .75 | .12 | 129.43 | 105.52 |
| [60, 192] | (.04/.47) | | | (45.98) | (35.29) |
| **EX/ST/C** | .28/.30 | .53 | .20 | 107.93 | 97.56 |
| [55, 55] | (.05/.53) | | | (33.64) | (42.51) |
| **EX/LT/C** | .27/.20 | .90 | .04 | 150.05 | 104.88 |
| [60, 192] | (.06/.33) | | | (43.88) | (43.38) |

*Notes*: [a]The sharing rules provided by the computer in the exogenous sessions replicated the pattern of the endogenous sessions; standard deviations and mode frequencies are in parentheses; [b]standard deviations are in parentheses; sample sizes (last five matches) are in brackets [number of sharing rule decisions, total number of teams].

Table A6: Frequencies of Principal's Sharing Rules and Agents' Actions
(All Rounds, Last Five Matches)

| Condition | Prisoner's Dilemma | | Stag-Hunt Game | | Total Sharing-Rule |
|---|---|---|---|---|---|
| | .20 | .25 | .30 | .35 | Decisions |
| **ST/NC** | .16 | .16 | .60 | .07 | 55 |
| EN | [.00, .89] | [.11, .89] | [.39, .03] | [1.00, .00] | |
| EX | [.00, .89] | [.00, .67] | [.36, .18] | [.75, .00] | |
| **LT/NC** | .10 | .30 | .47 | .13 | 60 |
| EN | [.00, .76] | [.91, .00] | [.86, .05] | [.90, .00] | |
| EX | [.76, .14] | [.78, .09] | [.72, .13] | [.83, .10] | |
| **ST/C** | .18 | .20 | .53 | .09 | 55 |
| EN | [.10, .30] | [.27, .09] | [.72, .00] | [1.00, ..00] | |
| EX | [.00, .60] | [.09, .45] | [.79, .00] | [1.00, .00] | |
| **LT/C** | .33 | .27 | .13 | .27 | 60 |
| EN | [.48, .30] | [.86, .08] | [.84, .12] | [.90, .04] | |
| EX | [.73, .12] | [1.00, .00] | [1.00, .00] | [.98, .00] | |

*Notes*: Agents' actions rates are in brackets ((W, W) and (S, S) rates, respectively).

Table A7: Effects of Treatments on the Likelihood of Team Cooperation
(Probit Tests of Differences across Conditions; All Rounds, Last Five Matches)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Marginal Effect | Conditions | Marginal Effect |
| EN/ST/NC vs. | .46*** | EN/ST/NC vs. | .22** |
| EN/LT/NC | (.10) | EN/ST/C | (.11) |
| Observations | 247 | Observations | 110 |
| | | | |
| EN/ST/C vs. | .20 | EN/LT/NC vs. | -.05 |
| EN/LT/C | (.18) | EN/LT/C | (.18) |
| Observations | 247 | Observations | 384 |
| | | | |
| EX/ST/NC vs. | .49*** | EX/ST/NC vs. | .25*** |
| EX/LT/NC | (.10) | EX/ST/C | (.07) |
| Observations | 247 | Observations | 110 |
| | | | |
| EX/ST/C vs. | .37*** | EX/LT/NC vs. | .15 |
| EX/LT/C | (.06) | EX/LT/C | (.10) |
| Observations | 247 | Observations | 384 |

*Notes:* Robust standard errors (using sessions as clusters) are in parentheses; *** and ** denote significance at the 1% and 5% levels, respectively; observations correspond to number of teams.

Table A8: Effects of Treatments on the Likelihood of Team Cooperation in Prisoner's Dilemma and Stag-Hunt Environments
(Probit Tests of Differences across Conditions; All Rounds, Last Five Matches)

| Effects of Long-Term Teams | | | | Effects of Communication | | |
|---|---|---|---|---|---|---|
| | P.D. | S.-H. | | | P.D. | S.-H. |
| Conditions | Mg. Eff. | Mg. Eff. | | Conditions | Mg. Eff. | Mg. Eff. |
| EN/ST/NC vs. | .63*** | .39** | | EN/ST/NC vs. | .14 | .31* |
| EN/LT/NC | (.13) | (.13) | | EN/ST/C | (.09) | (.14) |
| Observations | 93 | 154 | | Observations | 39 | 71 |
| EN/ST/C vs. | .46* | .13 | | EN/LT/NC vs. | –.01 | .01 |
| EN/LT/C | (.23) | (.15) | | EN/LT/C | (.23) | (.16) |
| Observations | 136 | 111 | | Observations | 190 | 194 |
| EX/ST/NC vs. | n.a.[a] | .35** | | EX/ST/NC vs. | n.a.[a] | .42*** |
| EX/LT/NC | | (.15) | | EX/ST/C | | (.12) |
| Observations | | 154 | | Observations | | 71 |
| EX/ST/C vs. | .80*** | .17*** | | EX/LT/NC vs. | .07 | .24** |
| EX/LT/C | (.05) | (.06) | | EX/LT/C | (.07) | (.11) |
| Observations | 136 | 111 | | Observations | 190 | 194 |

*Notes:* [a]Probit estimations were not possible because the frequency of team cooperation in the EX/ST/NC condition was zero (the frequencies of team cooperation in the EX/LT/C and EX/ST/C conditions were equal to .77 and .05, respectively); P.D. and S.-H. stand for prisoner's dilemma and stag-hunt games, respectively; robust standard errors are in parentheses (sessions used as clusters); *** , **, and * denote significance at the 1%, 5%, and 10% levels, respectively; observations correspond to number of teams.

Table A9: Effects of the Endogeneity of the Strategic Environment on the Likelihood of Team Cooperation under a Sharing Rule Equal to .20, .25, .30, and .35 (Probit Tests; All Rounds, Last Five Matches)

| | .20 | .25 | .30 | .35 |
|---|---|---|---|---|
| | Marginal Effect | Marginal Effect | Marginal Effect | Marginal Effect |
| Endogeneity | $-.37^{**}$ | $-.00$ | .08 | $-.02$ |
| | (.15) | (.11) | (.14) | (.09) |
| Observations | 174 | 206 | 226 | 162 |

*Notes*: Robust standard errors (using sessions as clusters) are in parentheses; ** denotes significance at the 5% level; observations correspond to number of teams.

Table A10: Effects of Treatments on the Likelihood of Sharing Rules Equal to .20 or .25 in Team Cooperation Cases (Probit Tests of Differences across Conditions; All Rounds, Last Five Matches)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Marginal Effects | Conditions | Marginal Effects |
| ST/NC vs. | $.27^{**}$ | ST/NC vs. | .08 |
| LT/NC | (.11) | ST/C | (.06) |
| Observations | 169 | Observations | 48 |
| | | | |
| ST/C vs. | $.39^{**}$ | LT/NC vs. | .20 |
| LT/C | (.23) | LT/C | (.24) |
| Observations | 172 | Observations | 293 |

*Notes:* Robust standard errors are in parentheses (sessions used as clusters); *** and ** denote significance at the 1 and 5% levels, respectively; observations correspond to number of teams (only cooperation cases).

Table A11: Effects of Treatments on the Likelihood of High Payoff for the Principal (Probit Tests of Differences across Conditions; All Rounds, Last Five Matches)

| Effects of Long-Term Teams | | Effects of Communication | |
|---|---|---|---|
| Conditions | Coefficients | Conditions | Coefficients |
| EN/ST/NC vs. | .24*** | EN/ST/NC vs. | .05 |
| EN/LT/NC | (.10) | EN/ST/C | (.04) |
| Observations | 247 | Observations | 110 |
| | | | |
| EN/ST/C vs. | .32** | EN/LT/NC vs. | .13 |
| EN/LT/C | (.19) | EN/LT/C | (.20) |
| Observations | 247 | Observations | 384 |

*Notes:* Robust standard errors (using sessions as clusters) are in parentheses; *** and ** denote significance at the 1% and 5% levels, respectively; observations correspond to number of teams.

***PLEASE GIVE THIS MATERIAL TO THE EXPERIMENTER***

***AT THE END OF THE SESSION***

# INSTRUCTIONS

This is an experiment in the economics of decision-making. The National Science Foundation has provided the funds for this research.

In this experiment you will be asked to play an economic decision-making computer game and to make decisions in several matches. The experiment currency is the "token." The instructions are simple. If you follow them closely and make appropriate decisions, you may make an appreciable amount of money. At the end of the experiment you will be paid your total game earnings in CASH along with your participation fee. If you have any questions at any time, please raise your hand and the experimenter will come to your desk.

# SESSION AND PLAYERS

The session is made up of ten matches. A match might involve more than one round. The first match is a practice match and will not be counted in the determination of your final earnings.

- Before the beginning of the practice match, the computer will randomly form groups of three people: Players **GRAY**, **RED**, and **BLUE**. The roles will be randomly assigned. **The roles will REMAIN THE SAME during the ENTIRE session.**

- After the practice match, nine actual matches of the game will be played.

- At the **beginning of each actual match, NEW GROUPS** of three people, Players **GRAY**, **RED**, and **BLUE** will be randomly formed. **The groups will REMAIN THE SAME during ALL the rounds of a match.**

You will not know the identity of the other two players who belong to your group in any given match. You know, however, that you will be playing with the **SAME OTHER TWO PLAYERS during ALL the rounds of a match**. You also know that **at the beginning of each match, NEW GROUPS** of three people, Players **GRAY**, **RED**, and **BLUE**, will be randomly formed.

# THE MATCH

Each match has two stages.

## STAGE 1

1) Player GRAY **decides whether to offer Proposal 1, 2, 3, or 4 to** Players **RED** and **BLUE. This proposal will hold for ALL the rounds of the match**.

   Before making his/her decision, Player **GRAY** should take into account that **his/her match payoff will depend on his/her decision and the decisions of** Players **RED and BLUE.**

2) Player **GRAY**'s decision is **immediately** revealed to Players **RED** and **BLUE**.

## STAGE 2

Stage 2 **will involve one or more ROUNDS**. The structure of each **ROUND** is as follows.

1) The round begins.
2) After observing Player **GRAY**'s decision and the history of their decisions, each Player **RED** and **BLUE** **sends a message** to the other player **(BLUE** and **RED**, respectively) stating his/her **intended choice**, i.e., whether he/she **plans to choose Option A or C.**
3) After receiving the message from the other player (**BLUE** and **RED**, respectively)**,** Players **RED** and **BLUE** **decide whether to choose Option A or C.**

   Before making their decisions, each Player **RED** and **BLUE** should take into account that **his/her match payoff will depend on his/her decision and on the decision of the other player** **(BLUE** and **RED,** respectively)**.**

4) The **round ends**.

After the ending of a round, the computer randomly determines whether **the match will continue** (75% chance) or **the match will end** (25% chance).

- If **the match continues**, **EACH GROUP WILL REMAIN INTACT.** The proposal made by Player GRAY in Stage 1 will continue to hold, and **a new Stage 2 round will begin**.
- If **the match ends**, **NEW GROUPS** will be randomly formed and a **new match will start at Stage 1**.

# ROUND PAYOFF

The Payoff Tables show the possible round payoffs for Players **RED** and **BLUE,** and **GRAY**.

**PROPOSAL 1:**

| | BLUE CHOOSES A | BLUE CHOOSES C |
|---|---|---|
| RED CHOOSES A | 31 31<br>[206] | 2 40<br>[120] |
| RED CHOOSES C | 40 2<br>[120] | 20 20<br>[60] |

**PROPOSAL 2:**

| | BLUE CHOOSES A | BLUE CHOOSES C |
|---|---|---|
| RED CHOOSES A | 48 48<br>[172] | 12 50<br>[100] |
| RED CHOOSES C | 50 12<br>[100] | 25 25<br>[50] |

**PROPOSAL 3:**

| | BLUE CHOOSES A | BLUE CHOOSES C |
|---|---|---|
| RED CHOOSES A | 65 65<br>[138] | 22 60<br>[80] |
| RED CHOOSES C | 60 22<br>[80] | 30 30<br>[40] |

**PROPOSAL 4:**

| | BLUE CHOOSES A | BLUE CHOOSES C |
|---|---|---|
| RED CHOOSES A | 82 82<br>[104] | 32 70<br>[60] |
| RED CHOOSES C | 70 32<br>[60] | 35 35<br>[30] |

The **RED** payoffs represent the payoffs for Players **RED**, the **BLUE** payoffs represent the payoff for Player **BLUE**, and the GRAY payoffs in brackets represent the payoffs for Player **GRAY.**

# MATCH PAYOFF

The match payoffs in tokens will be equal to the sum of the round payoffs for that match.

# SESSION PAYOFFS

The game earnings in tokens for the session will be equal to the sum of payoffs for the nine actual matches. The game earnings in dollars will be equal to (Game Earnings in tokens)/90 (in other words, 90 tokens = 1 dollar). Hence, the total earnings in dollars will be equal to the participation fee plus the game earnings in dollars.

# GAME SOFTWARE

The game will be played using a computer terminal. You will need to enter your decisions by using the mouse. In some instances, you will need to wait until the other players make their decisions before moving to the next screen. Please **<u>be patient</u>**. There will be two boxes, displayed in the upper right-hand side of your screen, that indicate the "Match Number and Round Number" and "Your Role."

Press the NEXT >> button to move to the next screen. Please **<u>do not press the NEXT button more than once</u>**, **<u>do not try to go back</u>** to the previous screen, and **<u>do not close the browser</u>**: the software will stop working and you will lose all the accumulated tokens.

Next, you will need to complete several exercises. Then, **a PRACTICE MATCH** will begin. After that, **NINE ACTUAL MATCHES** of the game will be played. **<u>You may consult these instructions at any time during the session</u>**.

# THANKS FOR YOUR PARTICIPATION IN THIS STUDY!!

***<u>PLEASE GIVE THIS MATERIAL TO THE EXPERIMENTER AT THE END OF THE SESSION</u>***

***PLEASE GIVE THIS MATERIAL TO THE EXPERIMENTER AT THE END OF THE DISCUSSION OF THE EXERCISES***

# EXERCISES: MATCH PAYOFFS

Four exercises related to the Payoff Tables are presented below. These exercises are constructed under various assumptions about the behavior of players.

**IMPORTANT: THE NUMBER OF ROUNDS PER MATCH AND THE BEHAVIOR OF PLAYERS IN THE PRACTICE MATCHES AND ACTUAL MATCHES WILL *NOT* NECESSARY FOLLOW THE PATTERNS DESCRIBED IN THESE EXERCISES.**

Please fill the blanks.

**Exercise 1.** **SUPPOSE** Player **GRAY** offers **Proposal 3** to Players **RED** and **BLUE** and that the match involves one round.

- **SUPPOSE** **RED** chooses **Option A** and **BLUE** chooses **Option C** in round 1. Then, **RED**'s round 1 payoff is equal to ______________________ tokens, **BLUE**'s round 1 payoff is equal to _____________________ tokens, and **GRAY**'s round 1 payoff is equal to ______________________ tokens.
- Hence, **RED**'s match payoff is equal to ______________________ tokens, **BLUE**'s match payoff is equal to _____________________ tokens, and **GRAY**'s match payoff is equal to ______________________ tokens.

**Exercise 2.** **SUPPOSE** Player **GRAY** offers **Proposal 1** to Players **RED** and **BLUE** and that the match involves two rounds.

- **SUPPOSE** both **RED** and **BLUE** choose **Option A** in round 1. Then, **RED**'s round 1 payoff is equal to ______________________ tokens, **BLUE**'s round 1 payoff is equal to _____________________ tokens, and **GRAY**'s round 1 payoff is equal to ______________________ tokens.

- **SUPPOSE** both **RED** and **BLUE** choose **Option C** in round 2. **RED**'s round 2 payoff is equal to ______________________ tokens, **BLUE**'s round 2 payoff is equal to _____________________ tokens, and **GRAY**'s round 2 payoff is equal to ______________________ tokens.
- Hence, **RED**'s match payoff is equal to ______________________ tokens, **BLUE**'s match payoff is equal to _____________________ tokens, and **GRAY**'s match payoff is equal to ______________________ tokens.

**Exercise 3.** **SUPPOSE** Player **GRAY** offers **Proposal 2** to Players **RED** and **BLUE** and that the match involves one round.

- **SUPPOSE** **RED** chooses **Option C** and **BLUE** chooses **Option A** in round 1. Then, **RED**'s round 1 payoff is equal to ______________________ tokens, **BLUE**'s round 1 payoff is equal to _____________________ tokens, and **GRAY**'s round 1 payoff is equal to ______________________ tokens.
- Hence, **RED**'s match payoff is equal to ______________________ tokens, **BLUE**'s match payoff is equal to _____________________ tokens, and **GRAY**'s match payoff is equal to ______________________ tokens.

**Exercise 4.** **SUPPOSE** Player **GRAY** offers **Proposal 4** to Players **RED** and **BLUE** and that the match involves four rounds.

- **SUPPOSE** both **RED** and **BLUE** choose **Option C** in round 1. Then, **RED**'s round 1 payoff is equal to ______________________ tokens, **BLUE**'s round 1 payoff is equal to _____________________ tokens, and **GRAY**'s round 1 payoff is equal to ______________________ tokens.
- **SUPPOSE** that **RED** chooses **Option A** and **BLUE** chooses **Option C** in round 2. **RED**'s round 2 payoff is equal to ______________________ tokens, **BLUE**'s round 2 payoff is equal to _____________________ tokens, and **GRAY**'s round 2 payoff is equal to ______________________ tokens.
- **SUPPOSE** that **RED** chooses **Option C** and **BLUE** chooses **Option A** in round 3. **RED**'s round 3 payoff is equal to ______________________ tokens, **BLUE**'s round 3 payoff is equal to _____________________ tokens, and **GRAY**'s round 3 payoff is equal to ______________________ tokens.
- **SUPPOSE** that both **RED** and **BLUE** choose **Option A** in round 4. **RED**'s round 4 payoff is equal to ______________________ tokens, **BLUE**'s round 4 payoff is equal to _____________________ tokens, and **GRAY**'s round 4 payoff is equal to ______________________ tokens.
- Hence, **RED**'s match payoff is equal to ______________________ tokens, **BLUE**'s match payoff is equal to _____________________ tokens, and **GRAY**'s match payoff is equal to ______________________ tokens.