ISSN 1936-5349 (print)
ISSN 1936-5357 (online)

HARVARD

JOHN M. OLIN CENTER FOR LAW, ECONOMICS, AND BUSINESS

INCENTIVE CONTRACTS FOR TEAMS: EXPERIMENTAL EVIDENCE

Claudia M. Landeo
Kathryn E. Spier

Forthcoming in *Journal of Economic Behavior & Organization*

Discussion Paper No. 836

09/2015

Harvard Law School
Cambridge, MA 02138

INCENTIVE CONTRACTS FOR TEAMS: EXPERIMENTAL EVIDENCE*

CLAUDIA M. LANDEO† and KATHRYN E. SPIER‡

August 25, 2015

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 environments. Our main findings are as follows. First, we demonstrate that ongoing interaction among team members positively affects the principal's payoff. Greater team cooperation is successfully induced with less generous sharing rules in infinitely-repeated environments. Second, we provide evidence of the positive effects of communication on team cooperation in the absence of ongoing team interaction. Fostering communication among team members does not significantly affect the principal's payoff, suggesting that agents' communication is an imperfect substitute for ongoing team interaction. Third, we show that offering low sharing rules can backfire. The agents are willing to engage in costly punishment (shirking) as retaliation for low offers from the principal. Our findings suggest that offering low sharing rules is perceived by the agents as unkind behavior and hence, triggers negative reciprocity.

KEYWORDS: Moral Hazard in Teams; Prisoner's Dilemma; Stag-Hunt Games; Infinitely-Repeated Games; Communication; Reciprocity; Laboratory Experiments

JEL Categories: C72, C90, D86, K10, L23

*We acknowledge financial support from NSF Grant SES-1155761. Part of this research was conducted at the Harvard Law School where Claudia Landeo was a visiting Senior Research Scholar in Law. We wish to thank the Editor, the Associate Editor and the Referees for insightful suggestions. We also thank Nick Feltovich, Jack Ochs, seminar participants at the 9th Summer Research School of the Max Planck Institute for Research on Collective Goods, and conference participants at the 2014 Annual Meetings of the American Law and Economics Association held at the University of Chicago for helpful discussions and comments. We thank Tim Yuan for programming the software used in this study, and the Computer Laboratory for Experimental Research (CLER) at the Harvard Business School for subject-recruitment assistance.

†University of Alberta, Department of Economics and Institute for Public Economics. Henry Marshall Tory Building 7-25, Edmonton, AB T6G 2H4. Canada. landeo@ualberta.ca, tel. 780-492-2553; corresponding author.

‡Harvard Law School and NBER. 1575 Massachusetts Ave., Cambridge, MA 02138. kspier@law.harvard.edu, tel. 617-496-0019.

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).

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). Seminal theoretical work on moral hazard in teams studies *static environments in which the agents interact just once* (see for instance, Hölmstrom, 1982). 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).

Building upon the insights from the work 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 theoretical model 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. Their framework involves multiple equilibria. 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 providing the first experimental evidence of the effects of long-term teams (ongoing team interaction) on the likelihood of team cooperation and the cost of achieving team cooperation for the principal. We first construct a sequential game involving a principal and two agents. Our model captures the features of Che and Yoo's (2001) framework that are essential for studying the effects of long-term teams on agents' effort decisions and principal's decision regarding agents' compensation (sharing rule decision). In particular, our framework allows for effort complementarity and the endogenous emergence of prisoner's dilemma or stag-hunt games under low and high sharing rules, respectively. Second, we replicate our theoretical environment in the lab.

Our experimental design encompasses three empirically-relevant features of teams: Ongoing team interaction, agents' communication, and endogenous design of agents' payoffs. First, our 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). Second, it encompasses 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). Third, it includes 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 separate set of subjects in an exogenous fashion (through the computer). A combination of these treatments generates eight experimental conditions.

Our experimental study provides important contributions to the literature on incentive contracts for teams. The main insights are as follows.

(1) We demonstrate 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 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 less generous sharing rules.

(2) We provide evidence of the positive effects of communication on team cooperation. Better communication among the agents leads to higher levels of team cooperation in the absence of long-term teams. 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 results do indicate that communication among agents helps the principal induce cooperation.

(3) We show that offering low sharing rules can backfire. The agents are willing to engage

in costly punishment (shirking) as retaliation for low offers from the principal. Our results suggest that offering low sharing rules might be perceived as unkind behavior and trigger agents' negative reciprocity.

Our work also contributes to the experimental economics literature on infinitely-repeated games, communication, and social preferences and reciprocity.

(1) We provide the first experimental evidence on the interaction between communication and infinite repetition in endogenous prisoner's dilemma games. First, we demonstrate that infinite repetition positively affects cooperation, across communication environments. These results are consistent with our theory: Cooperation is an equilibrium outcome only in infinitely-repeated environments.[1] Second, we show that communication does not affect cooperation, across one-shot and infinitely-repeated environments. These results are not surprising in one-shot environments, where cooperation is not an equilibrium outcome. The findings in infinitely-repeated environments suggest that infinite repetition acts as an effective coordination device. Infinite repetition increases cooperation in no-communication environments, making it more difficult for communication to achieve a significant impact on cooperation.

(2) We present the first experimental evidence on the interaction between communication and infinite repetition in endogenous stag-hunt games. First, we demonstrate that infinite repetition positively affects cooperation only in the absence of communication. This finding suggests that communication acts as an effective coordination device. Communication increases cooperation in one-shot environments, making it more difficult for infinite repetition to achieve a significant contribution on cooperation. Second, we show that communication positively affects cooperation only in the absence of infinite repetition. This result indicates that infinite repetition acts as an effective coordinate mechanism. Infinite repetition increases cooperation in no-communication environments, making it more difficult for communication to achieve a significant impact on cooperation.

(3) We provide the first experimental evidence on the interplay between infinitely-repeated games and the endogeneity of the strategic environment. We show that payoff endogeneity has a significant effect on the behavior of contract recipients in infinitely-repeated environments. In particular, we provide evidence on the emergence of negative reciprocity in infinitely-repeated games.

Our paper is motivated by workers with complementary efforts organized as teams. How-

[1]The findings also suggest that communication does not act as a coordination device in one-shot prisoner's dilemma games, where cooperation is not equilibrium outcome.

ever, 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).

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. Formal proofs and additional analysis are presented in Appendix A; instructions and software screens are presented in Appendix B.[2]

2 Related Literature

First, our work is related to the literature on team incentives. 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.[3] Although production 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.[4] Our work extends this literature by studying team cooperation and the cost of achieving team cooperation. Importantly, our environment allows for the interplay of three empirically-relevant features of teams: ongoing

[2]Both appendices are available at the Journal website.

[3]See also Meidinger et al. (2003, 2000).

[4]See Bandiera et al. (2013), Hossain and List (2012) and Fryer et al. (2012) for field experiments on teams. See Isaac and Walker (1988) for public good experiments with endogenous prisoner's dilemma and stag-hunt games; see also Palfrey and Rosenthal (1994).

team interaction, agents' communication, and endogenous design of agents' payoffs.

Second, our paper is connected with the work on infinitely-repeated games and the literature on communication. Experimental studies on infinitely-repeated prisoner's dilemma games with exogenous payoffs suggest that infinitely-repeated environments and subjects' experience enhance cooperation (see for instance, Dal Bó, 2005; Dal Bó and Fréchette, 2011).[5] Experimental work on one-shot coordination and prisoner's dilemma games provides evidence of the role of communication as a coordination device. Cooper et al.'s (1992) seminal study on stag-hunt games with exogenous payoffs suggests that two-sided communication practically guarantees that subjects coordinate on the Pareto-dominant equilibrium.[6] The robustness of these findings is confirmed by Landeo and Spier's (2009) work on one-shot stag-hunt games with endogenous payoffs.[7] Duffy and Feltovich (2002) find that, although communication induces coordination in prisoner's dilemma and stag-hunt games, it is more effective in stag-hunt games for which the Pareto-dominant outcome is also an equilibrium outcome. Cason and Mui's (2014) work on coordinated-resistance games is the only study involving infinite repetition and communication. Their environment includes endogenous coordination games with Pareto-rankable N.E. and games that have a unique N.E. They find that infinitely-repeated interaction and communication increase coordination on the Pareto-efficient outcome. We extend this literature by studying the interaction between infinite repetition and communication in endogenous prisoner's dilemma and stag-hunt games.

Third, our work is related to 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). 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.[8] In contractual environments, Landeo and Spier's (2012, 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'

[5]See also Normann and Wallace (2012), Blonski et al. (2011), Duffy and Ochs (2009), Camera and Casari (2009), Battalio et al. (2001), Van Huyck et al. (1997), and Rankin et al. (2000).

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

[7]See also Blume and Ortmann (2007).

[8]See Bigoni et al. (2013) for evidence of other-regarding preferences in a collective trust game setting. See also Berg, et al. (1995).

reciprocity considerations in infinitely-repeated team environments.

3 Theoretical Framework

This section describes the model setup and the parameterization used in our experimental design. The formal analysis and proofs are presented in Appendix A.

3.1 Model Setup

We present a sequential game of complete information involving three risk-neutral players, a principal and two identical agents (agents 1 and 2) who work together and are rewarded for their joint performance.

Our model includes 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: $R_{11} + R_{00} \geq R_{10} + R_{01}$. 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 $(1 - 2x)R_{kl}$. We assume 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). We also 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. 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 costly. In the long-term team setting, at the conclusion of each round, a random process determines whether the interaction ends or continues for another round. In each round, the game continues with probability $\delta \in (0,1)$. Hence, δ might be interpreted as a measure of the (expected) duration of team interaction. δ can be also interpreted as a common discount factor for the two agents. 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.

Our model captures the features of Che and Yoo's (2001) framework that are essential for studying the effects of long-term teams on the likelihood of team cooperation and the cost of achieving team cooperation for the principal. In particular, the chosen incentive scheme applied to a setting with effort complementarity allows for the endogenous emergence of prisoner's dilemma and stag-hunt games, under low and high sharing rules, respectively.[9] Che and Yoo's (2001) environment includes other empirically-relevant elements such as uncertain agents' compensation and endogenous task design.[10] Given that our is the first experimental investigation of long-term teams, we decided to abstract from these additional features.

[9]Note that our paper does not aim at studying the effectiveness of different endogenously-generated incentive schemes. Although our informational and revenue assumptions allow for the construction of alternative incentive schemes, our theoretical framework imposes a specific incentive scheme. The chosen incentive scheme responds to the need of using a simple scheme that allows for the endogenous emergence of prisoner's dilemma and stag-hunt environments when incentives are low and high, respectively. Finally note that an alternative incentive scheme consisting of a bonus in case of hard work will only generate endogenous stag-hunt game environments. Hence, endogenous stag-hunt and prisoner's dilemma environments cannot be studied under this alternative scheme.

[10]In Che and Yoo (2001), the agents' efforts influence the probability of project's success. The principal's optimal incentive scheme involves paying zero to the agents if the project fails and paying a positive amount if the project succeeds. In other words, other incentives schemes are irrelevant in equilibrium. Our model is a deterministic version of Che and Yoo's (2001) environment. 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 agents an amount xR if the project succeeds and nothing if the project fails.

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

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

3.2 Model Parameterization

This section describes the parameter values adopted in our experimental design. Additional details regarding model parameterization are presented in Appendix A.

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 $\delta = .75$. Due to effort complementarity, depending on the sharing rule chosen by the principal, the Effort Stage-Game has either a prisoner's dilemma or a stag-hunt structure.[11] 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.

To reduce subjects' computational efforts, we restrict the sharing rules to the set $x \in \{.20, .25, .30, .35\}$. This set exhibits several important features.

(1) 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.

(2) In long-term team settings, sharing rules equal to .20 and .25 generate (Work Hard, Work Hard) as risk-dominant actions (Blonski and Spagnolo, 2001; Blonski et al., 2011). In particular, when sharing rules are equal to .20 and .25, the critical δ-values are .71 and .39, respectively. Given that our numerical examination uses $\delta = .75$, (Work Hard, Work Hard) are risk-dominant actions under sharing rules equal to .20 and .25.

(3) In short-term team settings, sharing rules equal to .30 and .35 generate (Work Hard, Work Hard) as risk-dominated and risk-dominant actions, respectively

(4) From a behavioral point of view, these sharing rules generate payoffs for the three players

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

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.

that are large enough to trigger subjects' attention and effort, and simple enough to minimize subjects' cognitive costs.

Table 2 summarizes the equilibria for Stage 2. When the sharing rule is equal to .20 and .25, the short-term team setting (one-shot Effort Stage-Game) has a unique equilibrium where both agents shirk.[12] In the long-term team setting (infinitely-repeated Effort Stage-Game), cooperation (Work Hard, Work Hard) can be also sustained in equilibrium by grim trigger strategies. When, the sharing rules are equal to .30 and .35, both cooperation (Work Hard, Work Hard) and (Shirk, Shirk) are equilibria in 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*

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

sharing rule $x = .20$ and both agents decide to shirk.

Intuitively, 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. The preferred 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.*

Intuitively, 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.[13] 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 when the sharing rule equals .20 or .25. In contrast, cooperation (hard work) and non-cooperation

[13] 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 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.

(shirking) are both equilibria when the sharing rule equals .30 or .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 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 rule equals .35 but not when it equals .20, .25, or .30.

In long-term team settings, both cooperation and non-cooperation are equilibria across 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 environments, the cooperation equilibrium is Pareto-dominant across sharing rules. Then, we might expect that cooperation will be obtained across sharing rules in long-term team settings.[14] 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

[14]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.

team cooperation will be lower in long-term team settings.[15]

It is worth noting that previous experimental work on the effects of communication in one-shot prisoner's dilemma and stag-hunt games (Duffy and Feltovich, 2000) suggests that cooperation will be more frequent in communication environments (Hypothesis 2). 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.*

In short-term team settings, cooperation is the efficient outcome across sharing rules but is the equilibrium only under sharing rules equal to .30 or .35. Given previous experimental findings in one-shot environments (Cooper et al., 1992), we might expect that communication will increase the likelihood of team cooperation across sharing rules. In long-term team settings, cooperation is the Pareto-dominant equilibrium across sharing rules. Previous experimental findings on infinitely-repeated environments (Cason and Mui, 2014) suggest that communication enhances coordination on the efficient outcome. Then, we might expect higher likelihood of cooperation under communication across sharing rules. Anticipating these effects, the strategic principal will lower his sharing rule. As a result, the cost of achieving team cooperation will be lower under communication in short-term and long-term team settings.[16]

Given that cooperation will be more frequent in long-term team settings (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).*

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

[16]The principals might believe that low sharing rules will reduce the likelihood of team cooperation (due to negative reciprocity or payoff-salience issues), in short-term and long-term team settings. Alternatively, they might believe that the effects of communication on cooperation might be too weak in short-term team settings and sharing rules equal to .20 and .25 (for which cooperation is not achieved in equilibrium). As a result, the choice of a sharing rule by the principal and the cost of achieving team cooperation might not be affected by communication.

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, 2005). Given that retaliation by shirking is also costly for the agents, punishment might suggest the presence of strong negative reciprocity. A sharing rule equal to .20, which is the lowest possible sharing rule, might trigger negative reciprocity.[17] The elicitation of agents' reciprocity considerations will be stronger in the presence of a human principal (Blount, 1995). Then, we might expect that the likelihood of agents' cooperation will be lower in endogenously-generated prisoner's dilemma games.[18] 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 experimentally study the effects of long-term teams, non-binding pre-play communication between the agents, and environment endogeneity on team cooperation and the cost of achieving team cooperation. Table 4 summarizes the experimental conditions and number of subjects per condition.

5.1 The Games

Procedural regularity is accomplished by developing a software program that allows the subjects to play the game by using networked personal computers. The software consists of 8 versions of the game, reflecting the eight experimental conditions. To ensure control and

[17]If the normative expectation about fairness involves a 50-50 split of the pie between the principal and the team (a sharing rule equal to .25), then a sharing rule equal to .20 might be perceived by the agents as "unkind." Alternatively, if the expectation about "fairness" involves an equal split of the pie between the principal, agent 1, and agent 2 (a sharing rule equal to .33), only a sharing rule equal to .35 will be perceived by the agents as "fair."

[18]In the presence of strong negative reciprocity, three differences between exogenous and endogenous environment generated by the lowest sharing rule deserve to be mentioned. First, the choice of shirking reflects defection in exogenous environments; in endogenous environments, shirking will also reflect punishment to the principal. Second, the shirking equilibrium might Pareto dominate the working-hard equilibrium, in monetary and non-monetary terms. Third, in endogenous environments, punishment strategies might be used by the agents to induce coordination on shirking (i.e., on punishing the principal). We thank one of the referees for these suggestions.

Table 4: Experimental Conditions

	Endogenous Environments		Exogenous Environments	
	Condition	Subjects	Condition	Subjects
Short-Term Teams/No-Comm.	EN/ST/NC	[33]	EX/ST/NC	[22]
Short-Term Teams/Comm.	EN/ST/C	[33]	EX/ST/C	[22]
Long-Term Teams/No-Comm.	EN/LT/NC	[36]	EX/LT/NC	[24]
Long-Term teams/Comm.	EN/LT/C	[36]	EX/LT/C	[24]

replicability, a free-context environment is constructed. Specifically, neutral labels are used to denote the subjects' roles: Player Gray (principal), and Players Red and Blue (agents 1 and 2, respectively). The players' choices are also labeled in a neutral way: Proposal 1, 2, 3, or 4 (principal's sharing rule equal to .20, .25, .30., or .35, respectively); Option A or C (agent's decision to work hard or to shirk, respectively). 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. A laboratory currency called the "token" (90 tokens = 1 U.S. dollar) is used in our experiment.

The benchmark game corresponds to the Endogenous Strategic-Environment/Short-Term Teams/No-Communication condition (EN/ST/NC). Subjects play the role of principal, agent 1, or agent 2. The roles of agents 1 and 2 are similar. Each match involves two stages. In Stage 1, the principal chooses an Effort Stage-Game matrix among four possible matrices (corresponding to the four sharing rules). In Stage 2, 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). Variations of the benchmark game satisfy the other experimental conditions.

In the Long-Term Team conditions, the agents play an infinitely-repeated Effort Stage-Game. Following the experimental literature on implementation of infinite repetition in the lab (Fréchette and Dal Bó, 2011; Duffy and Ochs, 2009; Dal Bó, 2005; Murnighan and Roth, 1983; Roth and Murnighan, 1978), we use a random continuation rule approach. Specifically, in each match, we set the probability that the game would continue to the next round $\delta = .75$. To maximize control over match length effects (across sessions), before running the actual sessions, the computer randomly determines the number of rounds per match using $\delta = .75$ and the additional restriction that the total number of rounds for the nine matches should be equal to 36 (4 rounds per match, on average).[19] We then apply these round numbers to

[19]Theoretically, the expected number of rounds per match in long-term team settings with $\delta = .75$ is equal to four. This is the rationale for restricting the total number of rounds to 36.

all long-term team sessions.[20] Subjects are informed that the likelihood that a match will continue to the next round is equal to .75 (see The Experimental Sessions section and the Written Instructions in Appendix B). As argued by Dal Bó (2005), this information allowed us to control for subjects' beliefs about the likelihood of future interaction.

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. Structured communication is implemented. In particular, the only message that an agent can send to the other agent is whether she intends to work hard or to shirk. 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.

In the Exogenous Strategic-Environment conditions, the computer provides the proposal in Stage 1. Subjects are informed that the proposal is provided by the computer. We follow the methodology developed by Landeo and Spier (2009) for the implementation of exogenous environments in the lab. In particular, 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. To make the endogenous and exogenous conditions comparable: (1) For each exogenous session, the formation of groups (pair of agents in this case) replicates the randomization process of forming groups followed by the corresponding endogenous session; (2) to ensure that the sequence of proposals received by each individual agent in the exogenous and endogenous conditions follow the same pattern, each agent in the exogenous conditions is matched with an agent in the corresponding endogenous condition and follows the same pattern of sharing rules (and matching process with other agents); and, (3) both the exogenous and endogenous conditions include two stages.

[20] The software implementation was as follows. First, we wrote a simple JAVA computer program to randomly pre-determine the number of rounds per match with the restrictions mentioned before. We then incorporated the round number values into the software used in our experimental sessions (also written in JAVA). JAVA computer programs are available upon request.

5.2 The Experimental Sessions

We ran twenty-two 70- to 120-minute sessions[21] of 6 to 18 subjects each (two or three sessions per condition, 230 subjects in total)[22] at experimental laboratories of Harvard University. 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.[23] Subjects were allowed to participate in one experimental session only, and received information only about the game version that they were assigned to play.

At the beginning of each session, written instructions were provided to the subjects. The instructions about the game and the software were verbally presented by the experimenter to create common knowledge. Specifically, subjects were informed: (1) about the game structure, possible choices, and payoffs; (2) about the random process of allocating roles; (3) about the randomness and anonymity of the process of forming groups; (4) about the token/dollar equivalence, and that they would receive the dollar equivalent of the tokens they held at the end of the session; (5) in the long-term team sessions, subjects were informed that the likelihood that a match will continue to the next round was equal to .75 (see The Game section and the Written Instructions in Appendix B). Finally, subjects were required to fill out a short questionnaire to ensure their ability to read the information tables. The rest of the session was entirely played using computer terminals and the software designed for this experiment. Communication between players was done through pre-defined messages using computer terminals, and therefore, players were completely anonymous to one another. Hence, this experimental environment did not permit the formation of reputations across matches.

The experimental sessions included one practice match with one round and four rounds, for the short-term and long-term team settings, respectively.[24] The outcomes from the practice match were not considered in the computation of players' payoffs. Then, during these practice matches, subjects had an incentive to experiment with the different options and hence, learn about the consequence of their choices. Nine actual matches were included in

[21] The sessions run on condition EX/ST/NC lasted 70 minutes.

[22] 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 2 sessions; each of the other 6 conditions involved 3 sessions.

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

[24] Theoretically, the expected number of rounds per match in long-term team settings is equal to four (for $\delta = .75$). Then, we set the number of rounds in the practice match to 4, and applied across sessions and long-term team conditions.

the short-term and long-term team sessions. In the short-term team sessions, each actual match included one round. In the long-term team sessions, the randomly-generated rounds per match are as follows: 7, 3, 4, 6, 4, 5, 2, 4, 1 rounds for matches 1, 2, ..., 9, respectively (see The Games section for details regarding the application of the random continuation rule approach).

Before the practice match, every participant was randomly assigned a role. The roles remained the same during the entire session. A random-matching protocol for group formation was applied to the whole session participants. Specifically, 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.[25] 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. The average payoff was \$56, for an average time commitment of 90 minutes.[26] At the end of each experimental session, subjects received their monetary payoffs in cash.[27]

6 Results

Our probit analysis of learning suggests a significant effect of learning on the probability of team cooperation across no-communication conditions (p-value $< .01$, EN/ST/NC, EN/LT/NC, EX/LT/NC conditions; p-value $= .03$, EX/ST/NC condition). Then, only the last five matches (all rounds) are considered in our analysis. The main qualitative results hold when all matches are considered. For brevity, probit analysis of learning, descriptive statistics using all matches and the first four matches, and probit analysis using all matches and the first four matches are presented in Appendix A.

[25]The computer was programmed to randomly form groups taking into account the restrictions regarding group members across rounds in long-term team settings, the restriction that the three group members could not pertain to the same group in two immediately consecutive matches, and the maximization of the number of different groups per match in a nine-match session.

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

[27]A criticism to our lab implementation of the infinitely-repeated games refers to potential contagion effects (Kandori, 1992) due to the number of subjects per session and the random-matching protocol for group formation (Dal Bó, 2005). Contrary to Kandori (1992), Duffy and Ochs' (2009) findings on infinitely-repeated prisoner's dilemma games with exogenous payoffs do not suggest the presence of contagion effects when players are randomly matched.

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, 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)]Standard deviations and mode frequencies are in parentheses; [(b)]standard deviations are in parentheses; number of sharing rule decisions and total number of rounds are in brackets.

6.1 Data Summary

Table 5 provides descriptive statistics. Regarding the endogenous environments, the data suggest that long-term team settings increased team cooperation (the (W, W) rate) and the principal's payoff, with a stronger effect in no-communication environments. Our findings also indicate that communication increased team cooperation iand raised the principal's payoff in short-term team settings. The mode sharing rule chosen by the principal was equal to .30 across conditions, except for the long-term setting with communication for which the mode sharing rule was equal to .20. Similar effects of long-term teams and communication are observed in the exogenous environments.

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, .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 6 describes the agents' actions and principal's sharing rule for each condition. For instance, in the EN/ST/NC condition, principals chose a sharing rule equal to .25 in sixteen percent of the total cases. In eleven percent of the cases, both agents decided to work hard (team cooperation); and, in eighty-nine 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 across communication settings and no-communication settings with stag-hunt games generated by a a sharing rule equal to .30. Communication also raised the frequency of team cooperation, especially in short-term settings with stag-hunt games generated by a sharing rule equal to .30. 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 suggest 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, no-communication and communication conditions, respectively). Similarly, communication 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, short-term and long-term team conditions, respectively).

6.2 Analysis

The main findings are reported in a series of results. 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. Marginal effects, which are more easily interpreted, are reported. For brevity, additional supporting analysis is presented in Appendix A.

Team Cooperation

This section presents the analysis of the effects of long-term teams, agents' communication, and the endogeneity of the strategic environment on team cooperation.

Effects of Long-Term Teams

Table 7 reports the effects of long-term teams on the probability of team cooperation (hard work by both agents). It encompasses four probit estimations. Columns two and three correspond to probit estimations in endogenous environments (without and with communication); columns four and five correspond to probit estimations in exogenous environments (without and with communication). We take pair of conditions and estimate each probit model. In particular, each probit model includes a treatment dummy, and match and round variables as its regressors. The treatment dummy variable is constructed as follows. For instance, for the probit model that assesses the effects of long-term teams in endogenous and no-communication environments (second column), the dummy variable takes a value equal to one 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.

Our results suggest that, by implementing long-term teams (ongoing team interaction), the principal can effectively induce team cooperation when the agents cannot communicate.

Table 7: Effects of Long-Term Teams on the Likelihood of Team Cooperation
(Probit Tests of Differences across Conditions)

	EN/ST/NC vs. EN/LT/NC	EN/ST/C vs. EN/LT/C	EX/ST/NC vs. EX/LT/NC	EX/ST/C vs. EX/LT/C
	Mg. Effect	Mg. Effect	Mg. Effect	Mg. Effect
Long-Term Teams	.43***	.24	.47***	.41***
	(.11)	(.17)	(.11)	(.07)
Match	.01	.00	.01	−.01
	(.02)	(.03)	(.02)	(.02)
Round	.02*	−.03	.01**	−.02
	(.01)	(.02)	(.01)	(.01)
Observations	247	247	247	247

Notes: 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 rounds.

In particular, in no-communication environments, long-term teams significantly increase the likelihood of team cooperation across endogenous and exogenous settings (p-value $< .01$, both settings).[28] In fact, as a result of long-term teams, higher team cooperation rates are observed (79 vs. 33 and 75 vs. 27 percent, endogenous and exogenous settings). In communication environments, long-term teams significantly increase the likelihood of team cooperation when exogenous settings are present (p-value $< .01$). The relevant comparison is 90 vs. 53 percent. Our results provide support to Hypothesis 1.

RESULT 1: *When the agents cannot communicate with each other, long-term teams 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.*

We deepen our understanding of the effects of long-term teams on the probability of team cooperation by analyzing prisoner's dilemma and stag-hunt environments separately (see Appendix A for probit analysis). We find that, in prisoner's dilemma games, long-term teams significantly increase the likelihood of team cooperation across communication environments (p-value $< .01$ and p-value $= .02$, no-communication and communication in en-

[28]The effect of round is positive (as expected) and significant in two of the probit estimations.

dogenous environments; p-value $< .01$, communication in exogenous environments).[29] These results are aligned with our theory: Cooperation is an equilibrium only in long-term team environments. In stag-hunt games, long-term teams significantly increase cooperation when the agents cannot communicate (p-value $< .01$ and p-value $= .01$, endogenous and exogenous environments).[30] These findings suggest that communication acts as an effective coordination device, increasing the cooperation rate in short-term environments, and hence, making it more difficult for long-term teams to achieve a significant impact. Our analysis helps us understand why the overall effect of long-terms teams on cooperation is not significant in endogenous environments with communication. The overall significant effect of long-term teams on cooperation in exogenous environments with communication might be explained by the higher effects of long-term teams on the probability of team cooperation across sharing rules.[31] Our findings provide further support to Hypothesis 1.

RESULT 2: *In prisoner's dilemma games, long-term team settings significantly increase the likelihood of team cooperation.*

RESULT 3: *In stag-hunt games, long-term team settings significantly increase the likelihood of team cooperation when the agents cannot communicate with each other.*

Effects of Agents' Communication

Table 8 reports the effects of communication on the probability of team cooperation. Our results indicate that, by enhancing communication channels among team members, the principal can successfully induce team cooperation in the absence of long-term teams. Specifically, in short-term team environments, communication significantly increases the likelihood of team cooperation across endogenous and exogenous settings (p-value $= .039$ and p-value $< .01$, endogenous and exogenous settings).[32] The comparisons are 55 vs. 33 percent and 53 vs. 27 percent (endogenous and exogenous settings). In long-term team environments,

[29]The marginal effects are as follows: .58 and .48, no-communication and communication in endogenous environments; .81, communication in exogenous environments. A probit estimation on EX/LT/NC vs. EX/ST/NC was not possible because the frequency of team cooperation in EX/ST/NC conditions was zero.

[30]The marginal effects are as follows: .38 and .36, endogenous and exogenous environments.

[31]The high cooperation rate in stag-hunt games when short-term teams and communication are present, together with the high frequency of stag-hunt games, might explain the significant results.

[32]The effect of match is negative and significant in endogenous environments with short-term teams, suggesting that the effect of communication might be weakened with experience.

Table 8: Effects of Agents' Communication on the Likelihood of Team Cooperation
(Probit Tests of Differences across Conditions)

	EN/ST/NC vs. EN/ST/C	EN/LT/NC vs. EN/LT/C	EX/ST/NC vs. EX/ST/C	EX/LT/NC vs. EX/LT/C
	Mg. Effect	Mg. Effect	Mg. Effect	Mg. Effect
Communication	.22**	−.05	.25***	.15
	(.11)	(.18)	(.07)	(.10)
Match	−.07***	.04**	−.02	.01
	(.02)	(.01)	(.02)	(.01)
Round	–	.00	–	−.00
		(.01)		(.01)
Observations	110	384	110	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 rounds.

communication does not significantly affect the likelihood of team cooperation. Our findings provide support to Hypothesis 2 in short-term team environments.

RESULT 4: *In short-term team environments, communication between the agents significantly increases the likelihood of team cooperation.*

We strengthen our understanding of the effects of agents' communication on the probability of team cooperation by analyzing prisoner's dilemma and stag-hunt environments separately (see Appendix A for probit analysis). We find that, in prisoner's dilemma games, communication does not significantly affect the likelihood of team cooperation. The results are not surprising in short-term team environments, where cooperation is not an equilibrium outcome. The findings in long-term team environments are aligned with our theory and with previous experimental findings regarding the effects of infinitely-repeated games as a coordination mechanism: Long-term teams increase the likelihood of cooperation, making cooperation rates in no-communication and communication environments closer. In stag-hunt games, communication significantly increases the likelihood of team cooperation in short-term team environments (p-value $= .03$ and p-value $< .01$, endogenous and exogenous environments).[33] These results suggest that long-term teams act as an effective coordination device

[33] The marginal effects are as follows: .30 and .42, short-term teams with endogenous and exogenous

in no-communication environments, increasing the cooperation rates in no-communication environments, and hence, making it more difficult for communication to achieve a significant contribution. Our analysis might explain why the overall effect of communication on cooperation is not significant when long-term teams are present. The high cooperation rates in prisoner's dilemma and stag-hunt games when no-communication and long-term teams are present explain these results. Our findings provide further support to Hypothesis 2.

RESULT 5: *In short-term team environments and stag-hunt games, communication between the agents significantly increases the likelihood of team cooperation.*

Effects of Endogeneity

Table 9 reports the effects of endogeneity on the likelihood of team cooperation, in long-term team environments. Columns two to five correspond to the probit estimations for sharing rules equal to .20, .25, .30 and .35, respectively. 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. When the sharing rule is equal to .20, endogeneity significantly decreases the likelihood of team cooperation (p-value = .02). This result suggests the presence of negative reciprocity. Reciprocity is strongly elicited in endogenous strategic environments 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 reciprocate the principal's unkind behavior by shirking more frequently. In fact, lower team cooperation rates are observed under endogeneity when the sharing rule is equal to .20 (0 vs. 76 percent and 48 vs. 73 percent, no-communication and communication environments). Importantly, the agents are willing to sacrifice monetary payoffs (i.e., shirking involves lower payoffs for the agents) in order to punish the principal. Hence, reciprocity considerations seem to be very strong. Our findings provide support for Hypothesis 3.

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 principal can induce team cooperation by assigning agents to long-term teams or by enhancing agents' communication. The next important

environments.

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 across Conditions)

	.20	.25	.30	.35
	Marginal Effect	Marginal Effect	Marginal Effect	Marginal Effect
Endogeneity	$-.37^{**}$	.00	.08	$-.03$
	(.16)	(.11)	(.14)	(.09)
Match	.03	.01	.01	$.03^{**}$
	(.05)	(.01)	(.02)	(.02)
Round	$-.03$	$.04^{***}$	.00	$-.00$
	(.02)	(.02)	(.01)	(.02)
Observations	174	206	226	162

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 rounds.

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 cost of achieving 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 (see Appendix A for probit analysis). We find that long-term teams significantly increase the likelihood of a sharing rule equal to .20 or .25 in team cooperation cases (p- value = .02 and p-value = .08, no-communication and communication). 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 32 percent (no-communication) and from 13 to 52 percent (communication). These results might suggest the principal's anticipation of higher likelihood of cooperation in low-sharing rules when long-term team settings are present. Our results do not suggest a significant effect of communication on the likelihood of a sharing rule equal to .20 or .25 in team cooperation cases (p-value = .23 and p-value = .41, short-term and long-term teams).

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

We deepen our understanding of the cost of achieving team cooperation by assessing the effects of long-term teams and agents' communication on the probability of a high payoff

Table 10: Effects of Long-Term Teams on the Likelihood of High Payoff for the Principal (Probit Tests of Differences across Conditions)

	EN/ST/NC vs. EN/LT/NC	EN/ST/C vs. EN/LT/C
	Marginal Effect	Marginal Effect
Long-Term Teams	.24**	.32*
	(.10)	(.19)
Match	.04***	.01
	(.01)	(.04)
Round	.01*	−.01
	(.01)	(.01)
Observations	247	247

Notes: Robust standard errors (using sessions as clusters) are in parentheses; ***, ** and * denote significance at the 1%, 5%, and 10% levels, respectively; observations correspond to the number of rounds.

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 10 presents the effects of long-term team settings on the likelihood of a high payoff for the principal. The second and third column correspond to the probit estimations in no-communication and communication environments, respectively. We take pair of conditions and estimate each probit model. In particular, each probit model includes a treatment dummy variable and match and round variables as its regressors.

Long-term teams significantly increase the likelihood of high payoff for the principal across communication environments (p-value = .02 and p-value = .08, no-communication and communication).[34] In fact, as a result of the implementation of long-term teams, a higher frequency of high payoff for the principal is observed: 26 versus 2 percent and 39 versus 7 percent (no-communication and communication). These results might be explained by the higher frequencies of team cooperation when sharing rules are equal to .20 and .25, and the

[34]The effect of match is positive and significant in no-communication environments, suggesting that the effect of long-term teams might be strengthened with experience. The effect of round is positive (as expected) and significant.

higher frequency of these sharing rules. Importantly, these findings suggest that team cooperation is achieved at a lower cost when the agents are assigned to long-term teams. Our findings provide support to Hypothesis 1.

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

Our findings do not indicate a significant effect of communication on the likelihood of high payoff for the principal (p-value = .17 and p-value = .52, short-term and long-term teams).[35] These results suggests that communication among agents is an imperfect substitute for long-term team interaction. Although communication enhances team cooperation in short-term team environments, cooperation is not achieved at a lower cost when agents communicate. These findings are aligned with our theory: In short-term team settings, only sharing rules equal to .30 and .35 induce cooperation in equilibrium.

Summing up, our analysis underscores the significant impact of agents' communication and ongoing team interaction on team cooperation. In addition, we present evidence of the effectiveness of ongoing team interaction in enhancing team cooperation at a low cost. These last results provide support to Che and Yoo's (2001) key theoretical insights.

7 Summary and Conclusions

This paper studies incentives contracts for teams. We present the first experimental study of the effects of ongoing team interaction on team cooperation and the cost of achieving team cooperation. Our paper is inspired by Che and Yoo's (2001) important contributions to the theoretical literature on teams. Their work strengthens the analysis of team cooperation and group incentive schemes by allowing for infinitely-repeated interactions among team members. Che and Yoo (2001) theoretically demonstrate that ongoing team interaction reduces the principal's cost of achieving team cooperation. Interestingly, their model involves multiplicity of equilibria. The assumption of Pareto dominance as a equilibrium selection mechanism is crucial to their analysis and findings. Equilibrium selection is an empirical question that experimental economics methods can help address.

The theoretical framework used in this paper captures the essential features of Che and Yoo's (2001) framework. Specifically, our model allows for effort complementary and the

[35]Detailed probit analysis is presented in Appendix A.

endogenous emergence of prisoner's dilemma and stag-hunt games using a simple joint-performance incentive scheme. Our experiment explores the interplay of two important features of team work, infinitely-repeated team interaction and agents' communication. Our findings suggest that infinitely-repeated team interaction and agents' communication can be effective coordination mechanisms. Interestingly, the effectiveness of each individual mechanism precludes the other mechanism to have a significant additional contribution on enhancing team cooperation. Our work also underscore the importance of incorporating a direct assessment of the effects of intentionality into the analysis of incentive contracts for teams by exogenously administering (through the computer) the offers designed by human subjects. Although our results indicate that the previous findings observed in prisoner's dilemma and stag-hunt games with exogenous payoffs are in general robust to endogenous strategic environments, our study suggests the presence of other-regarding preferences and negative reciprocity.

Important lessons for the implementation of team work and organizational design are derived from our work. Our results suggest that organizations can promote team cooperation at a low cost by implementing long-term teams (ongoing team interaction). Compensation schemes that might be perceived as unkind by team members need to be avoided, however. Organizations might also enhance cooperation in the absence of long-term teams by designing work processes that promote communication among team members.

An extension to this study, which we are currently pursuing, involves the investigation of the behavioral factors that might affect the effectiveness of incentive contracts for teams. We use an environment characterized by effort complementarity and a simple group incentive scheme (consisting of a fixed payment and a bonus conditional on high performance from both team members). Stag-hunt games endogenously arise, and team cooperation occurs only if both agents coordinate on the efficient outcome. Building on previous work on contract frames (Hossain and List, 2012; Armantier and Boly, forthcoming) and endogenous stag-hunt games and reciprocity (Landeo and Spier, 2009), we investigate whether loss aversion and reciprocity affect team cooperation by acting as coordination mechanisms. Another interesting extension consists of assessing the effects of agents' risk attitudes on the effectiveness of group incentive schemes in a strategic environment characterized by uncertain revenues. These, and other topics, are fruitful venues for future research.

References

Abreu, D., 1988. On the theory of infinitely repeated games with discounting. Econometrica 56, 383–396.

Alchian, A., Demsetz, H., 1972. Production, information costs, and economic organization. American Economic Review 62, 777–795.

Armantier, O., Boly, A., forthcoming. Framing of incentives and effort provision. International Economic Review.

Aumann, R., 1990. Nash equilibria are not self-enforcing." In: Gabszewicz, J.J., Richard, J.F., Wolsey, L.A. (Eds.). Economic Decision- Making: Games, Econometrics and Optimisation. Amsterdam: Elsevier, 201–206.

Aumann, R., Shapley, L.S., 1994. Long-term competition: a game theoretic analysis. In: Megiddo, N. (Ed.). Essays in Game Theory in Honor of Michael Maschler. New York: Springer, 1–15.

Aumann, R., Shapley, L.S., 1976. Long-term competition – a game theoretic analysis. Mimeo.

Axelrod, R., 1984. The Evolution of Cooperation. New York: Basic Books.

Bandiera, O., Barankay, I., Rasul, I., 2013. Team incentives: evidence from a firm level experiment. Journal of the European Economic Association 11, 1079–1114.

Bandiera, O., Barankay, I., Rasul, I., 2007. Incentives for managers and inequality among workers: evidence from a firm level experiment. Quarterly Journal of Economics 122, 729–75.

Battalio, R., Samuelson, L., Van Huyck, J., 2001. Optimization incentives and coordination failure in laboratory stag hunt games. Econometrica 69, 749-764.

Berg, J., Dickhaut, J., McCabe, K., 1995. Trust, reciprocity, and social history. Games and Economic Behavior 10, 122–142.

Bigoni, M., Bortolotti, S., Casari, M., Gambetta, D., 2013. It takes two to cheat: an experiment of derived trust. European Economic Review 64, 129–146.

Blonski, M., Ockenfels, P., Spagnolo, G., 2011. Equilibrium selection in the repeated prisoner's dilemma: axiomatic approach and experimental evidence. American Economic Journal: Microeconomics 3, pp. 164–192.

Blonski, M., Spagnolo, G., 2001. Prisoners' other dilemma. Stockholm School of Economics Economic Research Institute Working Paper 437.

Blount, S., 1995. When social outcomes aren't fair: the effect of causal attributions on preferences. Organizational Behavior and Human Decision Processes 63, 131–144.

Blume, A., Ortmann, A., 2007. The effects of costless pre-play communication: experimental evidence from games with pareto-ranked equilibria. Journal of Economic Theory 132, 274–290.

Brandts, J., and Cooper, D.J., 2007. It's what you say, not what you pay: an experimental study of manager-employee relationships in overcoming coordination failure. Journal of the European Economic Association 5, 1223–1268.

Camera, G., Casari, M., 2009. Cooperation among strangers under the shadow of the future. American Economic Review 99, 979 –1005.

Cason, T., Mui, V.-L., 2014. Coordinating collective resistance through communication and repeated interaction. Economic Journal 124, F226 – F256.

Charness, G., Kuhn, P., 2011. Lab labor: what can labor economists learn in the lab? Coordination problems. In: Ashenfelter, O., Card, D. (Eds.). Handbook of Labor Economics. Amsterdam: Elsevier.

Charness, G., 2000. Self-serving cheap talk: a test of Aumann's conjecture. Games and Economic Behavior, 33, 177–194.

Che, Y.-K., 2002. Joint liability and peer monitoring under group lending. Contributions in Theoretical Economics 2, 1534–5971.

Che, Y.-K., Yoo, S.-W., 2001. Optimal incentives for teams. American Economic Review 91, 525–541.

Cooper, R. W., DeJong, D.V., Forsythe, R., Ross, T.W., 1992. Communication in coordination games. Quarterly Journal of Economics 107, 739–771.

Cooper, R., DeJong, D.V., Forsythe, R., Ross, T.W., 1990. Selection criteria in coordination games: some experimental results. American Economic Review 80, 218–33.

Crawford, V. P., 1998. A Survey of experiments on communication via cheap talk. Journal of Economic Theory 78, 286–298.

Dal Bó, P., 2005. Cooperation under the shadow of the future: experimental evidence from infinitely repeated games. American Economic Review 95, 1591–1604.

Dal Bó, P., Fréchette, G.R., 2011. The evolution of cooperation in infinitely repeated games: experimental evidence. American Economic Review 111, 411–429.

Duffy, J., Feltovich, N., 2002. Do actions speak louder than words? An experimental comparison of observation and cheap talk. Games and Economic Behavior 39, 1–27.

Duffy, J., Ochs, J., 2009. Cooperative behavior and the frequency of social interaction. Games and Economic Behavior 66, 785–812.

Farrell, J., 1987. Cheap talk, coordination, and entry. RAND Journal of Economics 18, 34–39.

Farrell, J., Rabin, M., 1996. Cheap talk. Journal of Economic Perspectives 10, 103–118.

Feess, E., Walzl, M., 2004. Optimal law enforcement and self-reporting when there are criminal teams. Economica 71, 333–348.

Fehr, E., Kirchler, E., Weichbold, A., Gächter, S., 1998. When social norms overpower competition – gift exchange in experimental labor markets. Journal of Labor Economics 16, 324–351.

Fryer Jr., R.G., Levitt, S.D., List, J., Sadoff, S., 2012. Enhancing the efficacy of teacher incentives through loss aversion: a field experiment. National Bureau of Economic Research, Working Paper 18237.

Gächter, S., Fehr, E., 2001. Fairness in the labour market – a survey of experimental results. In: Bolle, F., Lehmann-Waffenschmidt, M. (Eds.). Surveys in Experimental Economics. Bargaining, Cooperation and Election Stock Markets. Physica Verlag.

Gaynor, M., Pauly, M.V., 1990. Compensation and productive efficiency in partnerships: evidence from medical groups practice. Journal of Political Economy 98, 544–573.

Gilson, R.J., Mnookin, R.H., 1985. Sharing among the human capitalists: an Economic inquiry into the corporate law firm and how partners split profits. Stanford Law Review 37, 313 – 392.

Goerg, S.J., Kube, S., Zultan, R., 2010. Treating equals unequally – incentives in teams, workers' motivation and production technology. Journal of Labor Economics 28, 747–772.

Harsanyi, J.C., Selten, R., 1988. A General Theory of Equilibrium Selection in Games. Cambridge: MIT Press.

Hölmstrom, B., 1982. Moral hazard in teams. Bell Journal of Economics 14, 324–340.

Hossain, T., List, J.A., 2012. The behavioralist visits the factory: increasing productivity using simple framing manipulations. Management Science 58, 2151–2167.

Isaac, M.R., Walker, J.M., 1988. Group size effects in public goods provision: the voluntary contributions mechanism. Quarterly Journal of Economics 103, 179–199.

Kandel, E., Lazear, E., 1992. Peer pressure in partnerships. American Economic Review 100, 801 – 817.

Kandori, M., 1992. Social norms and community enforcement. Review of Economic Studies 59, 63–80.

Kornhauser, L.A., Revesz, R.L., 1994. Multidefendant settlements: the impact of joint and several liability. Journal of Legal Studies 23, 41–76.

Kornhauser, L.A., Revesz, R.L., 1989. Sharing damages among multiple tortfeasors. Yale Law Journal 98, 831–884.

Landeo, C.M., Spier, K.E., 2012. Exclusive dealing and market foreclosure: further experimental results. Journal of Institutional and Theoretical Economics 168, 150–170.

Landeo, C.M., Spier, K.E., 2009. Naked exclusion: an experimental study of contracts with externalities. American Economic Review 99, 1850–1877.

Lazear, E.P., Shaw, K.L., 2007. Personnel economics: the economist's view of human resources. Journal of Economic Perspectives 21, 91–114.

Leibowitz, A., Tollison, R., 1980. Free riding, shirking, and team production in legal partnerships. Economic Inquiry18, 380 – 394.

Meidinger, C., Rulliére, J.-L., Villeval, M.-C., 2003. Does team-based compensation give rise to problems when agents vary in their ability? Experimental Economics 6, 253–272.

Meidinger, C., Rulliére, J.-L., Villeval, M.-C., 2000. Free-riding and fairness in principal–multi-agent relationships: experimental evidence. Revista Internazionale di Scienze Sociali 153, 409–434.

Murnighan, J. K., Roth, A.E., 1983. Expecting continued play in prisoner's dilemma games. Journal of Conflict Resolution 27, 279–300.

Nalbantian, H.R., Schotter, A., 1997. Productivity under group incentives: an experimental study. American Economic Review 87, 314–341.

Normann, H.-T., Wallace, B., 2012. The impact of the termination rule on cooperation in a prisoner's dilemma experiment. International Journal of Game Theory 41, 707–718.

Palfrey, T.R. Rosenthal, H., 1994. Repeated play, cooperation and coordination: an experimental study. Review of Economic Studies 61, 545–565.

Rankin, F.W., Van Huyck, J.B., Battalio, R.C., 2000. Strategic similarity and emergent conventions: evidence from similar stag hunt games. Games and Economic Behavior 32, 315-337.

Roth, A., 1975. Self supporting equilibrium in the supergame. Mimeo.

Roth, A., Murnighan, J.K., 1978. Equilibrium behavior and repeated play of the prisoner's dilemma. Journal of Mathematical Psychology 17, 189–98.

Segerson, K., 1988. Uncertainty and incentives for nonpoint pollution control. Journal of Environmental Economics and Management 15, 87–98.

Sobel, J., 2005. Interdependent preferences and reciprocity. Journal of Economic Literature 63, 392–436.

Spagnolo, G., 2003. Divide et impera: optimal deterrence mechanisms against cartels and organized crime. Mimeo, University of Rome "Tor Vergata."

Van Huyck, J.B., Battalio, R.C., Rankin, F.W., 1997. On the origin of convention: evidence from coordination games. Economic Journal 107, 576-596.

Varian, H.R., 1990. Monitoring agents with other agents. Journal of Institutional and Theoretical Economics 146, 153–174.

6: 58–82.