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Partnerships, Imperfect Monitoring and Outside Options: Theory and Experimental Evidence

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Abstract

We study theoretically and experimentally a two-person partnership game whereby agents only see the uncertain outcome of their joint effort but not how much the other agent contributed to it. The model combines problems of free-riding present in public good production and in teams with imperfect monitoring. We analyse effort and exit behaviour conditional on subjects' beliefs over the action taken by their partners and consider the effect of the availability and profitability of outside options. Our subjects do not adapt effort as a response to changes in their beliefs about the effort of their partner. Subjects display aversion for team work by exiting the partnership even when they believe their partner exerts sufficient effort to sustain it. Higher outside options do not either motivate or discourage effort in joint work but rather result in not only inefficient but also irrational breakdown in partnerships. Overall, social welfare decreases as the incentive to exit increases.

Keywords: Imperfect monitoring; outside options; partnerships; public good production; repeated games; teams.

JEL classifications: D82, H41.

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September 10, 2012

> GARCIN. — Alors c'est ça l'enfer. Je n'aurais jamais cru... Vous vous rappelez : le souffre, le bûcher, le gril... Ah! Quelle plaisanterie. Pas besoin de gril : l'enfer, c'est les Autres.
>
> Jean-Paul Sartre, Huis Clos

1. Introduction

In many situations cooperative efforts or joint ventures are needed to bring uncertain endeavours to success. Whenever that is the case, a social dilemma can arise, in which the social optimum is obtained only if all (or most of) the parties contribute, with each having an individual incentive to free ride. This central dilemma has been extensively studied experimentally (for a review see Ledyard, 1995). The Public Good Game ("PGG", Bergstrom et al., 1986) is the workhorse for the study of such problems. One central assumption of this model is, however, observability of choices – that is, the contribution of the partner(s) is (at least ex-post and in repeated games) observable. In the real world, though, imperfect monitoring of partner's contributions seems to be the norm rather than the exception: observability of partner's efforts is at best incomplete, if not totally lacking. More often than not, it can only be imperfectly inferred from the outcome of the partnership and not observed directly. Strategies supporting cooperation when partners' decision are only imperfectly observed have been studied theoretically in the context of the Prisoner Dilemmas ("PD"; see Kandori, 2002 for a survey) but have not given rise to much experimental investigation.

Moreover, the models used to investigate the central dilemma of collective action do not allow for a breakdown of the group, as agents cannot usually opt-out, *i.e.*, choose not to participate in the joint effort. In the real world partners might stop collaboration upon failure or for other reasons before its natural conclusion. Planning for exit can prove very important both for the decision to start the joint project and to motivate effort to foster its success. Not surprisingly, a sizeable part of contract law is devoted to what happens in case of resolution of a contract. An array of different rules govern exit from a variety of different joint endeavour – in case of breakdowns in joint ventures, disagreements within collaborative teams, dissolutions in partnerships, forking in open source projects, divorce, breakdown of political party coalitions *etc...*; those rules combine to determine the relative profitability of being within the partnership, and provide alternative strategies and credible threats that might help sustain cooperation and solve the free-riding dilemma.

Several social and economic phenomena have been linked to the availability or absence of outside options. For example, the enclosure movement in Tudor England has been interpreted as a move away from the inefficiency of open field systems to a more effective private field system (McCloskey, 1972; Turner, 1986; Boyer, 1993). Similarly, Lin (1990) argues explicitly that the loss of the right to exit was instrumental in the decline of agricultural productivity in China from 1958 until de-collectivization in the late 70s – early 80s (this is much debated, see Dong and Dow, 1993; Putterman and Skillman, 1992; Dong, 1998). In other cases, debate arose precisely around the definition of outside options and its consequences for a joint endeavour, as in the free-software movement's ongoing cleavage between "no-deviation"-GPL licensing, that keeps the code in an open commons, to an "exit-allowed"-BSD licensing that explicitly allows closing the source of a branch. Some idea of the controversy can be gleaned from Montague (2008); Bezroukov (2011), and a number of references find higher developers' effort in BSD licensed projects (Lerner, 2005; Stewart et al., 2006; Comino et al., 2007; Fershtman and Gandal, 2007; Sen et al., 2008; Colazo and Fang, 2009; Subramaniam et al., 2009; Sen et al., 2011).

We develop a new model that captures unobservability of actions and the possibility of dissolution of a joint venture and test its behavioral implications in the lab. We call this new model the *Partnership Game*. In the Partnership Game two agents are paired and asked to make two choices: first, they must independently choose whether to join a *public* or a *private* project; second, they independently choose how much to contribute to the project they have joined. The project choice of one's partner is observable at the moment of contribution, but not her contribution level. Projects can succeed or fail following a stochastic process, whereby contributions increase the likelihood of success, without however allowing subjects to secure success with probability one. Contributions can therefore only be imperfectly monitored by observing success or failure, leading to a "metering problem" (Alchian and Demsetz, 1972) whereby team members attempt to shirk. Contributions are modelled as sunk costs – they increase the probability of success but are not recovered in case of failure. The public project accepts contributions from both partners, while only the initiator of a private project can contribute to it. The public project can thus generate higher probabilities of success, though at the cost of providing a free-rider incentive, while the private project allows agents to shield themselves from the uncertainty of free-riding of the potential partner, though at the cost of a lower probability of success. The game is played repeatedly to allow for dynamic strategies whereby more or less credible threats not to cooperate can sustain cooperative equilibria.

This basic structure is simple, yet it introduces unobservability of contributions in an intuitive way. Moreover, it allows for several variations. In this study we explore two possible variations from the base game. First, we study the effect of varying the returns to the private project on private project take up and cooperation in the public project, that is, we vary the attractiveness of the outside option. As non-cooperation periods can be used to sustain cooperative equilibria of the repeated game (as per the folk theorem, Friedman, 1971), the availability of an outside option, and its profitability *vs.* staying in a partnership can influence what happens within the partnership. Second, we introduce asymmetry in earnings – allowing for projects to yield different payoffs to different players in case of success. Relinquishing symmetry is a step rarely taken in the experimental literature, as it introduces a further layer of complexity to the game; nonetheless, it allows to naturally model situations in which partnerships are not equally beneficial to both parties, and could prove crucial in the analysis of partnerships, especially in the presence of outside options.

In order to derive insights on the functioning of teams under imperfect monitoring and outside options, we first solve the model assuming risk-neutral self-oriented utility maximizing agents, and then experimentally study it, allowing for a range of outside options, from no exit allowed to a subsidized outside project, in both a symmetric and asymmetric case, in a pure between subjects design. We find limited evidence for either free riding or conditional cooperation as subjects do not adjust their effort to changes in their beliefs about the effort of their partners. We find however that subjects make too much use of the outside option, meaning that they leave the partnership even when staying in would give them higher payoffs given their beliefs about the effort of their partner. Combined with how our subjects devote too much effort to their own private projects, this makes higher outside options detrimental from the point of view of welfare.

The paper is organised as follows. In Section 2 the model is described in detail, the possible solution options are discussed and a benchmark static Nash Equilibrium solution for the stage game is provided. In Section 3 two strands of literature that are related to the Partnership Game are reviewed: public good and other games with imperfect information about other players' choices, and models investigating the effect of allowing exit and varying the attractiveness of outside options on cooperation within a public project. Section 4 introduces the experimental design and implementation along with the hypotheses that guide our analysis. Section 5 reports the experimental results, starting with the base game with no exit, proceeding with an analysis of exit behavior and finishing with the determinants of effort within a public project. Section 6 concludes.

2. Model

We consider an indefinitely repeated game, with probability δ of continuation, whereby two risk-neutral agents (i and j) must decide each period whether to exert effort (e_i and e_j respectively) in the development of a project, with the option to decide whether to do it in a private or a public project. Agent i (resp. j) obtains v_i (v_j) if the project she was involved in was successful, 0 else; v_i and v_j are commonly known. We assume generally $v_i \geq v_j$, that is, agent i is paid more on successful completion of a project than agent j; the symmetric case $v_i = v_j = v$ will be derived as a special case. The public project is successfully completed in period t with probability $\pi(p_{it}e_{it} + p_{jt}e_{jt})$, with $\pi(\cdot)$ an increasing and strictly concave function taking values between 0 and 1 and such that $\pi(0) = 0$. p_{it} (resp. p_{jt}) is the decision of i (resp. j) to participate in the public project in period t, $= 1$ if i (j) decided to participate, $= 0$ else. If i (resp. j) decided instead to lead her own private project in period t, this one is successful with probability $\pi(x + e_{it})$, in which x models the productivity gain (when $x > 0$) or loss (when $x < 0$) that the private project enjoys when compared to the public project.

The game is played repeatedly for T periods. Each period $t = 1, \ldots, T$ the game proceeds as follows:

1. Agents i and j independently decide whether to participate in the development of the public or the private project.
2. Agents learn each other's *participation decision*.
3. Agents choose how much effort e_{it}, $e_{jt} > 0$ to contribute to the development of the project they chose.
4. Random outcomes are drawn, determining whether projects were successful. In particular, for every active project $k \in \{pub, priv_i, priv_j\}$, i.e., a project chosen by at least one player, a random draw r_k is independently generated from a uniform distribution over $[0, 1]$ for each k; that project is successful if the relevant $\pi_k(\cdot) \geq r_k$.
5. Agents learn if the project they contributed to was successful, but not how much effort the other participant contributed either to her own or the public project, neither whether other projects were successful.
6. With probability $1 - \delta$ the game ends; with probability δ the agents go through another period.

From the structure of the game two important issues regarding exit follow:

1. Exit is fully reversible: the game is a repeated and not a dynamic, path dependent game. Agents can choose to take part in the public project, then move

to the private project, then return to the public project in different periods; and

2. Defection to the private project by one agent does not imply that the public project is dissolved – it simply implies that the player staying in the public project has to develop it alone.

The between period timeline may thus take the following form:

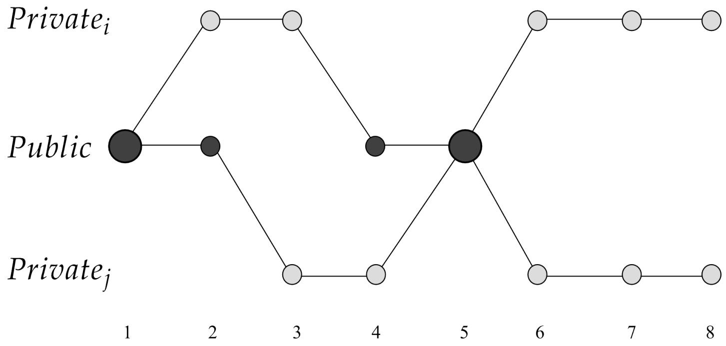


Figure 1: Between-period timeline

In the above example, both i and j work together on the public project in the first period. In period 2, i leaves the public project opting for the private, while j keeps working on the public project. In period 3, j exits to the private project, so both work privately. In period 4 i comes back to the public project while j keeps working privately, and in period 5, both are back in the public project. However, from period 6 onward both i and j work privately.

In the remainder of this section we will first analyze and solve the stage game, then investigate possible equilibria of the repeated game, and finally detail the aims of our experimental analysis.

2.1. Equilibria of the stage game

We consider first the social optimum, which will serve as a benchmark. We then consider agent's decisions when they both join the respective private projects, and solve for agents' choice of effort when both join the public project. This then allows us to consider a player's decision in a given period whether to contribute to the common project or to develop her own project.

2.1.1. Social optimum

Suppose both agents participate in the public project. Total expected welfare generated by the joint project is

$$\pi(e_i + e_j)(v_i + v_j) - e_i - e_j$$

Given that $\pi(\cdot)$ is an increasing concave function, expected welfare is maximized in $e_i + e_j$ by setting its derivative w.r.t. $e_i + e_j$ equal to 0. We thus obtain the first order condition for the maximization of this function as follows:

$$\pi'(e_{it} + e_{jt})(v_i + v_j) = 1$$

which determines an optimal joint effort of e^*. Maximum social welfare when both agents are involved in a common project is then

$$\pi(e^*)(v_i + v_j) - e^*$$

Suppose now both agents develop privately. In that case, total expected welfare generated by the two private projects is

$$\pi(x + e_i)v_i + \pi(x + e_j)v_j - e_i - e_j$$

in which x is the productivity gain (or loss) of the private project. Agent i chooses effort e_i^* such that $\pi'(x+e_{it})v_i = 1$ while j chooses effort e_j^* such that $\pi'(x+e_{jt})v_j = 1$. Social welfare when both agents are involved in private projects is then

$$\pi(x + e_i^*)v_i - e_i^* + \pi(x + e_j^*)v_j - e_j^*$$

Finally, provided that $x \geq 0$, the total welfare generated if only one agent works privately while the other works in the public project is lower than if both work privately. Whether both working privately or both working in the public project is socially optimal will depend on the level of x.

2.1.2. Effort in the private project

When involved in her private project, agent i will be maximizing her expected profit $\pi(x + e_{it})v_i - e_{it}$ in e_{it} which, given that $\pi(\cdot)$ is an increasing concave function, is maximized by setting e_{it} such that $\pi'(x + e_{it})v_i = 1$. Since $\pi(\cdot)$ is strictly concave, there is only one value x_i such that $\pi'(x_i)v_i = 1$. Since $\pi'(\cdot)$ is decreasing, x_i will be an increasing function of v_i. Effort e_{it} will be therefore such that $e_{it} = x_i - x$.

2.1.3. Nash equilibrium of the common project

Consider i's effort choice if both participants are involved in the public project. i will maximize her own payoff

$$\pi(e_{it} + e_{jt})v_i - e_{it}$$

Given that $\pi(\cdot)$ is an increasing concave function, i's objective function is maximized in e_{it} by setting its derivative w.r.t. e_{it} equal to 0. We thus obtain the first order condition for the maximization of this function as follows:

$$\pi'(e_{it} + e_{jt})v_i = 1$$

Since $\pi(\cdot)$ is strictly concave, there is only one value, which we denote x_i, such that that $\pi'(x_i)v_i = 1$. Since $\pi'(\cdot)$ is decreasing in its argument, x_i will be an increasing function of v_i. There is thus a best response function $e_{it}(e_{jt}) = x_i - e_{jt}$ which determines the optimal choice e_{jt} of i for every effort by j. Defining similarly the best response function for j, and given that $\pi'(\cdot)$ is decreasing in its argument, x_i will be higher than x_j. Among other implications, effort by each player will depend on how much effort he expects the other player to devote to the project, which itself depends on (v_i, v_j).

A Nash equilibrium (e^*_{it}, e^*_{jt}) is such that each player's effort is a best-response to the other player's effort, that is, $e^*_{it} = x_i - e^*_{jt}$ and $e^*_{jt} = x_j - e^*_{it}$. Since $x_i > x_j$, the equilibrium is such that $e_i = x_i$ and $e_j = 0$. One can note that there will be under-provision of effort compared to the social optimum. Also, there is no unique NE in the case where $v_i = v_j$, whereby any combination of efforts such that $e^*_{it} = x_i - e^*_{jt}$ is a NE.

2.1.4. The exit decision

Denote e^e_{jt} agent i's expectation of the level of effort exerted by j in the public project. Given this expectation, her optimal level of effort in the public project is $e^*_{it} = x_i - e^e_{jt}$. Comparing her payoff in such a case with payoffs she would obtain if on her own, i will decide to exit to her private project if:

$$\pi(x_i - e^e_{jt})v_i - (x_i - e^e_{jt}) < \pi(x_i - x)v_i - (x_i - x)$$

which is the case as soon as $e^e_{jt} < x$. In plain terms, i will exit as soon as she expects her partner to devote less effort to the project than x, which measures the efficiency gain from working alone.

Considering the NE of the common project when players are asymmetric, we observe that i (the high value individual) will prefer staying in the public project if $x < 0$, will be indifferent between expending effort in the public or the private project if $x = 0$ (0 is the effort he ought rationally to expect from j), and will strictly prefer working on her own as long as $x > 0$. j is better off participating in the public project as long as $x < x_i$ (x_i is the effort he ought rationally to expect from i in a NE).

2.1.5. Graphical summary

The following graph, where we plot social welfare and individual profits as a function of x (the level of efficiency in working alone), summarizes our findings. The function $\pi(\cdot)$ that is represented there is the one we use in the experiment, that is, $\pi(e) = \sqrt{\frac{e}{22}}$. We consider here the case, also used in the experiment, where players are asymmetric, that is, $v_i = 24$ (high type) and $v_j = 16$ (low type).

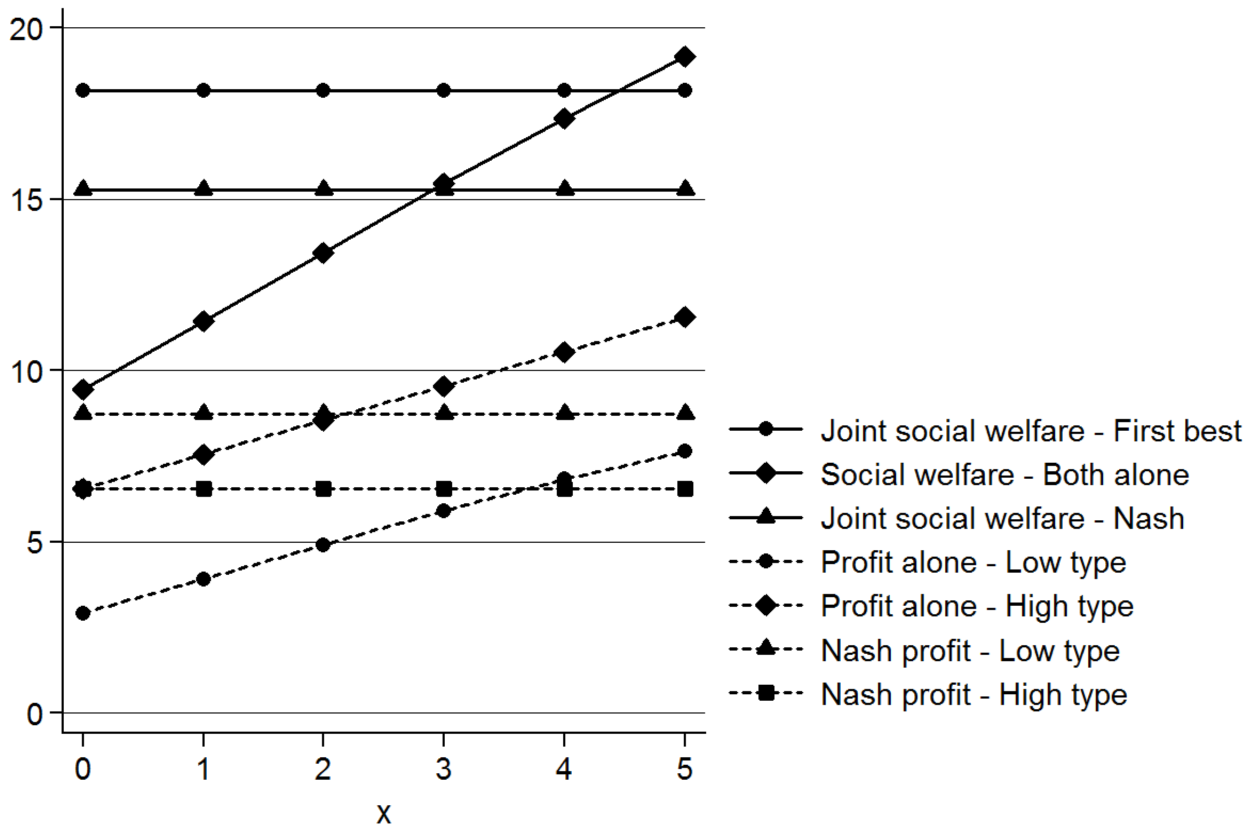


Figure 2: Graphical summary

Given these parameters, two private projects are socially more efficient than a single public project for $x > 4.45$. However the Nash equilibrium of joint work is such that both working alone obtain higher social welfare for $x > 2.91$. The Nash equilibrium is such that the high type is at least better off working on his own for any value of $x > 0$ while the low type would prefer to do so only if $x > 6.55$. Interestingly, the high type makes lower profits than the low type when both play Nash equilibrium strategies and are both involved in the common project.

2.2. Equilibria of the repeated game

As the Partnership Game is indefinitely repeated, dynamic strategies can be sustained as an equilibrium of the repeated game that could sustain outcomes that are Pareto-superior to any feasible outcome of the one-shot game. Such strategies have the bang-bang property of alternating between two states, a cooperative and a punishment phase. A punishment phase may occur after a number of negative outcomes and last for a given number of periods, after which cooperation is re-established (Aumann and Shapley, 1976).

Despite this theoretical possibility, the likelihood that such strategies could be sustained as an equilibrium in the Partnership Game is quite low because the game features imperfect monitoring of actions through stochastic outcomes. In such a setting, and in contrast with the theory of repeated games with deterministic outcome, cooperation may be sustained only "most of the time" (Green and Porter, 1984; Fudenberg et al., 1994), that is, there will be periods of non-cooperation that may be triggered by a succession of bad outcomes even if both agents keep to the cooperative strategies. Moreover, crucial for such cooperative equilibria to exist is that both agents know exactly when non-cooperation will be triggered, and how long non-cooperation will last. As shown in recent papers (Mailath et al., 2002; Kandori and Obara, 2006), agents may further improve their payoffs by following strategies that depend both on the public signal (realization of output) and on their own actions, in what have been dubbed "private sequential equilibria". For example, an agent may "check" the behavior of another by withdrawing effort; success in such a case would be a clear signal that the partner does indeed make effort. Since such strategies depend on one's own effort, which is not observable by the partner, it is difficult for either player to predict the other's continuation strategy, or to infer how long punishment will last when it is triggered, and respond appropriately. Unless one assumes a very high level of rationality and common knowledge of rationality, it is rather unlikely that these sort of equilibria could be sustained, especially if, as in our case, players cannot communicate to coordinate on a course of action.

This is not to say that players will not try to punish their partner in case of bad outcome and so as to sustain cooperation even if at a cost to themselves, as evidenced, among others, by Fehr and Gächter (2000). However, stochastic outcomes may hamper the mechanism of conditional cooperation (Keser and van Winden, 2000; Fischbacher et al., 2001), that is, the correction of one's action towards the action of the other. As shown in Bereby-Meyer and Roth (2006), the process whereby, in a deterministic environment, agents learn to reciprocate cooperative behavior with experience breaks down in a stochastic environment, as agents cannot be sure that the partner is learning. Stochasticity in outcomes may also hamper social motives for cooperation, such as a feeling of shame associated with making low effort or free-riding, as one's own effort is shielded by the random mechanism. On the other hand, imperfect monitoring may prevent the decaying of contributions over time that is often observed in deterministic games, as it may insulate each others' decisions and thus make the aim of maximizing joint-welfare more salient. Indeed, agents may end up thinking less in strategic terms, since behavior of the other is partially hidden, and think more in terms of what is optimal behavior.

For all these reasons, we will not engage in an attempt at identifying equilibria of the dynamic game, but will rather carry out an experimental exercise, in which we will try to single out behavioural regularities when agents are faced with different experimental conditions in the Partnership Game. Our experimental analysis aims at exploring the rich set of possible strategies that could populate the dynamic version of the Partnership Game. By eliciting beliefs about the partner's project and effort choices, we will be able to assess how individuals respond to changes in their beliefs. The Nash outcome of the stage game will act as our benchmark with respect to both effort and project choices.

To check for cooperative dynamic strategies, we will then analyze the evolution of beliefs and their correlation with success/failure of the project(s) and one's own action. In the Partnership Game agents have two ways of signalling dissatisfaction with the joint project: in a transparent but possibly extreme way through exit, and in a hidden but less radical way by lowering effort. Both signals are nonetheless ambiguous. Exit may occur either for signaling purposes, or, in case of perceived lack of cooperation by the partner, because the agent believes that her probability of success will be higher in the private project. Lowering one's effort, in turn, can be used both as a signalling device and for free-riding purposes. We expect that reaction to failure will vary among agents and will depend on an agent's past actions, as well as on the agent type – high or low in the asymmetric structure – and on the value of the outside option, i.e., the productivity of the private project.

3. Related literature

The possibility of exit in the Partnership Game has an equivalent in the standard PGG setting whereby agents' private account allows them to disengage themselves from public good production. Making the participation choice observable while keeping the effort choice behind a stochastic veil allows us to represent situations in which agents have a limited ability to monitor the effort of others in the partnership, *i.e.,* are only able to assess whether the partner is present or absent, but not their actual effort. This makes our design similar to papers exploring the effects of allowing outside options on cooperation. Overall, it is not clear from the theoretical literature whether more attractive outside options will improve the partnership's quality or will result in a higher likelihood of the partnership breaking down. MacLeod (1993) argues that exit rights improve efficiency in that they give agents "the ability to vote with their feet and avoid joining institutions that they believe to be inefficient". Orbell and Dawes (1993) also underline how the availability of an outside option may allow to efficiently sort out between those agents who intend to cooperate, and thus stay, and those who do not intend to cooperate and thus leave. Finally, Fujiwara-Greve and Yasuda (2011) consider a Prisoner Dilemma with outside option, where, to the difference of our paper, actions of others are observable and exit by one forces exit by the other as well ("unilateral exit"). They make the point that very low outside options can help better sustain cooperation if the exit payoff for both agents is lower than the worst payoff they can inflict on each other while in the partnership.

The Partnership Game hence allows us to contribute to the literature on partnerships by experimentally testing whether more attractive outside options encourage or discourage effort within the partnership. In that vein, Keser and Montmarquette (2011) is the paper that is most similar to ours. The game they study features a deterministic outcome and observable actions while our model applies to a more general and we think realistic setting, in which partners' effort is difficult to evaluate. Moreover, Keser and Montmarquette assume "unilateral exit", i.e., exit by one agent forces exit by the partner as well, while in our setting exit is fully reversible and does not affect the stayer. This allows us to distinguish between the punishment aspect of leaving (which is constant across treatment as leaving always leaves one's partner alone with the same payoff) and the efficiency aspect of leaving (which can be varied across treatments as the returns of the outside options are manipulated).

The Partnership Game is also close to a range of models featuring imperfect public information (Radner et al., 1986; Abreu et al., 1990; Fudenberg et al., 1994) (which however employed as a workhorse the repeated PD), to models of incentives in team work with moral hazard and imperfect monitoring from a principal-agent perspective (Holmstrom, 1982), and to dynamic versions of the Cournot oligopoly with imperfect observation of competitor's price (Green and Porter, 1984), where the issue is to sustain collusion in a market subject to external shocks. There are only few studies in the experimental literature in which the outcome of joint effort is stochastic and/or agents imperfectly monitor each other's action. Bereby-Meyer and Roth (2006) consider repeated play in a PD where joint cooperation only resulted in higher probability of obtaining a positive payoff. However, players know the action chosen by the other player. Their paper focuses on reinforcement learning, and the result is that subjects are slower in learning not to cooperate when outcomes are random. Xiao and Kunreuther (2010) also consider a stochastic PD whereby players can invest to reduce the probability of a bad outcome and have access to a punishment technology. As in Bereby-Meyer and Roth (2006) and contrary to our experiment, players also observe the action of the other player. Moreover, in their setting players can ensure no adverse event will occur by both investing, so that it is straightforward for a cooperator to conclude from an adverse event that their partner did not cooperate, and punish him accordingly. Nonetheless, Xiao and Kunreuther (2010) find that non-cooperators are less likely to be punished if the outcome is stochastic rather than deterministic. In our setting, this means that agents may be unlikely to retaliate by lowering their effort in case of failure of the project because of the difficulty of attributing this to chance or to low effort by their partner.

While the two above papers still allow for perfect observability of the actions of one's partner and focus on reinforcement learning, other papers consider imperfect observability of the partner's actions. Ambrus and Greiner (Forthcoming) consider a PGG where "even if the subject contributed to the public good, with 10% probability the public record indicates no contribution". In their paper, punishment enforces cooperation but is used so often it negates any benefits from its use. In a similar way, in our setting, exit might be used to enforce cooperation, but be used too often: More attractive outside options may encourage cooperation within partnerships but also more (inefficient) exit.

Holcomb and Nelson (1997) consider a setting where agents in a duopoly are informed about their opponent's action only 50% of the time. They find that "imperfect monitoring made it difficult for subjects to maintain a collusive consensus". Similarly, in our setting, imperfect monitoring might impair "collusion" towards higher effort by both parties. Aoyagi and Fréchette (2009) consider a PD with imperfect monitoring of the others' actions via a public signal with a value that depends on both players' actions and a noise factor. They show that levels of cooperation decrease as the link between input and output decreases (i.e. as the noise factor increases). Unlike in our setting, players may follow trigger strategies that depend on the level of the public signal. However, Aoyagi and Fréchette (2009) show that agents follow very simple threshold strategies that depend only on last period's signal.

Cason and Khan (1999) introduce another form of imperfect monitoring whereby agents learn others' contributions only every six periods. They do not observe much of a difference in terms of contributions between imperfect and perfect monitoring of others' action, while allowing communication between players plays a much more important role. Finally, Suleiman et al. (2001) consider provision of a step-level public good when the provision threshold is uncertain and participants do not learn others' contributions. They show that higher uncertainty regarding the threshold increases contributions if the threshold is low on average but decreases them if the threshold is high on average. They find that those results are consistent with agents following a cooperative heuristic whereby they assume that other agents will contribute as much as they do and choose their level of contribution accordingly. In our setting, this means that elicited beliefs regarding the contribution of others might be tightly correlated with one's own contribution and be at least in part independent of objective factors and experience.

4. Experimental design and hypotheses

4.1. Parametrization and treatments

We replicated closely the structure of the theoretical model in the experiment. We chose to endow participants with 10 tokens, so that effort was bound to be $e_{i,j} \in \{0, 10\}$. The probability of continuation of each period was set at $\delta = 0.9$. The function $\pi(\cdot)$ for the public project was parametrized as $\pi(e_i, e_j) = \sqrt{\frac{e_i + e_j}{22}}$. As effort was bounded to 10, $\pi(\cdot)$ did not allow participants to ever secure success of the project with probability 1. The function $\pi(\cdot)$ for the private project was set at $\pi(e_i + x) = \sqrt{\frac{e_i + x}{22}}$, with x varying across treatments.

Given this basic structure, we implemented two treatment variations, in a 5×2 factorial, between subjects design.

Along the first dimension we varied the returns of the private project, by manipulating x. We devised five different cases for the probability of success of the private project (see table 1).

	Exit	Productivity change of the private project	Probability of success of the private project
No exit	No	-	-
Exit: Zero	Yes	$x = -e_i$	0
Exit: Alone	Yes	$x = 0$	$\sqrt{\frac{e_i}{22}}$
Exit: Low subsidy	Yes	$x = 2$	$\sqrt{\frac{e_i+2}{22}}$
Exit: High Subsidy	Yes	$x = 4$	$\sqrt{\frac{e_i+4}{22}}$

Table 1: Probability of success in the public and private project for the five exit treatments

The attractiveness of the private project was hence naturally increased in the different treatments, from impossible, to self-harming, to neutral (the probability of success as a function of effort is the same in both projects), to more and more attractive.

As a second variation, we investigated the effect of asymmetry in the game. Each treatment along the *Exit* dimension was repeated in a *Symmetric* setting, in which the value of the project was set at $v_i = v_j = 20$ and in an *Asymmetric* setting, in which participants were randomly assigned to a high or a low type, with $v_{high} = 24$ and $v_{low} = 16$.

The 5×2 design resulted in 10 treatments. The optimal Nash behavior in the one-stage game for each of the 10 treatments is shown in Table 2. Individual Pareto optimal effort, and Nash effort in the game with symmetric payoff is not uniquely determined; for the sake of a clearer presentation we assume an equal split of effort at the Pareto optimum.

		Symmetric	Asymmetric Low	Asymmetric High
Pareto		9.09	9.09	9.09
No Exit		2.27	0	6.55
Exit: Zero	In	2.27	0	6.55
	Out	0	0	0
Exit: Alone	In	2.27	0	6.55
	Out	4.55	2.91	6.55
Exit: Low subsidy	In	2.27	0	6.55
	Out	2.55	0.91	4.55
Exit: High subsidy	In	2.27	0	6.55
	Out	0.55	0	2.55

Table 2: Optimal effort choice by treatment

4.2. Experimental details

The experiment was run in March 2012 in the experimental laboratory of the Max Planck Institute for Economics in Jena, Germany. A total of 316 participants took part in 10 experimental sessions, one per treatment. For each treatment a session involving 32 participants was run, with the exception of the *No Exit / Symmetric* treatment, in which only 28 participants were involved. The experiment was computerized using z-Ttree (Fischbacher, 2007).[1]

Upon arrival to the lab, the participants found on their desk printed instructions, and were given time to read them on their own. The instructions contained both the formula to compute the probability of success as well as detailed tables displaying the probability of success for all the integer values of e_i and e_j. To ensure the complete understanding of the instructions, the participants were asked to answer a set of control questions correctly before they were allowed to move on, and the number of wrong answers for each question and the overall time spent on the control questions was recorded in order to be used as a control. After having answered the control questions, the participants were allowed 3 minutes to explore the consequences of different constellations of choices through the use of an on-screen probability calculator. The participants could input a choice of project and effort for themselves and for the partner, and see the resulting probability of success. This calculator extended the printed-out tables as it allowed participants to investigate the consequences of choosing non-integer values for e_i and e_j.

The game was played repeatedly: participants were randomly and anonymously coupled and played with the same partner for an indefinite number of periods, each period facing a 10% chance of being the last.

The timeline of each repetition followed closely the timeline of the model as described in Section 2. The only variation was the introduction of two belief elicitations. First, immediately after the participation choice participants were asked to state their belief about the project choice of the partner, as the percentage likelihood that the partner had started a private project, between 0 and 100. Second, immediately after the effort choice participants were asked to state their belief about the effort choice of their partner ($e_j \in \{0, 10\}$), whether the partner was in the same project as themselves or not. Both belief elicitations were incentivized using a linear scoring rule. The resulting timeline of each experimental period can be seen in Figure 3.

[1]The experimental software and the original German and translated English instructions are available in the online supplementary material. The experimental procedure was fine tuned in two previous pilot sessions, run in December 2011 in the experimental laboratory of the Friedrich Schiller University, Jena, with 32 participants, and in February 2012, in the MPI lab, with 64 participants.

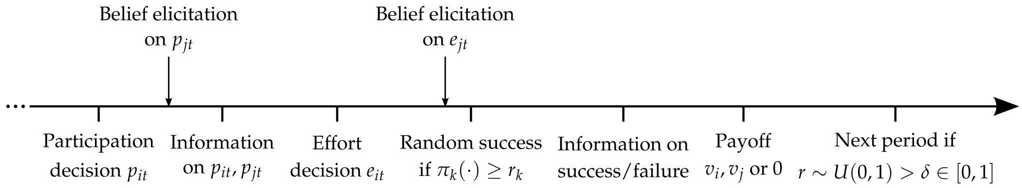


Figure 3: Timeline of a period in the experiment

The participants were shown at the end of each period a history box showing past project and effort decision, and project success or failure for the projects they participated in. They were given no information about the effort and success of their partner. The random numbers responsible for project success or failure were drawn beforehand from a uniform distribution once per period per group per repetition and were then applied to all the sessions and treatments in the same sequence. This was done in order to control for possible effects of biased random draws in small samples.

Each participants went through three such repeated games, each time being matched with a new random stranger as partner. To ensure comparability across treatments, the sequence of random numbers governing period ending was also drawn beforehand; this resulted in the three repetitions lasting 8, 14 and 10 periods each.[2]

At the end of the last period of the third repetition, participants were faced with two unannounced and incentivized control tasks to assess their attitudes to risk, to strategic uncertainty and their social value orientation. Those were introduced in order to enable us to identify the main drivers of the exit and effort decisions.

First, the participants were asked to complete the short, 6-item version of the Social Value Orientation (SVO) measure by Murphy et al. (2011). We used the SVO to control for the effects of a more or less socially oriented attitude on the part of participants. After having completed the SVO, participants were asked to complete the Strategic Uncertainty and Risk Aversion task (SU-RA, Heinemann et al., 2009). The task elicits both risk aversion and the individual attitude towards the uncertainty that comes from strategic settings. In addition to the incentivized controls, a demographic and socio-economic questionnaire was administered, including questions about trust, social success, and open questions about the chosen strategies and the understanding of the game.[3]

[2]The random algorithm for these and the above random draws, as well as the results of its single run are available in the online supplementary material.

[3]The z-Tree implementation of the SVO and of the SU-RA task, as well as the z-Tree questionnaire, are available in the online supplementary material.

At the end of the experiment, a random period was drawn, for which the payoffs for the project and the belief elicitation were paid out in cash. The final payment hence included the payoff from the main game, the belief elicitation, a 2.50 Euro show-up fee and the payoffs accrued in the control tasks. The sessions lasted around one hour and a half, and the subjects earned a payoff of 14.50 Euro on average.

4.3. Hypotheses and predictions

We first derive hypotheses from the Nash Equilibrium predictions and then discuss the effect that individual characteristics might have on decisions. We finally discuss the expected treatment effects along the exit and symmetry dimensions.

4.3.1. Nash equilibrium predictions

The following hypotheses derive directly from the Nash solution of the model from the point of view of a rational selfish and risk-neutral agent.

H1: Effort in the private project. As is readily apparent from the solution of the model, effort while in the private project will be an increasing function of v_i and a decreasing function of x. This implies that agents with a high value will exert more effort than low value agents (H1a), and that effort will be decreasing from treatment *Alone* to *High subsidy* (H1b). Moreover, the subsidy should perfectly crowd out effort: there should be no significant difference across treatments in $x + e_i$ (H1c).

H2: Effort in the public project. Following the best response function in the Nash solution, individual effort in the public project will be decreasing in one's expectation regarding effort by the other participant (H2a). Moreover, in *Asymmetric* treatments, lower value agents will devote no effort to the public project as long as the high value agent participates in it (H2b, see Table 2). This notwithstanding, as optimal total effort expended in the public project in *Asymmetric* treatments is such that $\pi'(e_i) \times 24 = 1$ (only agent i contributes), while in *Symmetric* treatments it is such that $\pi'(e_i + e_j) \times 20 = 1$, total public project effort will be higher in *Asymmetric* treatments (H2c). Finally, within *Asymmetric* and *Symmetric* treatments, total effort expended in the public project will be constant between *Exit* treatments (H2d).

H3: Exit. Agents will choose the private project if $x > e^e_{jt}$, that is, if she expects agent j to devote less effort to the public project than the subsidy of the private project (H3a). This implies that in *Asymmetric* treatments the high type will be indifferent with respect to project choice in *Alone*, and will choose the private project in *Low* and *High subsidy* (H3b); conversely, the low type will never exit (H3c), as no treatment introduces an $x > 6.55$, the level at which the low type would switch to a private project in a NE. Moreover, as the participation decision is based on expected partner's effort in the public project, and as no further information is available after exit and so no update of beliefs can take place, an agent will never come back to the public project once she left it (H3d). As no agent will ever come back, no agent will stay in the public project once the partner left if $x > 0$, and will be indifferent between projects if $x = 0$ (H3e). This implies that there will be no private project started in *Zero*, a mix of private and public projects in treatment *Alone*, and only private projects in treatments *Low* and *High* (H3f).

H4: Beliefs. Failure of the common project lowers one's expectation over effort from the other participant in the project, while success increases one's expectation (H4). Note that this holds if agents are to take the partner's effort as a given value one has to discover. Indeed in that case $Pr(e = x|outcome) = Pr(outcome|x)/\int_t Pr(outcome|t)dt$ will be increasing in outcome (from failure to success) subject to the function $Pr(outcome|x)$ satisfying the monotone likelihood ratio property. However, an agent reasoning strategically and who anticipates that success will induce her partner to decrease her effort will want to compensate for this by increasing her effort (since efforts are strategic substitutes). This may mean that in the end both agents increase their effort after a success. Whether agents' beliefs will increase (H4) or decrease after a success is therefore not a foregone conclusion.

4.3.2. Influence of individual characteristics

The SVO and SU-RA tasks allow us to control for factors that may influence behaviour. Agents with higher degree of risk aversion will exert higher levels of effort (H5). This can be shown by rewriting profit for a risk sensitive agent (in case both are involved in the public project) as follows: $\pi(e_{it} + e_{jt})u(v_i - e_{it}) + (1 - \pi(e_{it} + e_{jt}))u(-e_{it})$ and solving for the optimal level of effort. We also expect agents who indicate having social preferences in the social value orientation task will derive more utility from the public project, and will therefore exert higher levels of effort in the public project (H6). Furthermore, as strategic ambiguity is inherent to the set-up of the public project, while it is absent in a private project, agents with higher levels of strategic ambiguity aversion will prefer the private project (H7).

4.3.3. Treatment effects

Our hypotheses about the effects of the *Symmetric/Asymmetric* treatments are already summarized in H2 and H3 above. In terms of treatment by the attractiveness of exit, one can make the following remarks:

- In *No exit* the participants are not offered the option of starting a private project, and therefore have to stay together in every period. This treatments acts as a benchmark, being equivalent to a public good game with unobservability of contributions and stochastic outcome.
- In *Zero*, exit is possible, but entails a probability of success of zero. Although from a profit maximizing point of view this self-harming outside option should not have an effect on the play compared to *No exit*, its presence adds a further degree of strategic uncertainty, giving participants an empty threat that can be nonetheless used as a signaling device to warn off a shirker. In this treatment, collaboration, when maintained, can be held to be voluntary, at least in a minimal sense. This case allows us to consider the role of coercion in public good provision, the determinants of exit, as well as its impact on the stayer.
- In *Alone* the exiting participant sets up her own venture that features the same function for the probability of success as the common project but without any possibility of contribution by the partner. This case allows us to consider how much participants value the gain in efficiency from public good provision, as compared to its various costs in terms of uncertainty over the partner's effort provision (mental cost of ambiguity) and unhappiness at (possible) unequal provision of effort by each partner (free riding, shirking, moral hazard). As staking out on one's own is never efficient even if one believes the partner is exerting the lowest allowed effort, exit can come only from dissatisfaction with the public good provision set-up as compared with an independent private good provision.
- In *Low* and *High subsidy*, exit is rewarded with higher productivity, in order to make it a more attractive option and hence a more credible threat. The low subsidy was set to 2 to give a mild incentive to exit, while the high subsidy of 4, as noted in 2.1.5, was chosen to give the highest integer incentive that would not make both choosing a private project socially optimal.[4]

[4] In one of the pilots we ran also sessions with $x = 3$ and $x = 6$. When $x = 6$, participants have a dominant strategy to choose the private project. The pilot resulted, as expected, in very little variation, as we observed that virtually all participants set up private projects, never to return to the public.

In all of our treatments, the value of the outside option is set such that, given equilibrium beliefs, it is socially optimal to work in the public project – *i.e.* optimal social welfare generated in a team is higher than when both agents engage in private production. Allowing outside options means that in order for cooperation in the public project to be maintained, expectations must be sustained at a level higher than x. This may lead agents to wish to fulfil this required level of expectation in order to sustain cooperation so that those agents who wish to maintain cooperation may exert effort higher than x while they would otherwise exert effort lower than x. Alternatively, effort may increase in a public project as subsidies to exit increase due to a self-selection effect whereby agents who exert higher effort also have higher expectations from their partner and are thus less likely to exit.

Quite apart from this, making participation in the public project voluntary might have positive consequences as it opens up the possibility to signal dissatisfaction with the outcomes of the collaboration. Exit gives the possibility to clearly mark the beginning of a punishment phase, and can thus facilitate coordination. However, other issues remain, such as coordination on how long exit will last, whether exit will be perceived as justified by both sides – i.e. whether both will "agree" on being punished for perceived failure to cooperate – and whether both will go back to cooperation once the exiting agent comes back. We therefore expect agents to use exit in a rather different way than as a "punishment", as they would realize it is unlikely that their partner will understand or "take" the punishment of exit. We thus expect that exit will not be followed by return, that is, it will not be used to sustain cooperation, but rather as an alternative to cooperation. In this case, the outside option will determine the threat point, *i.e.* the minimum acceptable degree of cooperation within the partnership that can be sustained without one or the other partner being better off leaving.

We therefore allow, along Keser and Montmarquette (2011), for an alternative hypothesis to H2d whereby more attractive outside options will have an ambiguous effect on overall participants' payoffs: they will increase effort provision while within a venture in order to maintain cooperation at the cost of a more likely and inefficient eventual breakdown of the relationship.

H8: Effort as a function of the outside option. Effort in public projects will increase as the subsidy x to *Exit* increases.

5. Results

5.1. Contributions and Exit decisions

In this section we first consider behavior of agents when they are in a private project, and will see that agents tend to over-invest. We then consider effort in the public project and find no differences in effort between treatments. We next consider what drives agents' decision to leave the public project and find that agents tend to overstay in the public project given their belief over their partner's effort. We end with a joint analysis of the effort and exit decision in order to control for what type of agents choose to leave the public project. The next section will conclude the exposition of results with an analysis of welfare by treatment.

5.1.1. Contributions to the private and to the public projects

Table 3 shows the number of periods spent and the average effort exerted in public and private projects by treatment.

Table 3: Effort in public and private projects

		Symmetric	Asymmetric	
			Low	High
No Exit				
Public	Mean	5.58	4.79	5.68
	St.Dev.	2.49	2.02	2.69
Exit: Zero				
Public	Number of periods	1000 of 1024	502 of 512	502 of 512
	Mean	5.65	5.11	5.87
	St.Dev.	2.52	2.38	2.38
Private	Number of periods	12 of 1024	8 of 512	2 of 512
	Mean	1.42	0.75	0
	St.Dev.	3.06	2.12	0
Exit: Alone				
Public	Number of periods	878 of 1024	450 of 512	450 of 512
	Mean	5.08	5.00	6.10
	St.Dev.	2.65	2.84	2.61
Private	Number of periods	78 of 1024	29 of 512	40 of 512
	Mean	8.4	7.57	5.38
	St.Dev.	2.34	2.59	2.56
Exit: Low Subsidy				
Public	Number of periods	602 of 1024	349 of 512	349 of 512
	Mean Effort	5.40	5.10	7.05
	St.Dev.	2.66	2.12	2.66
Private	Number of periods	327 of 1024	101 of 512	130 of 512
	Mean Effort	4.38	4.36	6.35
	St.Dev.	3.0	3.33	3.28
Exit: High Subsidy				
Public	Number of periods	320 of 1024	145 of 512	145 of 512
	Mean Effort	6.06	4.34	5.88
	St.Dev.	2.60	2.13	3.11
Private	Number of periods	563 of 1024	328 of 512	301 of 512
	Mean Effort	4.39	5.4	5.73
	St.Dev.	3.41	3.23	3.46

We first assess take up of and effort within private projects. Very few participants chose to exit in the *Zero* treatment (this happened in 22 periods across all participants and phases, from a total of 2048 periods), and of those, most understood there was no point doing effort in that case (effort was 0 in 17 of the 22 periods in which exit occurred). The number of participants exiting was higher in the *Alone* treatment, and exit was not more frequent in the *Asymmetric* condition (total of 69 periods out *vs.* 78 in the *Symmetric* condition). Private project take up was again higher in the *Low* treatment. Effort was on average 2.58 units lower than in the *Alone* treatment, meaning that the low subsidy (2) did crowd out individual effort as expected. However, there was only partial crowding out in the *High* treatment, where effort was on average about the same as in the *Low* treatment while it ought to have been lower by the difference in subsidy (2) if crowding out occurred. Effort was generally significantly above optimal behavior for a risk neutral agent (compare with table 2) and effort of the high type was not significantly different from that of the low type. Participants with a high value from the project were also not more likely to exit first. This might be because they correctly anticipated that the low type were not shirking; indeed, effort of the low type was similar to that of the high type and high types held correct belief in that matter. Overall, one therefore finds no support for H1a, partial support for H1b and H1c, no support for H3b and H3c, and support for H3f. Testing of other sub-hypotheses in H3 will be done later.

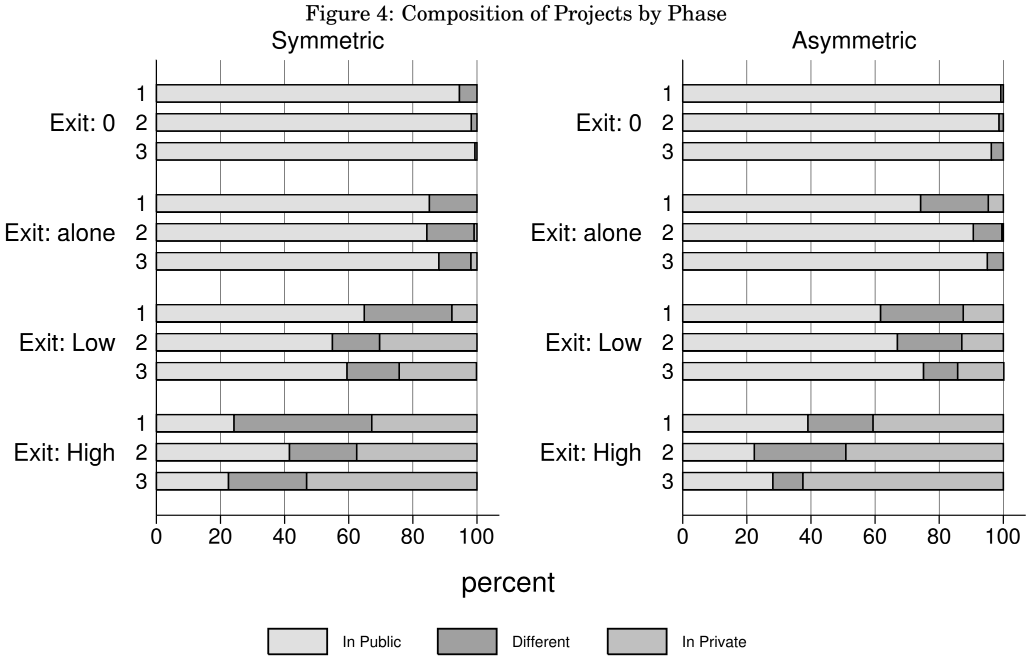
Let us now consider effort in the public project. Consider again table 3 which shows the average effort exerted when both agents were participating in the public project, by treatment. One does not observe significant differences in total effort provision in the asymmetric *vs.* the symmetric case. Total effort provision is significantly lower than the first best of 18.18 and does not vary depending on the value of the outside option. Contributions are consistently above the Nash effort of 2.28 in the symmetric game. The low type contributes far more than Nash effort of 0 in the asymmetric game. Anticipating this, as can be seen from their beliefs, the high type contributed less on average than the Nash effort of 6.55. Figure A.7 in the appendix shows the development of contributions in the public project and the share of participants in a private project by period, along with their beliefs regarding effort by their partner. From the graph, there is little evidence that participants exerted lower effort than they expected the other to exert (no free-riding). Higher value outside options either induced coordination problems (one agent out, the other in) or joint exit from the project. There was no apparent decline in contributions levels over time and no apparent "restart" effect as observed in many public good games after the groups changed (see for example Andreoni, 1988; Cookson, 2000) in periods 10 and 23. Beliefs on the probability of the other to exit converged quickly (and correctly) to 0 in treatments *Zero* and *Alone*, and to 1 in treatment *High*, while they never settled in treatment *Low* which showed the highest level of miscoordination among partners, few of them settling into either the public or a private project.

Overall, one finds no support for H2b, H2c and H2d. Testing of H2a will be done later.

5.1.2. Miscoordination on exit

Increasing values of the outside option spurred private project take up as can be seen from the increasing number of periods in private projects as the value of the outside option increases in table 3. However, this also induced miscoordination among participants: for many periods, especially in the first phase, either one or the other participant was left alone in the public project. This constitutes a bad outcome from an individual's point of view but also from the point of view of welfare in treatments *Low* and *High*, since the participant that is left alone could have obtained higher payoffs by also being in a private project. Figure 4 illustrates the amount of miscoordination by treatment and phase.

Figure 4: Composition of Projects by Phase



In treatments *Zero* miscoordination occurred only to a limited extent as the exiting partner quickly came back to the public project. In treatment *Alone*, miscoordination occurred to a larger extent, with very few cases where both were in a private.[5]

[5]Note that in *Alone* the person left in the public project gets the same payoff as if she was in a private project

There is a convergence across phases towards all agents working privately in the *High* treatment, while there is no such convergence in the *Low* treatment. Miscoordination on exit, along with too high effort when in a private project (*cf.* above section), will combine to decrease social welfare compared to the optimum in the treatments with low to high subsidies for outside options.

5.1.3. Rationality and determinants of exit from the public project

We analyse the determinants of exit from the public project before turning to the determinants of effort in the public project, as this will help us correct for the self-selection into the private project that may bias the results of regressions of effort. The decision to exit has two aspects: either one initiates exit because one believes one's partner did not exert sufficient effort in the public project last period, or one follows one's partner in exiting because he exited last period.

Rationality of initiating exit.. We first wish to evaluate whether the decision to choose to initiate exit is individually profit maximizing given beliefs of the participants over the contribution of their partner in the public project (test of H3a). Irrationality can take two forms: choosing the public project when it was rational to stake out on one's own, or choosing the private project when beliefs would have justified staying in the public project. We define a *rational* decision as a decision where:

1. *When both partners are within the public project*, belief over effort of the partner is larger than the subsidy x specific to the treatment;
2. *When a partner exits the public project*, his belief over effort of the partner last period when they were together was smaller than the subsidy specific to the treatment (that is, never in *Zero*, smaller than zero in *Alone*, and smaller than 2 and 4 in *Low* and *High* respectively). We need to rely on last period beliefs because we did not elicit counter-factual beliefs in the case where one chose the public project and the partner chose a private project (i.e. beliefs over the effort of the partner if he had stayed in the public project). Since beliefs were shown to be impacted negatively by failure (table 8), some of this "irrational exit" might be due to a re-evaluation of beliefs due to failure last period when together.

Table 4 gives an overview of the percent of decisions that do not conform to points 1 and 2 above in each treatment.

Table 4: Irrational decisions, in percent by treatment.

	Symmetric	Asymmetric	
		Low	High
Exit: Zero			
Periods in public	1000 of 1024	502 of 512	502 of 512
...of which irrational	0%	0%	0%
Exit	8 of 1024	5 of 512	2 of 512
...of which irrational	100%	100%	100%
Exit: Alone			
Periods in public	878 of 1024	450 of 512	450 of 512
...of which irrational	2%	2%	8%
Exit	25 of 1024	16 of 512	16 of 512
...of which irrational	92%	100%	100%
Exit: Low subsidy			
Periods in public	602 of 1024	349 of 512	349 of 512
...of which irrational	1%	7%	4%
Exit	23 of 1024	11 of 512	26 of 512
...of which irrational	100%	73%	88%
Exit: High subsidy			
Periods in public	320 of 1024	145 of 512	145 of 512
...of which irrational	11%	20%	20%
Exit	30 of 1024	18 of 512	13 of 512
...of which irrational	73%	83%	92%

An example of how the tables can be read goes as follows: In *High*/*Asymmetric* there were 18 occurrences where a low type chose to exit while both partners were in the public project last period. In 83% of those cases, the exit was not warranted by previous period beliefs.

Choosing the private project in the *Zero* treatment is always irrational, and it did not occur often. Only very few exits in the *Alone* treatment were rational, *i.e.* occurred because the agent thought his partner did zero effort last period. The *proportion* of rational exit keeps on increasing with the value of the subsidy, but never exceeds 20%. Agents thus exited more often than hypothesized in H3a, indicating aversion to working together. The number of periods where both agents were together decreased as the subsidy increased (See Figure 4) but the total number of exits did not increase by treatment. This is because exit was often followed by coming back in treatments with low or negative subsidy, while exit was more permanent in treatments with high subsidy. There was no consistent difference across symmetric or asymmetric treatments, or between the decision of high and low types whether to exit. We also did not find robust effects indicating that the rationality to stay in or exit increased by phase in the game or by period.

Since exit occurred too often, one can deduce that agents stayed in the public project only when it was really rational to do so. Indeed, data shows us that the decision to stay in was overwhelmingly rational (at most 7% of it was irrational), *except* in treatment *High* where, of the few who stayed together, up to 20% did so irrationally (in the asymmetric treatment). This indicates that the (few) subjects who stayed in the public project in this treatment may have done so not because they expected others to do high effort but rather because they were averse to working alone.

Rationality in following exit.. Another aspect of the exit decision is whether to follow one's partner when this one took the initiative to exit last period. It is rational to exit in treatments *Alone*, *Low* and *High* and choose the private project if one's partner was out last period *and one expects him to stay out* (testing of H3e). Table 5 reports the percentage of subjects who were left alone in a public project last period and chose to exit it the next period, and table6 with the percentage of agents who came back to the public project after exiting.

As seen in Figure 4, instances when one or the other agent were out of the project were rarely observed in the first two treatments, while that type of configuration was more frequent in the last two treatments. There was little follow up on exit by one's partner in treatments *Zero* and *Alone*, while following on partners' exit was much more frequent in treatments *Low* and *High* (see table 5).

Table 5: Percentage of agents exiting the public project when their partner exited it last period

	Symmetric	Asymmetric Low	Asymmetric High
Exit: Zero			
Number of periods left alone in public	10 of 1024	2 of 512	7 of 512
of which followed by counter-exiting	20%	0%	0%
Exit: Alone			
Number of periods left alone in public	62 of 1024	31 of 512	21 of 512
of which followed by counter-exiting	5%	3%	14%
Exit: Low subsidy			
Number of periods left alone in public	89 of 1024	56 of 512	31 of 512
of which followed by counter-exiting	28%	30%	42%
Exit: High subsidy			
Number of periods left alone in public	136 of 1024	38 of 512	60 of 512
of which followed by counter-exiting	40%	42%	35%

Agents not always following on exit in treatments *Low* and *High* contradicts H3e and indicates agents did not necessarily believe an agent who left would not come back (which is hypothesis H3d). However, hypothesis H3d was at least partially verified in the data, as shown in the table 6 below, which shows the percentage of agents returning to the public project. Not following on exit in treatments *Low* and *High* was therefore probably based on incorrect beliefs regarding the probability of getting back together.

Table 6: Percentage of private project participants switching to the public project

	Symmetric	Asymmetric	
		Low	High
Exit: Zero			
Number of periods in private project	10 of 1024	7 of 512	2 of 512
of which followed by switching back to public	90%	57%	100%
Exit: Alone			
Number of periods in private project	70 of 1024	27 of 512	37 of 512
of which followed by switching back to public	33%	74%	51%
Exit: Low subsidy			
Number of periods in private project	294 of 1024	91 of 512	116 of 512
of which followed by switching back to public	13%	26%	27%
Exit: High subsidy			
Number of periods in private project	498 of 1024	292 of 512	270 of 512
of which followed by switching back to public	12%	9%	8%

Determinants of exit from the public project. As in Keser and Montmarquette (2011), we did regressions of the decision to exit, conditional on both agents having been together in the past period. We used as independent variables the beliefs about the effort of one's partner last period, one's own effort, the agent type, the phase in the game, the period within a phase – to measure decline in cooperation over time within a matching phase – and individual controls including scores in the SVO and the SU-RA tasks. Since belief over effort of the partner is an endogenous variable, i.e. it is influenced by some of the same factors as the decision to exit, we need to instrument it in order to isolate its effect on the exit decision. We therefore instrumented belief over effort of the partner with success in the last period. Success in the last period is a good instrument because the decision to exit is not directly affected by success in the last period, but rather by how success affects one's belief over effort of the partner via (Bayesian) updating.

We first show results of the regression of beliefs over our dependent variables in columns 1 and 2. Those are linear panel regression, with fixed and random effects, conditional on both being in the public project, excluding the first period of each matching since we use success in the previous period as an independent variable, and excluding the treatment with no exit (although the evolution of beliefs in that case does not differ in practice from the cases with exit). We then present regressions of the decision to exit (=0 if in public project, =1 if in private project). Those are logit panel regression, fixed and random effects, conditional on both having been in the public project in the last period, excluding as well the first period in each matching. The last two columns present the same regressions with belief instrumented with success in the last period. Linear regressions use the Huber-White sandwich variance estimator.

Table 7: Decision to exit, conditional on both partners having been in the public project last period

	(1) Belief fe	(2) Belief re	(3) Exit fe	(4) Exit re	(5) Exit iv fe	(6) Exit iv re
main						
L.success_together	0.3133***	0.3210***				
	(4.57)	(4.67)				
L.belief_effort			-0.1244+	-0.1781**	-3.3998***	-3.7484***
			(-1.66)	(-2.85)	(-4.00)	(-4.79)
L.effort			0.1690*	0.1239*	0.1546	0.0546
			(2.26)	(2.06)	(1.52)	(0.80)
type 20		-0.2960		-0.3279		-1.4195*
		(-0.98)		(-0.67)		(-2.54)
type 24		-0.1716		0.3162		-0.3877
		(-0.45)		(0.59)		(-0.68)
treat Alone		-0.1520		1.2186*		0.5509
		(-0.40)		(2.04)		(0.90)
treat Low		0.2379		2.4186***		3.2194***
		(0.66)		(4.14)		(5.08)
treat High		0.5107		3.4283***		4.4862***
		(1.35)		(5.56)		(5.64)
Phase 2	-0.2722**	-0.2695**	-0.4704+	-0.6690**	-1.0484*	-1.4839***
	(-2.97)	(-2.95)	(-1.81)	(-2.69)	(-2.47)	(-3.73)
Phase 3	-0.3205**	-0.3191**	-0.9008**	-1.0045***	-1.3017**	-1.6116***
	(-2.93)	(-2.93)	(-3.14)	(-3.68)	(-2.74)	(-3.71)
period in phase	-0.0203*	-0.0201*	-0.0254	-0.0395	-0.0621	-0.0820+
	(-2.17)	(-2.15)	(-0.76)	(-1.19)	(-1.38)	(-1.87)
RA		-0.0531		-0.1985		-0.2936*
		(-0.59)		(-1.61)		(-2.12)
SU		-0.0530		-0.0740		-0.2638**
		(-0.82)		(-0.86)		(-2.64)
SVO		0.6594		0.8986		2.8311**
		(1.13)		(1.13)		(2.85)
_cons	6.1049***	6.3765***		-4.1769***		19.0923***
	(61.24)	(9.63)		(-4.19)		(3.66)
N	4342	4342	1269	4636	861	4183
ll	-7054.2060		-267.0717	-500.6157	-165.5013	-340.8778
df_m	3.0000	12.0000	5.0000	13.0000	5.0000	13.0000

t statistics in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A Hausman test rejects the consistency of the random effect estimator in the regression of beliefs over our dependent variables. Success in the common project last period leads one to update one's beliefs upward, confirming H4. Beliefs decrease over time within a partnership and across partnership over time. Mixed effect regressions (not reported) show that the parameter on success exhibits significant variation across individuals, as does the constant in this regression.

The fixed effect estimator is also favored in logit regressions for the decision to exit (columns 3 and 4). Those regressions indicate that agents are more likely to exit the lower was their belief over the effort of their partner last period (compared to their average belief). Those who do more effort are also more likely to exit. Finally, agents do not appear more likely to exit over the life of a project, and are not more likely to exit from matching to matching. Results of the same regressions using instrumented beliefs as a predictor confirm the above observations. Random effects regressions indicate that agents are more likely to exit the higher is the outside option, as was observed from the summary data above. Participants with lower levels of aversion to strategic uncertainty were less likely to exit (confirming H7).

5.1.4. Determinants of effort in the public project

Table 8 shows the results of fitting a range of panel data models to our data. Effort conditional on both agents being together in the public project is the dependent variable. Independent variables are belief over the effort of the partner, the type of the agent, that is, the value he derives from completion from a project, the phase in the game, that is, whether this is the second or the third matching with a different partner, the period within a phase, to measure decline in cooperation over time within a matching phase, and individual controls including scores in the SVO and the SU-RA tasks. All regressions use the Huber-White sandwich variance estimator. As in previous regressions, belief over effort of the partner is an endogenous variable, i.e. it is influenced by some of the same factors as effort, so we instrument it using again success in the last period. Treatments with higher subsidies had more agents exiting, so that while we have 1450 observations in the *No exit* treatments, there are only 402 observations in *High*. This means one has to correct for the sample selection bias which occurs because agents self-select into the public project. Our selection equation is the decision to exit determined as a probit model (results are very similar to the logit model reported in table 7), and use the estimated parameters to calculate the inverse Mills ratio for each observation, which is then included as an additional explanatory variable in an OLS regression of effort (Chapter 17, Wooldridge, 2002).

Table 8: Effort when Both in Public Project

	(1) be	(2) fe	(3) re	(4) iv fe	(5) iv re	(6) iv select OLS	(7) iv no exit fe	(8) iv no exit re
belief_effort	0.5509***	0.0939	0.1156+	-0.2558+	-0.2312	0.8490***	0.0968	0.1081
	(7.81)	(1.38)	(1.75)	(-1.67)	(-1.55)	(4.62)	(0.98)	(1.11)
type 20	0.3044		0.2078		0.1265	0.6620+		0.9619
	(0.89)		(0.60)		(0.23)	(1.71)		(1.29)
type 24	0.9509*		0.8390*		0.8404	1.0857*		0.8646
	(2.47)		(2.10)		(1.37)	(2.34)		(0.98)
treat Alone	-0.1151		-0.2021		-0.2973	-0.6188		
	(-0.31)		(-0.52)		(-0.51)	(-1.58)		
treat Low	0.0629		0.1646		0.1574	-1.0784*		
	(0.17)		(0.45)		(0.27)	(-2.39)		
treat High	-0.1891		0.1787		0.1719	-1.4245*		
	(-0.44)		(0.40)		(0.26)	(-2.38)		
Phase 2	-0.1070	-0.1696	-0.1656	-0.2804***	-0.2731***	-1.0106	-0.1382	-0.1356
	(-0.09)	(-1.44)	(-1.40)	(-3.77)	(-3.75)	(-1.09)	(-1.22)	(-1.20)
Phase 3	-0.7203	-0.1923	-0.1891	-0.3062***	-0.2991***	-0.4756	-0.2241+	-0.2201+
	(-0.76)	(-1.50)	(-1.49)	(-3.86)	(-3.84)	(-0.55)	(-1.90)	(-1.88)
period	-0.1442	-0.0172*	-0.0168*	-0.0216**	-0.0210**	0.1324	-0.0226+	-0.0223
	(-0.58)	(-2.03)	(-1.98)	(-2.83)	(-2.79)	(1.47)	(-1.65)	(-1.64)
RA	-0.2120*		-0.2349**		-0.2794*	-0.1657*		-0.1771
	(-2.58)		(-2.71)		(-2.14)	(-2.46)		(-0.65)
SU	0.0832		0.0665		0.0489	0.1666**		0.1039
	(1.41)		(1.07)		(0.52)	(2.65)		(0.62)
SVO	1.5420**		1.8018**		1.9524*	0.9332		-0.6776
	(2.77)		(2.66)		(2.19)	(1.14)		(-0.47)
IMR						-1.1952***		
						(-4.37)		
Constant	3.0050*	5.2134***	4.7031***	7.4156***	7.0990***	2.8451	5.1154***	4.8897***
	(2.15)	(13.32)	(6.32)	(7.62)	(5.35)	(1.50)	(8.55)	(3.42)
N	4617	4617	4617	4342	4342	4003	1450	1450
ll	-427.0429	-7828.0760						
chi2			34.5653	68071.9997	41.6849	167.7293	17052.8935	14.6181
df	12.0000	3.0000	12.0000	204.0000	12.0000	40.0000	54.0000	9.0000

t statistics in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We first show results without accounting for the endogeneity of beliefs and for the selection effect (columns 1, 2 and 3). Column (1) shows the results of a between effect panel data regression which captures determinants of differences in effort between individuals. Participants with higher expectations in terms of effort by their partner did higher effort as well, though hypotheses dealing with response functions are better tested with within-subjects regressions. High types exert higher effort than others (one unit more), though low types did not do less efforts than participants in the symmetric treatment. Support for H2b is therefore mixed. Overall however, this means that effort in the asymmetric case was higher than in the symmetric case (H2c). There is no difference in effort levels across treatments, confirming H2d and against H8. Participants with higher score in the risk aversion task, meaning those with lower aversion to risk, did less effort (H5). Participants with a higher SVO index (more socially oriented) exerted higher effort (H6).

Column (2) shows the results of a fixed effect panel-data regression, which a Hausman test favors over a random effect specification shown in column (3). This captures the determinants of individual changes in effort level between periods. Effort exerted varies positively with one's belief about the partner's effort, though we will see that instrumenting beliefs with success last period will disclaim this initial finding. Effort is lower in phases 2 and 3 than in phase 1, and decreases from period to period within a phase. A mixed effects regression (not shown) to take effect of differences in the reaction function of different participants confirms that the parameter on beliefs varies significantly across individuals (mean: 0.16, sd: 0.31).

We instrument belief over effort of the partner with success in the last period in columns 4 and 5. In this case, a Hausman test does not reject consistency of the random effect estimator. Column 4 shows the results of the fixed effects regression. We see that the link between effort and belief over effort of the partner breaks down (parameter on beliefs negative and not significant). While success last period led one to update one's beliefs upwards, upwardly updated beliefs did not lead one to either increase or decrease effort. This indicates that agents may not be following the usual pattern of complementarity in effort that has been observed in standard PGG and has been attributed either to conditional cooperation or to a false consensus effect. This might be because subjects do not have definite information about the level of effort of their partner, and know that their partner does not know how much effort they are exerting as well. This means that the perception of social pressure may be alleviated in this setting so that more agents may be adopting Nash best response, i.e. decreasing effort as their belief over their partner's effort increases. Again, a mixed effects regression underlines significant variation in the parameter on belief (not reported).

Regressions above are consistent only if selection into the public project is due only to time-invariant characteristics of the individual. We correct for sample selection in Column 6, which shows the results of an OLS regression of effort on instrumented beliefs and the inverse Mills ratio ("IMR") calculated from the probit selection equation – which predicts whether the agent stays in the public project or not. We do not report estimates of the parameters on the cross effect of time dummies with the inverse Mills ratio, none of which are significant. We find that the parameter accounting for the selection effect is significant, and that the parameter on beliefs is now positive and significant. Column 7 and 8 show the results of the same fixed and random effect regression as before, but limited to the case where exit is not allowed, whereby one does not have to correct for sample selection bias. Here again a Hausman test does not reject the consistency of the random effects estimator. The parameter on beliefs turns out not to be significant in this case.

Overall, one finds no support for H2a, with most specifications showing no change in effort as a function of belief over effort of one's partner.

5.2. Welfare Implications

We calculate expected welfare for each pair for each period for the cases where both were in the public project, both were in the private project, and one was in a private project while the other was in a public project. This allows us to compute expected welfare given the actual mix of those different configurations in the experiment. Namely, average expected social welfare in treatment with subsidy x is:

$$\begin{aligned} ESW &= \tfrac{1}{N}\tfrac{1}{T} \sum_t \sum_i 1_{i,j\,in}(\pi(e_{it}+e_{jt})(v_{it}+v_{jt}) - e_{it} - e_{jt}) + ... \\ &\quad ... + 1_{i\,in,j\,out}(\pi(e_{it})v_{it} - e_{it} + \pi(e_{jt}+x)v_{jt} - e_{jt}) + ... \\ &\quad ... + 1_{i\,out,j\,in}(\pi(e_{it}+x)v_{it} - e_{it} + \pi(e_{jt})v_{jt} - e_{jt}) + ... \\ &\quad ... + 1_{i\,out,j\,out}(\pi(e_{it}+x)v_{it} - e_{it} + \pi(e_{jt}+x)v_{jt} - e_{jt}) \end{aligned}$$

with t the periods in the game and T the number of periods, i the subject and j the subject she was paired with (which changes depending on the phase in the game), N the number of subjects, $\pi()$ the function determining success as a function of total effort expended in a project, and the function $1_{i,j\,in}$ taking value 1 if both agents are in the public project, 0 else.

In order to be able to make meaningful comparisons across treatments, we need to adjust for the subsidy x to private project development. We normalize to the treatment where $x = 0$ by subtracting x from the expected payoff of agents that were involved in a private project. Namely, the corrected social welfare is then:

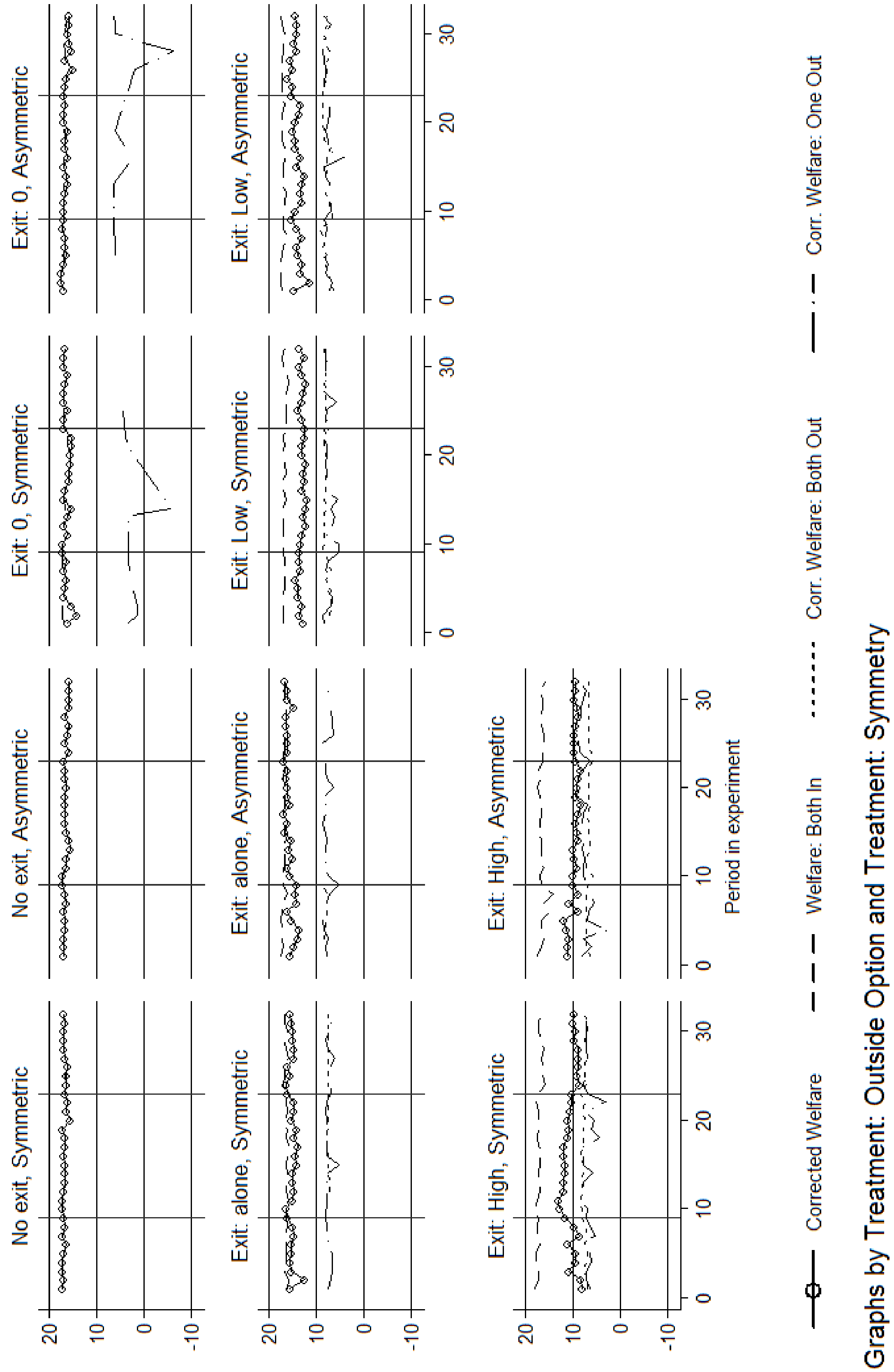
$$
\begin{aligned}
ESW &= \frac{1}{N}\frac{1}{T} \sum_t \sum_i 1_{i,j\ in}(\pi(e_{it}+e_{jt})(v_{it}+v_{jt}) - e_{it} - e_{jt}) + ... \\
&\quad ... + 1_{i\ in,j\ out}(\pi(e_{it})v_{it} - e_{it} + \pi(e_{jt}+x)v_{jt} - e_{jt} - x) + ... \\
&\quad ... + 1_{i\ out,j\ in}(\pi(e_{it}+x)v_{it} - e_{it} - x + \pi(e_{jt})v_{jt} - e_{jt}) + ... \\
&\quad ... + 1_{i\ out,j\ out}(\pi(e_{it}+x)v_{it} - e_{it} - x + \pi(e_{jt}+x)v_{jt} - e_{jt} - x)
\end{aligned}
$$

This is because x is the additional effort an agent would have had to exert in order to attain the same success probability in the treatment with $x = 0$ as they actually attained in the treatment with $x > 0$.

Figure 5 illustrates the corrected expected average welfare over periods by treatments. As expected considering the small difference in effort, welfare is similar across treatments when both agents are in the public project. In treatment *Zero* there are only very few cases where agents exited, and in most of those cases only one was out at a time. Welfare for those cases is of course very low, but given how seldom this occurred, this does not decrease average welfare significantly. In the *Alone* treatments, actual expected welfare is nearly all the time equal to welfare when both partners are in the public project because while expected welfare when either one or the other is alone is lower, this configuration did not occur often. This changes when looking at the *Low* and *High* treatments. In terms of unadjusted welfare, both being out generates higher welfare than only one being out. However, adjusting for subsidies x, and given the higher rate of exit in those treatments, both the *Low* and *High* treatments obtain lower adjusted expected welfare. Moreover, even if one did not adjust for the subsidies x, expected welfare in the high and low treatment would be actually lower than in the other treatments.

In summary, attractive outside options did not encourage higher effort when both were in, so potential welfare in that case did not increase. Exit behavior, which could have sustained higher effort when both were in, in fact decreased welfare because exit was too frequent, and when it occurred, resulted in too much effort being expended on private projects. The combination of those forces resulted in both actual welfare and adjusted welfare decreasing as the incentive to exit increased.

Figure 5: Expected Welfare with Actual Effort Level



6. Conclusion

We studied in this paper the Partnership Game, a model of collaborative production that involves imperfect peer monitoring. Our model is a natural combination of models of public good production and of moral hazard in teams. We were able to compare the behavior of our experimental subjects to what is typical in public good games (decline in effort over time, complementarity in effort of the partners), and to the predictions of models of cooperation in the prisoners' dilemma with imperfect observability (use of tit-for tat or trigger strategies). We also studied the effect of allowing exit from a partnership by varying the availability and profitability of outside options. We found that our subjects updated their beliefs about the effort of their partner upward following success in the partnership, and that success therefore encouraged them to stay in the partnership. However, they did not appear to increase or decrease effort as a response to changes in their beliefs about the effort of their partner. This is not consistent either with rational behavior, whereby one ought to decrease effort if one believes one's partner increased it, or with standard findings in the public good literature whereby one would increase effort along with one's partner and vice-versa. Agents did not appear to attempt to punish perceived non-cooperation of their partner by exiting or lowering their effort. Rather, their decision to exit the partnership was for the most part final, especially when the returns to their private project were high. We also found that agents exited the partnership in a way that was not consistent with their beliefs about the effort of their partner, that is, they exited even when, given their beliefs, they would obtain higher payoffs by staying in the partnership. This would indicate some level of aversion to team work, which involves strategic uncertainty, *vs.* work on one's own, which while less profitable is at least more under one's control. Surprisingly however, agents did not always follow their partner in exiting the public project even though very few of those who had exited came back to the public project. This may be reconciled with the above by assuming that those who stayed in the public project even after exit of their partner valued team work and hoped for a return of their partner. We did not find that outside options encouraged either higher or lower effort in the public project. Higher outside options encouraged exit and resulted in inefficient breakdown of partnerships. Combined with subjects exerting inefficiently high levels of effort in their own private projects, this resulted in social welfare decreasing as the incentive to exit increased.

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AppendixA. Additional figures and tables

Figure A.6: Development of Contributions in the NO EXIT treatment

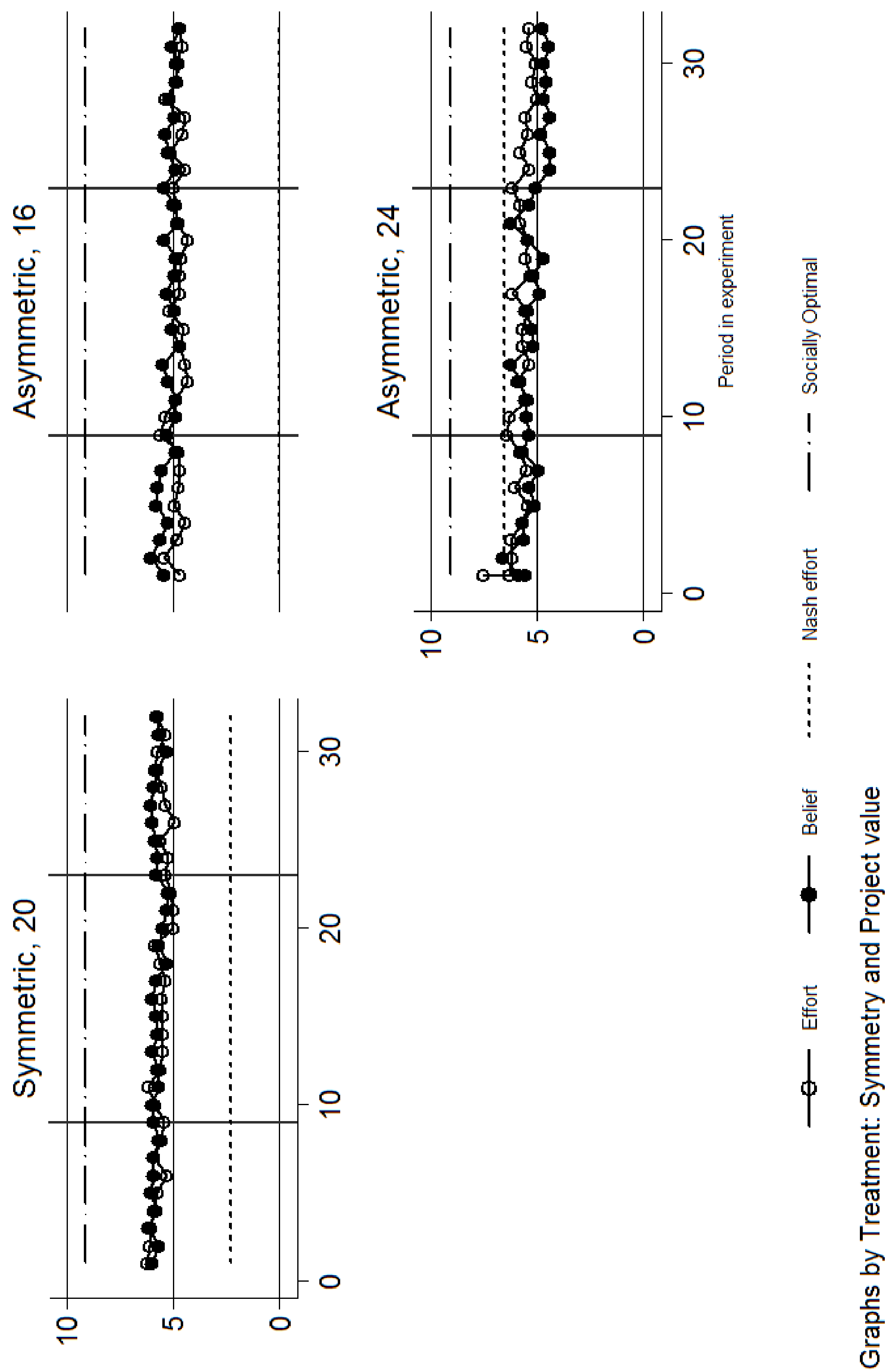

Figure A.7: Average Effort Public Project, and share in private projects, by treatments