Crowdfunding for Public Goods with Refund Bonuses: An Empirical and Theoretical Investigation*

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Abstract

We study "all-or-nothing" crowdfunding for public good provision. Our main focus is on an extension with refund bonuses aimed at resolving the problems of equilibrium coordination and free riding. In the case of insufficient contributions, contributors not only have their contributions refunded but they also receive refund bonuses proportional to their pledged contributions. Thus, refund bonuses encourage more contributions but ultimately enough is raised given sufficient preference for the public good and in equilibrium no bonuses need to be paid. We test the predicted effects of refund bonuses in an experiment using a laboratory-based crowdfunding platform that features most main aspects of real-life platforms. Our main empirical result is that refund bonuses substantially increase the rate of funding success when contributors can support multiple projects. Furthermore, our findings also demonstrate that refund bonuses lead to significant economic gains even after accounting for their costs.

Keywords: Crowdfunding, public goods, provision point mechanism, refund bonuses, equilibrium coordination.

JEL Classification: C72, C92, H41.

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1 Introduction

This paper is concerned with the problem of improving crowdfunding for the purpose of public good provision. Crowdfunding is a fundraising method where entrepreneurs and fundraisers use the Internet to seek funds directly from the "crowd" of potential, typically small, investors or donors. The crowdfunding industry has been developing at an incredible trajectory over the last decade. According to Massolution (2015), its total funding volume increased from $0.5bn in 2009 to $34.5bn in 2015 (estimated), out of which $5.5bn were contributions to various projects and causes that did not involve any financial rewards.

Crowdfunding's distinctive feature is its operation on a peer-to-peer basis without intermediation. As such, it has become an important source of funding for fundraisers shunned by banks in the case of entrepreneurial projects or by cash-strapped public authorities in the case of public projects. Crowdfunding's direct access to investors and donors is considered by the World Bank particularly advantageous in developing countries as a way of bypassing their institutional inefficiencies (World Bank (2013)). But the latter argument is also relevant for developed countries. For instance, in the UK an increasing number of cancer patients seek to crowdfund their treatment, with a goal of bypassing inefficient services of national public healthcare.[1] An interesting example of crowdfunding is the MetPatrol Plus program that was launched by London's Metropolitan Police Service in 2008. This program offers commercial districts and communities a possibility to crowdfund hires of police officers whose numbers were reduced in response to budgetary cuts.[2]

While equity- and bond-based crowdfunding and its growth can be explained by the diminished role of financial intermediation in raising capital due to the reduction in costs of acquiring and processing information, donation-based crowdfunding remains fraught with the same problems that most decentralized methods of public good provision face, in particular, multiple equilibria and free riding. In a typical "all-or-nothing" crowdfunding

[1] "Private cancer therapy crowdfunding rise" *http://www.bbc.co.uk/news/health-38858898*, 4 Feb 2017.
[2] "How to hire your own London policeman" *The Economist*, 15 Dec 2016.

campaign – in the language of economics, the provision point mechanism – contributions are pledged over a pre-specified period of time. If a pre-specified target is met then the funds pledged are released to the project developer, otherwise the contributors are fully refunded. Because of the equilibrium coordination problem and subsequent free riding, an immediate prediction about "all-or-nothing" crowdfunding is a high occurrence of low-contribution outcomes. This prediction finds strong empirical support. As of October 2017, one of the most popular platforms, Kickstarter, reports the success rate of 35.9% for the total of its 376,635 launched projects.[3] Out of 238,592 unsuccessfully funded projects, 52,302 (22%) received 0% funding and 148,461 (62%) received between 1% to 20% funding. It should also be noted that most of Kickstarter's projects are typically small in size with a target of less than $10,000. Furthermore, according to Kuppuswamy and Bayus (2018), an important factor of a campaign's success is the fundraiser's social circle, where many contributions typically originate, adding toward limitations of crowdfunding when done for public projects.

This paper investigates, empirically and theoretically, contributing behavior under conditions very close to those of "all-or-nothing" crowdfunding. For this purpose, we created a laboratory-based crowdfunding platform with most important and realistic elements of crowdfunding in practice. This platform allows asynchronous contribution pledges over continuous time, upward pledge revisions, and constant updating of individual and aggregate pledge amounts until a fixed deadline. It can simultaneously accommodate multiple fundraising campaigns and also allows for different designs of crowdfunding campaign, in particular, for refund bonuses.

The main emphasis of our work is on the modification of the "all-or-nothing" crowdfunding mechanism that is proposed by Zubrickas (2014) and further explored by Cason and Zubrickas (2017). The modification is to introduce refund bonuses payable to contributors in the event of an unsuccessful fundraising campaign.[4] Specifically, with the

[3]According to The Verge (2013), the success rate of Indiegogo, another popular crowdfunding platform, is only 10%. The difference between this rate and Kickstarter's could be attributed to that Kickstarter initially prescreens its projects whereas Indiegogo does not.

[4]The idea similar to refund bonuses first appeared in Tabarrok (1998) in the form of dominant assurance contracts applied to collective action problems with binary choice.

"all-or-nothing" mechanism extended with refund bonuses contributors not only have their contributions refunded if the funding threshold is not met but also receive a refund bonus proportional to their contribution pledged, e.g., 10% of their contribution. Set to increase in contributions, refund bonuses provide incentives for more contributions but ultimately these incentives, together with contributors' preference for the project, ensure that in equilibrium enough is raised without any bonuses paid.[5] Importantly, this modification not only eliminates inefficient equilibria but also reduces the set of efficient equilibria because refund bonuses create more opportunities for profitable deviations, which results in a fewer combinations of contributions that can be sustained as equilibria. From the contributors' perspective, refund bonuses give contributors assurance that they will receive a positive utility from contributing – either from the public good or from refund bonuses – whereas free riders may end up with nothing.

The findings of Cason and Zubrickas (2017), which is the first experimental study on refund bonuses, considered only a static (simultaneous contributions) environment and provide further motivation for the present study.[6] First, Cason and Zubrickas (2017) demonstrate that experimental subjects respond to incentives created by refund bonuses in predicted ways. For example, and counter to simple intuition, project funding rates decline if the refund bonus is set very high. This is consistent with equilibrium predictions. Most importantly, they also demonstrate that (sufficiently small) refund bonuses can achieve a higher success rate compared to the standard "all-or-nothing" mechanism without bonuses. These findings illustrate the potential of refund bonuses for practical applications, to which the present paper provides further support.

Our main result is that in a more realistic dynamic environment the "all-or-nothing" mechanism extended with refund bonuses can increase funding and economic returns

[5]In this paper, we do not study the question of sources for refund bonuses. An example can be an insurance fund created by the crowdfunding platform out of insurance premiums paid by successful campaigners. Another example can be a third-party donor, perhaps introduced as seed funding.

[6]Besides considering only simultaneous contributions, the experiment in Cason and Zubrickas (2017) employed an environment that is considerably different from the one studied here and from crowdfunding in practice. In Cason and Zubrickas (2017) contributors could only pledge support for one project at a time, they could not add additional contributions to this project, they faced no aggregate uncertainty since the total value of the project was known and unchanging across periods. Treatments in that study included very large refund bonuses to explore some counter-intuitive predictions of the mechanism's equilibria.

from crowdfunding. In the setting with multiple funding campaigns, the introduction of refund bonuses increases the success probability from 30% to 60% and yields significant economic gains even after accounting for refund bonus costs. Compared to the levels of coordination reported by Cason and Zubrickas (2017), we find that adding a (continuous) time dimension for contributions results in higher levels of coordination under the standard "all-or-nothing" mechanism but only for single-project conditions. However, the equilibrium coordination problem resurfaces in full when subjects can choose among several projects as we observe more failed campaigns with relatively low total contributions. Nevertheless, the performance of the mechanism extended with refund bonuses remains robust to the presence of alternative projects. Another finding is that the introduction of refund bonuses can change the pattern of contributions over time as aggregate contributions accumulate more slowly under conditions with refund bonuses.

Importantly, our empirical findings are consistent with theoretically predicted contributing behavior. We develop a model of "all-or-nothing" crowdfunding that allows for refund bonuses. The model belongs to the class of models of dynamic provision of discrete public goods. Following the related literature (Kessing (2007); Choi et al. (2008); Battaglini et al. (2014, 2016); Cvitanic and Georgiadis (2016)), our modeling approach is to use Markovian strategies to characterize equilibrium contributions.[7] The distinctive feature of our model is that, in line with the practice of crowdfunding, contributions are refunded in the case of the campaign's failure or rather contributions are only made in the event of success. This feature implies linear costs and no discounting and, as a result, has important implications for strategic interactions between individual continuation contributions and aggregate accumulated contribution. In particular, Kessing (2007) shows that with discrete public goods aggregate and individual contributions are strategic complements (also see Cvitanic and Georgiadis (2016)). An additional contribution increases the probability of success, which implies a higher marginal value of further contributions. However, we show that strategic complementarity is attenuated by the condition that contributions are refunded in the case of failure, i.e., they are not sunk. While additional

[7] In addition, Choi et al. (2008) and Battaglini et al. (2016) demonstrate a close match between equilibrium Markovian strategies and empirically observed contributions.

contributions increase the probability of success, they also decrease the probability of failure and, thus, of obtaining contribution refunds. Hence, refunds affect the value function of the project, which now bears some resemblance to a value function for continuous public good projects; the implication is that, drawing on Fershtman and Nitzan (1991), individual and aggregate contributions can become strategic substitutes. The introduction of refund bonuses shifts the balance more toward strategic substitutability, which can explain our empirical finding about the slower accumulation of contributions under refund bonuses.

The remainder of the paper is organized as follows. After a literature review, we present the model, dynamic contribution problem, and its solution in Section 2. Based on our theoretical findings, we formulate testable hypotheses in Section 3. Section 4 presents the design of the experiment, and in Section 5 we discuss its results. Section 6 concludes the study.

Related literature. The present paper is related to the strands of literature on non-coercive methods of public fundraising and on dynamic contribution games. The idea of using pecuniary incentives to induce contributions appears in a number of studies. For example, in Falkinger (1996) contributors are rewarded for above-average contributions; in Morgan (2000) contributors are motivated by the means of lottery prizes. The advantages of the all-pay auction design in enhancing fundraising are studied by Goeree et al. (2005). Another example is the multi-stage mechanism of Gerber and Wichardt (2009) that precommits consumers to optimal contributions with conditionally refundable deposits. See Falkinger et al. (2000), Morgan and Sefton (2000), Lange et al. (2007), and Corazzini et al. (2010) for experimental evidence on the performance of these mechanisms. Dorsey (1992) and Kurzban et al. (2001) are previous experimental studies that allow upward revisions in pledged contributions targeting a provision point. For alternative fundraising methods, also see Varian (1994), Kominers and Weyl (2012), and Masuda et al. (2014). However, the practical applicability of many of these mechanisms is questionable because of concerns over group manipulability, distributive efficiency, and, most importantly, complexity which perhaps explains why the simple provision point mechanism remains the most preferred choice of practitioners.[8]

The extension of the provision point mechanism with refund bonuses is a novelty in the literature on contribution mechanisms. At the same time, our findings in baseline (no bonus) treatments are in line with findings reported by recent related studies. Bigoni et al. (2015) find higher levels of cooperation in social dilemmas when actions are taken in continuous time. They explain this finding by that in continuous time agents are able to react more swiftly to the instances of non-cooperative behavior.[9] Motivated by the practice of crowdfunding, Corazzini et al. (2015) focus on the effects of multiple projects on the average success rate. Similarly to the present study, Corazzini et al. (2015) show reduced levels of contributions in treatments with multiple threshold public goods. They attribute this reduction to the augmented equilibrium coordination problem, for which we provide further support and relate to the literature on two-arm bandit problems. Extending these earlier studies, our experiment considers the simultaneous funding of multiple threshold public goods with continuous time contributions, which is the environment closest to crowdfunding in practice.[10]

In general, the literature on dynamic contribution games gives mixed answers to the question whether a time dimension facilitates contributions. The predicted outcome crucially depends on the structural aspects of the dynamic contribution game studied. Admati and Perry (1991) predict an inefficient allocation of resources when contributions are made in a sequential order and are sunk because of the opportunity to free-ride on earlier contributions. But this finding is not robust, as they demonstrate, to the case of non-sunk costs (which limits the scope of dynamic free-riding), nor to the simultaneity of periodic

[8]Besides simplicity, another important advantage of the provision point mechanism is its "all-or-nothing" feature. As argued by, e.g., Kosfeld et al. (2009) and Gerber et al. (2013), minimum participation rules can reduce the severity of the free-riding problem and so can deadlines for collaborative projects (Bonati and Hörner (2011)).

[9]In contrast, in a public good environment Palfrey and Rosenthal (1994) report that repeated play (tantamount to discrete time) results only in a modest increase in the level of coordination and cooperation compared to one-shot play.

[10]Ansink et al. (2017) also consider continuous time contributions and multiple public goods, but in a very different environment with homogeneous and common knowledge valuations for the public good with a much longer (four-day) contribution window. Their focus is on seed money to help make specific projects more focal.

contributions (Marx and Matthews (2000)), nor to the asymmetry of contributors' valuations (Compte and Jehiel (2003)). In connection to the problem of dynamic free-riding, Battaglini et al. (2014) theoretically and Battaglini et al. (2016) experimentally demonstrate that the irreversibility of contributions is beneficial for public good outcomes, but again this result is not robust if the reversibility of contributions can be used for trigger strategies overcoming the free-riding problem (Lockwood and Thomas (2002), Matthews (2013)). As already discussed, the problem that early contributions can crowd out later contributions, thus leading to inefficient outcomes, was also emphasized by Fershtman and Nitzan (1991). But as Kessing (2007) and Cvitanic and Georgiadis (2016) show, this may not be the case if the public good is discrete. Regarding this comparison, our findings suggest that the difference in outcomes also depends on whether contributions are sunk. If they are not sunk, e.g., refunded, earlier accumulated contribution and individual continuation contributions may no longer be strategic complements even with discrete public goods. They can actually turn into strategic substitutes if refund bonuses are offered.

Lastly, our paper also contributes to an incipient literature on crowdfunding. Presently, most of this literature deals with the entrepreneurial side of crowdfunding; see Cumming and Hornuf (2018). Recently, Strausz (2017) develops a model of crowdfunding where an entrepreneur finances the investment into a new product out of funds raised from the crowd of consumers in return for the future delivery of the new product. While crowdfunding can resolve the problem of demand uncertainty, it also creates the problem of entrepreneurial moral hazard and private information that may impair the benefits of crowdfunding. Strausz (2017) demonstrates the usefulness of crowdfunding unless the agency costs are relatively too high. Even though our paper does not directly relate to this work, we note that crowdfunding for new products also suffers from the public good problem. In this type of crowdfunding, the public good is the opportunity of consumption for everyone. Then, those who do not participate in crowdfunding are likely to be better-off than those who participate because the former do not risk their funds in the case the project fails or falls short of expectations but choose to consumer only when all these uncertainties are resolved.

2 Model

Consider a set $\mathcal{N}$ of agents, indexed by $i \in \mathcal{N}$, that can benefit from a public good project. Each agent i has a privately known valuation for the public good which is given by v_i. It is common knowledge that individual valuations are independently distributed over $[\underline{v}, \overline{v}]$ according to a distribution $F(.)$ with the density function $f(.)$. The project costs C to implement. The fundraising campaign runs over a fixed period of time $[0, T]$. During any moment of time agents can pledge contributions toward the project. If at the end of the campaign the sum of contributions falls short of the target C, then the contributions are refunded together with refund bonuses as a share $r \geq 0$ of the contributions pledged; otherwise, the contributions are collected and the project is implemented.

2.1 Static Contribution Problem

For the subsequent analysis of the dynamic contribution problem, it is useful first to summarize the main results of the static model presented in Zubrickas (2014) and its companion working paper Zubrickas (2013). Without refund bonuses, $r = 0$, besides equilibria with a positive probability of provision there are also equilibria that have the zero probability of provision. For example, the zero-contribution outcome is equilibrium and so is any combination of contributions that sum up to less than $C - v^{max}$, where v^{max} is the highest valuation in the group. The introduction of refund bonuses eliminates the equilibria with the zero probability of provision as otherwise agents could gain in utility by marginally increasing their contributions and, thus, their refund bonuses.

Refund bonuses also have other effects. Refund bonuses not only eliminate inefficient equilibria but they also reduce the set of efficient equilibria. Refund bonuses create possibility for profitable deviations and, therefore, in equilibrium each contributor needs to obtain a sufficiently large net utility from the public good. This implies that fewer combinations of contributions can be sustained as equilibria. For instance, in the case of no aggregate uncertainty there exists a bonus rule that uniquely implements the public good. In the case of aggregate uncertainty, however, bonuses that are too large may reduce the probability of provision. Intuitively, at low realizations of valuations such that their aggregate V has $V < C(1+r)$, agents prefer refund bonuses, which are rC in total at the limit, over the net utility of the project, $V - C$. In what follows, and in our experimental design, we consider environments where $\Pr(V < C(1+r))$ is small or, in words, that the project is almost always efficient to implement even after accounting for refund bonuses.

2.2 Dynamic Contribution Problem

Let $g_i(t)$ denote agent i's total contribution made from the start of the campaign up to time t and, respectively, let $G(t)$ denote the aggregate contribution of all agents, $G(t) = \sum_i g_i(t)$, and $G_{-i}(t)$ the aggregate contribution of the agents other than i, i.e., $G_{-i}(t) = \sum_{j \neq i} g_j(t)$. At every moment of time t each agent i observes the aggregate contribution $G(t)$ and can make an additional contribution $a_i(G(t), g_i(t), v_i)$ as a function of $G(t)$, $g_i(t)$, and own valuation v_i that maximizes his expected payoff after accounting for strategies of other agents $\{a_j(G(t), g_j(t), v_j)\}_{j \neq i}$. We note that individual total contribution $g_i(t)$ is a state variable because it is not a sunk cost as it is repaid in the event of the campaign's failure and it also determines the amount of refund bonus. We also refer to function $a_i(.)$ as a Markovian strategy.[11]

We express agent i's problem as choosing strategy $a_i(G(t), g_i(t), v_i)$ such that at every

[11] Our exposition of the dynamic problem closely follows Cvitanic and Georgiadis (2016). Besides refund bonuses, another difference is that in our model contributions are actually made only in the event of success which implies linear costs and no discounting. These observations have important consequences for the solution of the model.

t it maximizes the value function

$$J_i(a_i(.), \{a_j(.)\}_{j\neq i}) = \int_t^T [-1 + (1+r)\Pr(G(T) < C \mid G(t))]\ a_i(g(t'), g_i(t'), v_i)dt' + \tag{1}$$
$$(1 - \Pr(G(T) < C \mid G(t)))(v_i - g_i(t)) + \Pr(G(T) < C \mid G(t))\ rg_i(t)$$

subject to

$$dg_i(t') = a_i(g(t'), g_i(t'), v_i)dt', \tag{2}$$

$$dG(t') = \sum_i a_i(g(t'), g_i(t'), v_i), \tag{3}$$

$$\text{and initial conditions } G(t) = g \text{ and } g_i(t) = g_i,\ i \in \mathcal{N}. \tag{4}$$

Above, $\Pr(G(T) < C \mid G(t))$ is the probability that the aggregate contribution $G(T)$ falls short of the target conditional on $G(t)$ raised at time t. The integrand of the first term of the value function $J(.)$ stands for the expected (after accounting for refund bonuses) instantaneous utility of an additional contribution, and the rest of the function gives the expected scrap value. The side constraints describe the evolution of the state variables.

We predict that the outcome of the fundraising campaign is Markov Nash equilibrium (MNE) defined as

Definition 1. *A profile of Markovian strategies* $\{a_i^*(G(t), g_i(t), v_i)\}_{i\in\mathcal{N}}$ *is Markov Nash equilibrium if at every moment* $t \in [0, T]$ *the strategy* $a_i^*(G(t), g_i(t), v_i)$ *is a solution to (1)-(4) given* $\{a_j^*(G(t), g_j(t), v_j)\}_{j\neq i}$ *for all admissible initial conditions* $G(t)$ *and* $g_i(t)$*,* $i \in \mathcal{N}$*.*

Similar to the static case, we can immediately observe that low-contribution outcomes with the zero probability of provision can be equilibrium for $r = 0$, e.g., $a_i^* = 0$ for all i and t. With $r > 0$, however, such outcomes are not equilibria because any agent could increase his contribution and, subsequently, refund bonus. For the remainder of this section, we restrict attention to equilibria with a positive probability of provision.

2.3 Equilibrium Characterization

First, we observe that only total contributions matter for payoffs and not their dynamics over time, as the costs of contributions are linear and are payable only at the end of the campaign conditional on its success. Specifically, integrating the side constraint (2) yields

$$g_i(T) - g_i(t) = \int_t^T a_i(g(t'), g_i(t'), v_i)dt' \equiv g_i^T(G(t), g_i(t), v_i), \tag{5}$$

and the side constraint (3) can be accordingly expressed as

$$G(T) = G(t) + \sum_i g_i^T(G(t), g_i(t), v_i). \tag{6}$$

Using (5) and (6), we can transform agent i's problem, where at every moment of time t each agent i chooses continuation contribution $g_i^T(G(t), g_i(t), v_i)$ to maximize his expected payoff given by

$$\widetilde{J}_i(g_i^T(.), \{g_j^T(.)\}_{j\neq i}) = (1 - \Pr(G(T) < C \mid G(t)))\ (v_i - g_i(t) - g_i^T(.)) + \tag{7}$$
$$\Pr(G(T) < C \mid G(t))\ r(g_i(t) + g_i^T(.))$$
$$\text{subject to (6) and initial conditions } G(t) \text{ and } g_i(t),\ i \in \mathcal{N}. \tag{8}$$

Second, at any moment of the campaign we can determine the equilibrium conditional probabilities of success and failure using the dynamic consistency of equilibrium play and that the initial condition $G(t)$ needs to lie on the admissible path. Letting $\mathcal{H}(.)$ be the distribution of equilibrium aggregate contribution $G(T)$, we have by Bayes rule that the probability of failure conditional on $G(t)$ raised until time t is determined by

$$\Pr(G(T) < C \mid G(t)) = \frac{\mathcal{H}(C) - \mathcal{H}(G(t))}{1 - \mathcal{H}(G(t))}. \tag{9}$$

Then, the problem presented in (7)–(8) can be viewed as a static Bayesian game where agent i's strategy is a continuation contribution $g_i^T(G(t), g_i(t), v_i)$ which is a function of previous aggregate and own contributions and of own valuation, respectively. At any moment t the solution to the initial program (1)–(4) determines the continuation contributions that are a solution to the static fundraising game for the remainder of the funds required, $C - G(t)$, with the players' beliefs about the probability of success being consistent with the equilibrium play up to time t. We summarize these observations in the following proposition.

Proposition 1. *Suppose that* $\{a_i^*(G(t), g_i(t), v_i)\}_{i\in\mathcal{N}}$ *is Markov Nash equilibrium. Then, the resultant continuation contributions* $\{g_i^{T*}(G(t), g_i(t), v_i)\}_{i\in\mathcal{N}}$*, defined by (5), form a Bayesian Nash equilibrium of the fundraising game, where for every* t *the players pledge contributions for the remainder* $C - G(t)$ *and their beliefs about the failure probability are consistent with past contributions as determined by the Bayes' rule in (9).*

2.4 Equilibrium Properties

According to Proposition 1, a profile of Markov strategies is Markov Nash equilibrium only if it forms a Bayesian Nash equilibrium of the static contribution game. An immediate outcome of this observation is that our findings about the static contribution model presented earlier also apply to the dynamic contribution problem. Next, we consider Bayesian Nash equilibria with a positive probability of provision in order to characterize comparative statics properties of equilibrium continuation contributions at any time t, which will form a basis for empirical analysis. The properties established below apply to all Bayesian Nash equilibria and, therefore, can be used to characterize equilibrium Markovian strategies.

For subsequent analysis it is useful to replace the state variable $G(t)$ with the aggregate contribution of agents other than i, $G_{-i}(t)$, since we have that $G_{-i}(t) = G(t) - g_i(t)$. Let $\mathcal{H}_{-i}(.)$ be the distribution of the equilibrium total contribution $G^*_{-i}(T)$ of the other agents. We can rewrite the problem in (7)–(8) so that the equilibrium continuation contribution $g_i^{T*}(G_{-i}(t), g_i(t), v_i)$ or just g_i^{T*} for brevity maximizes agent i's expected payoff from time

t onwards determined by

$$U_i(g_i^T, \{g_j^T\}_{j\neq i}; G_{-i}(t), g_i(t), v_i) = \frac{1-\mathcal{H}_{-i}(C-g_i^T-g_i(t))}{1-\mathcal{H}_{-i}(G_{-i}(t))}\,(v_i - g_i^T - g_i(t)) + \tag{10}$$
$$\frac{\mathcal{H}_{-i}(C-g_i^T-g_i(t))-\mathcal{H}_{-i}(G_{-i}(t))}{1-\mathcal{H}_{-i}(G_{-i}(t))}\,r(g_i^T+g_i(t)).$$

Assuming differentiability, we have that the non-zero equilibrium contributions are determined by the first-order condition which, premultiplied by $1-\mathcal{H}_{-i}(G_{-i}(t))$, reads as

$$-\left(1-\mathcal{H}_{-i}(C-g_i^{T*}-g_i(t))\right) + h_{-i}(C-g_i^{T*}-g_i(t))\,(v_i-g_i^{T*}-g_i(t)) - \tag{11}$$
$$h_{-i}(C-g_i^{T*}-g_i(t))\,r(g_i^{T*}+g_i(t)) + \left(\mathcal{H}_{-i}(C-g_i^{T*}-g_i(t))-\mathcal{H}_{-i}(G_{-i}(t))\right)r = 0$$

where $h_{-i}(.)$ is the density function of the distribution $\mathcal{H}_{-i}(.)$.

Implicitly differentiating the condition in (11), we can establish several properties of equilibrium contributing behavior. First, not surprisingly, the continuation contribution g_i^{T*} increases in own valuation for the public good:

$$\frac{dg_i^{T*}}{dv_i} = -\frac{h_{-i}(C-g_i^{T*}-g_i(t))}{\partial^2 U_i/\partial(g_i^T)^2} > 0,$$

where we use that $\partial^2 U_i/\partial(g_i^T)^2 < 0$ by the second-order condition. Second, we obtain that the derivative of the continuation contribution with respect to own previous contribution is equal to

$$\frac{dg_i^{T*}}{dg_i(t)} = -\frac{\partial^2 U_i/\partial g_i^T \partial g_i(t)}{\partial^2 U_i/\partial(g_i^T)^2} = -1.$$

In words, own previous and further contributions are perfect substitutes, and the reason is that previous contributions are not sunk costs and have the same effect on payoffs as any further contribution. Lastly, the derivative of the continuation contribution with respect to others' previous contributions is

$$\frac{dg_i^{T*}}{dG_{-i}(t)} = -\frac{-rh_{-i}(G_{-i}(t))}{\partial^2 U_i/\partial(g_i^T)^2}. \tag{12}$$

For $r \geq 0$ this derivative is non-positive, which indicates substitutability between individual continuation contributions and previous contributions of others. However, the degree of substitutability is inversely related to the refund bonus rule r, which, intuitively, is due to stronger incentives to miss the target for larger refund bonuses. We also note that with $r < 0$, which implies that a part of contribution is sunk, we obtain strategic complementarity between individual contributions and aggregate contribution in line with the results of Kessing (2007) and Cvitanic and Georgiadis (2016).

In general, our finding in (12) can be related to other findings from the literature on the dynamic provision of public goods. Whether own contribution and the previous contributions of others are strategic complements or substitutes depends on the type of the public good. In particular, for continuous public goods there is strategic substitutability (Fershtman and Nitzan (1991)), whereas for discrete goods – strategic complementarity (Kessing (2007)). Intuitively, with continuous public goods and a concave utility an additional contribution reduces the marginal value of subsequent contributions, thus, yielding strategic substitutability. At the same time, with discrete public goods an additional contribution increases the probability of provision and, thus, the marginal value of subsequent contributions, yielding strategic complementarity. Even though in the present paper we deal with discrete public goods, the introduction of refunds and refund bonuses implies that the project generates payoffs not only upon completion, which makes the value function look more like in the case of a continuous public good though preserving a discontinuity at the point of provision.

Lastly, we also note that our analysis is more about total individual contributions (from any moment of time) rather than their dynamics. Given that the costs of contribution are linear and conditional, multiple Markov Nash equilibria can be consistent with the same total contributions including, e.g., equilibria with open-loop strategies or degenerate equilibria where everyone contributes at the very last moment of the campaign.

3 Empirical Implications

This section draws on the implications of the model to formulate testable hypotheses about contributing behavior. We are interested in comparing (i) the performance of mechanisms with and without refund bonuses and (ii) predicted and observed contribution patterns.

Hypothesis 1. *The introduction of refund bonuses increases the rate of provision.*

This hypothesis is based on the observation that refund bonuses eliminate equilibria with low contributions and, thus, with the zero rate of provision. In a static (simultaneous-contribution) environment, a similar hypothesis was tested in Cason and Zubrickas (2017). Their finding is that in larger groups (10 experimental subjects) the rate of provision significantly drops in treatments without refund bonuses compared to treatments with refund bonuses. Here, we test this hypothesis in a more realistic dynamic environment also allowing for multiple project alternatives.

In campaigns without refund bonuses, we can distinguish two sources of failure. The first is low-contribution equilibria, and the second is the problem of coordination among efficient equilibria. However, in campaigns with refund bonuses we have only the second source of failure. The next hypothesis is centered on the postulate that in campaigns without refund bonuses both sources of failure play a role.

Hypothesis 2. *The contribution target is missed by larger amounts under the mechanism without refund bonuses than with refund bonuses.*

The next two hypotheses are about patterns of individual contributions as predicted by equilibria with a positive probability of provision. When comparing equilibrium contributions between treatments with and without bonuses, we restrict the set of outcomes only to successful campaigns which is done to remove the outcomes of inefficient equilibria that can arise under the mechanism without refund bonuses.

Hypothesis 3. *Conditional on successful campaigns, individual continuation contributions positively depend on own valuation and negatively on own previous contribution.*

Hypothesis 4. *Conditional on successful campaigns, under the mechanism with (without) refund bonuses the previous aggregate contribution of others has a negative (neutral) effect on individual continuation contributions.*

Hypothesis 4 follows from our finding, presented in (12), that previous contributions of others have a negative impact on individual continuation contributions but only under the mechanism with refund bonuses. Because of this strategic substitutability, we can conjecture that contributions accumulate more slowly under the mechanism with refund bonuses:

Conjecture. *Conditional on successful campaigns, contributions accumulate more slowly under the mechanism with refund bonuses.*

4 Experimental Design

We controlled subjects' preferences over funding public goods, termed 'projects' in the instructions, using randomly drawn induced values. It was common knowledge that all $N = 10$ subjects received an independent value for each project every period drawn from $U[20, 100]$. Actual drawn values v_i were private information. The threshold for funding each project was fixed at $C = 300$ experimental dollars. Since the average aggregate project value across all 10 contributors (600) far exceeds the project cost, for this study all projects were efficient to fund. If the group's aggregate contributions during the two-minute funding window reached this threshold, every group member received his or her drawn value for that project irrespective of their own contribution. Contributions in excess of the threshold were not refunded and they did not improve the quality of the project. Excess contributions were simply wasted. Therefore, net subject earnings for successfully funded projects equalled their drawn value minus their own total contribution.

Like most crowdfunding mechanisms in the field, the contribution mechanism operated in continuous time, with a hard close and full information about aggregate contributions at all times. While the two-minute timer counted down in one-second increments, any subject could submit a contribution. These contributions were instantly displayed to all nine others in the group on an onscreen table listing.[12] Subjects could make as many contributions, in whatever amounts they desired, during the two-minute window. Contributions could not be withdrawn. In addition to the table listing each individual contribution, subjects' screens displayed the total contribution sum raised at that moment, next to the target contribution threshold (300). The screen also continuously updated the subject's own total contribution for the period, summed across their individual contribution amounts.

The experiment employed a 2×3 design, and within subject treatment variation. The first treatment variation concerns the availability of alternative projects for potential contributions, in order to investigate whether coordination difficulties caused by multiple projects affect the performance of refund bonuses. In some periods subjects could only contribute towards one project, while in other periods subjects could contribute to two projects during the same time window. Their value draws for these two projects were independent. Both projects or one project could be funded successfully. The second treatment variation was the availability and amount of the refund bonus, $r \in \{0, 0.1, 0.2\}$, with $r = 0$ being the no bonus baseline. Under the mechanism with a positive refund bonus r, the individual's total contribution g_i determines her net earnings for the period in the event that aggregate total contributions G do not reach the threshold C. To summarize, subjects earnings for every project are determined by $\mathbb{1}_{G \geq C}(v_i - g_i) + \mathbb{1}_{G<C}\, r g_i$.

As noted above, we varied the treatment conditions within subjects. Table 1 displays the ordering of treatment conditions across different sessions. Each session began with 15 periods in one treatment followed by one treatment switch before the final 15 periods. Half of the sessions began with only one project available to fund, while the other half began with two project alternatives. All the different combinations of refund bonuses

[12]This individualized contribution listing indicates the distribution of contributions at each point in time. This is a simple approximation to the information provided by online crowdfunding sites, where many projects display how many individual contributions fall into various ranges. Furthermore, displaying individual contributions has no theoretical implications because of the aggregative structure of the public good game, i.e., the distribution of others' contributions does not matter as long as their aggregate is the same.

Table 1: Experimental Design

Values v	Periods 1-15	Periods 16-30	Num. Subjects	Num. Groups
$U[20, 100]$	$r_1 = 0$, $r_2 = 0.1$	Only $r = 0.2$	20	2
$U[20, 100]$	$r_1 = 0$, $r_2 = 0.2$	Only $r = 0.1$	20	2
$U[20, 100]$	$r_1 = 0.1$, $r_2 = 0.2$	Only $r = 0$	20	2
$U[20, 100]$	Only $r = 0$	$r_1 = 0.1$, $r_2 = 0.2$	20	2
$U[20, 100]$	Only $r = 0.1$	$r_1 = 0$, $r_2 = 0.2$	20	2
$U[20, 100]$	Only $r = 0.2$	$r_1 = 0$, $r_2 = 0.1$	20	2

were presented to subjects in different sessions. We did not include alternative projects with identical refund bonuses, or both with no refund bonus, because previous research (Corazzini et al. (2015); Ansink et al. (2017)) has already investigated coordination and contributions to multiple projects with similar or identical characteristics. Two groups of ten subjects (fixed matching within ten-subject groups) participated in each of the six treatment ordering configurations, for a total of 120 subjects in the experiment.

All sessions were conducted at the Vernon Smith Experimental Economics Laboratory at Purdue University, using z-Tree (Fischbacher (2007)). Subjects were undergraduate students, recruited across different disciplines at the university by email using ORSEE (Griener (2015)), and no subject participated in more than one session.

At the beginning of each experimental session an experimenter read the instructions aloud while subjects followed along on their own copy. Appendix A presents this exact instructions script. Earnings in the experiment are denominated in experimental dollars, and these are converted to U.S. dollars at a pre-announced 50-to-1 conversion rate. Subjects are paid for all project rounds and also received a $5.00 fixed participation payment. Subjects' total earnings averaged US$24.25 each, with an interquartile range of $20.00 to $27.50. Sessions usually lasted about 90 minutes, including the time taken for instructions and payment distribution.

5 Experimental Results

We report the results in four subsections. The first subsection considers the main treatment effects, specifically the funding rate and individual contributions for the different re-

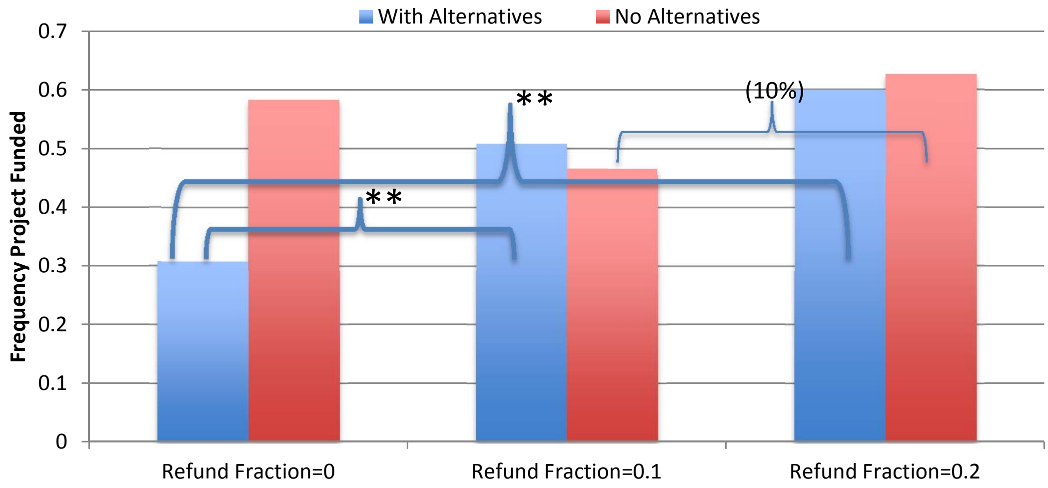

Figure 1: Overall project funding rates by treatment condition. ** indicates significant difference at the 0.01 level.

fund bonus conditions. The data indicate that treatment differences emerge most strongly when multiple projects are available for funding, and the second subsection explores this further. The third subsection reports individual contributions within the continuous time contribution window, and how they depend on the bonus rate and previous contributions within the period. The final subection presents additional results on the contribution dynamics.[13]

5.1 Main Treatment Effects

The overall project funding rate is about 40 percent in the baseline condition without refund bonuses. This success rate increases to about 50 percent with the smallest (0.10) refund bonus rate, and further to about 60 percent with the larger (0.20) bonus rate. Figure 1 illustrates that these increases in project funding due to the refund bonus occur only when alternative projects are available for contributions. Without alternative projects to fund, the funding rate without refund bonuses is similar to those projects with bonuses. That is, the data support Hypothesis 1 only when alternative projects are available.

[13] In one session the subjects in one group were clearly confused in the first period, as they contributed 820 to the project when only 300 was needed for funding. This single period was dropped prior to the data analysis.

Result 1. Refund bonuses increase the rate of provision and individual contributions only when multiple projects are available to receive contributions. Contributions also increase in the aggregate and individual valuation of the project, but are not affected by the existence or level of the alternative project's refund bonus.

Support. Table 2 reports random effects regressions of project funding outcomes (columns 1 and 2) and individual contributions (columns 3 and 4) on exogenous treatment variables and the randomly-drawn project valuations. The regressions also control for (insignificant) experience and time trends. The omitted treatment is the zero bonus baseline. The treatment dummies for the positive refund bonuses are only statistically significant with alternative projects available (columns 2 and 4). Funding success and individual contributions also increase when the drawn project valuations are greater, indicating that this voluntary contribution mechanism is able to identify and fund the more worthy projects. Importantly, the lower rows of the table indicate that funding rates and individual contributions are not lower when the alternative project has a positive refund bonus. Only the individual subjects' value for the alternative project has a negative impact on contributions.

The next result considers outcomes for unsuccessful projects. Inefficient, low-contribution equilibria exist only for the mechanism without refund bonuses, so Hypothesis 2 postulates that the contribution target of 300 is missed by larger amounts without refund bonuses. While we do not observe outcomes at exactly zero total contributions in any treatment, refund bonuses raise average contributions closer to the threshold.

Result 2. For projects that are not funded successfully, refund bonuses raise average contributions closer to the funding threshold only when multiple projects are available to receive contributions.

Support. Figure 2 shows that when no alternative projects are available to receive contributions, on average unsuccessful projects fall short of the funding threshold by the highest amount (38) when no refund bonuses are offered, but this average is not

Table 2: Funding Success and Individual Contributions

	Logit: Funding Success		Individual Contributions	
	No Alternatives (1)	w/Altern. (2)	No Alternatives. (3)	w/Altern. (4)
Dummy (bonus=0.1)	-0.114 (0.086)	0.200** (0.061)	0.429 (0.814)	4.926** (1.465)
Dummy (bonus=0.2)	0.046 (0.052)	0.260** (0.079)	1.041 (0.624)	5.523** (1.146)
Total Value	0.002** (0.0007)	0.002** (0.0004)		
Own Value			0.295** (0.021)	0.379** (0.020)
Period	-0.010 (0.006)	-0.005 (0.008)	0.048 (0.086)	0.088 (0.104)
Dummy (Periods 16-30)	-0.093 (0.063)	-0.064 (0.059)	0.317 (0.585)	1.145 (1.019)
Alternative Project Total Value		-0.0007 (0.0003)		
Alternative Project Own Value				-0.048** (0.017)
Dummy (Alt. bonus=0.1)		0.002 (0.059)		0.662 (1.127)
Dummy (Alt. bonus=0.2)		-0.050 (0.082)		0.065 (0.902)
Constant			10.39** (1.86)	2.60 (1.97)
Observations	179	360	1790	3600

Note: Random-effects regressions, with standard errors clustered by sessions; robust standard errors are reported in parentheses. Marginal effects shown for logit models. ** indicates coefficient is significantly different from zero at the .01 level; * at .05.

significantly higher than the average $(28 - 31)$ with refund bonuses. When alternatives projects are available, however, contributions fall short of the target of 300 by 90 on average without bonuses, which is statistically and economically much greater than the levels for unsuccessful projects with refund bonuses.[14]

Generally, Results 1 and 2 suggest that refund bonuses help resolve the equilibrium

[14]These statistical conclusions are based on tobit models that control for experience and time trends, and robust standard errors clustering on sessions.

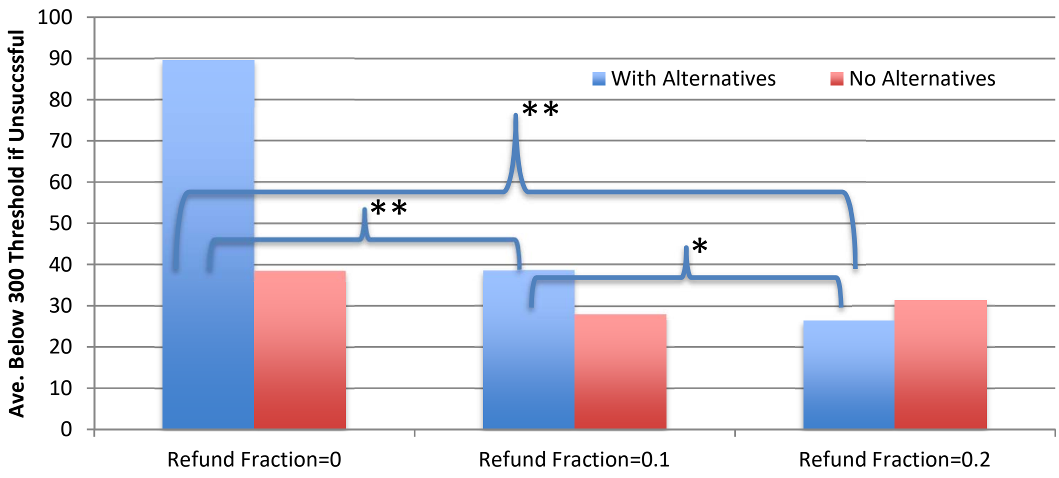

Figure 2: Average amount short of threshold for unsuccessful projects, by treatment condition. ** indicates significant difference at the 0.01 level; * at 0.05 level.

coordination problem. With a single project, we observe that both mechanisms produce a similar rate of provision and average contributions and, as implied by Result 2, low-contribution equilibria do not seem to play a role under zero bonus conditions. From a different perspective, having a time window for contributions helps individuals coordinate on efficient outcomes.[15] However, with multiple projects low-contribution equilibria seem to have an effect under zero bonus conditions as judged by the significantly lower rate of provision and contributions. Drawing on Corazzini et al. (2015), we conjecture that the necessity to coordinate over multiple projects exacerbates the equilibrium coordination problem under zero bonus conditions. Furthermore, the findings in Results 1 and 2 are consistent with the findings in Cason and Zubrickas (2017), where we demonstrate that in a static environment refund bonuses result in a higher rate of provision in larger groups.

Our final results for the main treatment comparison concern overall funding efficiency and net returns. Due to the drawn individual values for the different projects, some have a greater social value V than others. We define funding efficiency as $[V - G(T)]/[V - C]$ when the project is funded ($G(T) \geq C$) and 0 otherwise. It is an index that ranges from 0 for unsuccessful projects to 1 for those projects whose total contributions $G(T)$

[15]The 58 percent success rate without refund bonuses when no alternatives are available compares favorably to the 20-30 percent success rate for the 10-contributor, no refund case in Cason and Zubrickas (2017) with single, simultaneous contribution opportunities. Although this improvement could be due to improved coordination from the continuous contribution window, it could be due to other environment differences in the two experiments noted above in footnote 6.

exactly reach the threshold C. Excess contributions above C, which are common due to miscoordination, lower this index below one. Refund bonuses paid for $r > 0$ on unsuccessful projects do not factor into funding efficiency, since these are simply transfers and do not affect total surplus.

We also use an alternative performance index, termed net return (NR), to penalize the outcome from the mechanism designer's perspective when refund bonuses are paid.

$$NR(G(T), r) = \begin{cases} V - G(T) & \text{if} \quad G(T) \geq C \\ -rG(T) & \text{if} \quad G(T) < C \end{cases}$$

This simply replaces the social value for successful projects with the refund bonuses that have to be paid by the mechanism designer when fundraising is unsuccessful. By definition, of course, these net returns can only be negative when refund bonuses can be paid ($r > 0$).

Result 3. Funding efficiency increases monotonically with the amount of the refund bonus rate r, but only when multiple projects are available to receive contributions. Net returns are also significantly greater than the $r = 0$ baseline for the high refund bonus $r = 0.2$ when alternative projects are available, but are significantly lower than the $r = 0$ baseline for the low refund bonus $r = 0.1$ when no alternative projects are available.

Support. Table 3 reports average funding efficiency and net returns for each of the treatments. None of the efficiency figures shown in the first column are significantly different from each other for the case where no alternative projects are available for funding. By contrast, the monotonic increase in efficiency with alternatives available, as the refund bonus rises from 0 to 0.1 to 0.2, are all significantly different at 1 percent.[16] The net returns average 158 with the high refund bonus $r = 0.2$ when alternative projects are available to fund, which exceeds the 101 average without refund bonuses at the 5 percent level. Without alternative projects, the net returns of 192 without refund bonuses exceed

[16]These statistical conclusions are based on tobit models that control for experience and time trends, and robust standard errors clustering on sessions.

the 129 average returns for the small refund bonus $r = 0.1$.[17]

Table 3: Average Funding Efficiency and Net Returns

	Funding Efficiency		Net Returns	
	No Alternatives	w/Altern.	No Alternatives.	w/Altern.
No Refund Bonus ($r = 0$)	0.567	0.300	192.3	101.0
	(0.062)	(0.041)	(21.9)	(14.1)
Refund Bonus $r = 0.1$	0.437	0.487	129.4	138.6
	(0.061)	(0.044)	(22.8)	(15.5)
Refund Bonus $r = 0.2$	0.585	0.575	172.3	158.1
	(0.060)	(0.043)	(24.3)	(16.7)
Observations	179	360	179	360

Note: Standard errors are reported in parentheses.

To summarize these main treatment effects, we generally see that mechanism performance is improved with refund bonuses, but only when contributors have more than one project that they can fund. For this case, refund bonuses increase the rate of project provision, raise aggregate and individual contributions, raise average contributions closer to the funding threshold when fundraising is unsuccessful, and increase funding efficiency and net returns to the public good.

5.2 Multiple Projects for Funding

Crowdfunding sites offer potential contributors multiple projects to fund, which can make coordination among potential contributors difficult (Corazzini et al. (2015)). Details of the funding mechanism can also differ across projects, and across crowdfunding platforms, which is a key reason that we included treatments in this experiment in which multiple projects featuring different refund bonuses could be funded simultaneously. As just noted, performance differences emerge in the environment with multiple projects.

Models (2) and (4) shown earlier in Table 2 indicate that conditional on having alternative projects to fund, the level of the alternative projects' refund bonus did not affect funding likelihood or individual contributions. Here we turn to examine more closely

[17]Conclusions are based on a regression with experience and time controls, with robust standard errors clustered on sessions.

whether presence of alternative projects and their refund bonus levels affect contributions and funding. The top panel of Table 4 displays marginal effects from logit models of the likelihood of funding success, pooling across standalone projects and projects soliciting contributions while other projects are available.

The dummy variable shown in the top row indicates that when pooling across all treatments (model 1), having multiple projects to fund modestly reduces the chances of reaching the funding threshold, with marginal statistical significance. The other two columns consider different subsets of treatments. Model (2) indicates that $r = 0$ projects without any refund are significantly less likely to be funded when an alternative $r = 0.1$ project is available for contributions, compared to standalone $r = 0$ projects without alternatives. A similar result (not shown) obtains when a no-bonus project is paired with an alternative paying a $r = 0.2$ bonus.

By comparison, model (3) indicates that projects with the low $r = 0.1$ bonus are not negatively affected by being paired with projects offering a higher $r = 0.2$ bonus. Similar regression results, not shown in the table, indicate that the $r = 0.1$ treatment is not negatively affected by pairing with the no-bonus treatment, and that the $r = 0.2$ project funding likelihood is also not affected by the availability of alternative projects.

The lower panel of Table 4 displays analogous results for contribution choices. Models (4) and (5) replicate the earlier treatment effects documenting greater contributions with positive refund bonuses, and also show that contributions fall when alternative projects are available. Models (6) and (7) illustrate that this negative impact of multiple projects is limited to the no-bonus case. Other comparisons for $r > 0$ projects, as in column (7), never indicate significant negative impacts of project alternatives. To summarize:

Result 4. Projects without refund bonuses ($r = 0$) receive lower contributions and are less likely to be funded successfully when they solicit contributions while alternative projects are simultaneously available for funding. Projects with refund bonuses ($r > 0$) are unaffected by the availability of alternative projects.

This result provides suggestive evidence that refund bonuses help coordinate contribu-

Table 4: Impact of Multiple Projects for Funding

	Panel A: Logit - Funding Success (Marginal Effects)		
	Any Alternatives (1)	$r = 0$ vs. $r = 0, 0.1$ (2)	$r = 0.1$ vs. $r = 0.1, 0.2$ (3)
Dummy (Multiple Projects)	$-0.063^{\dagger}$ (0.034)	-0.218** (0.077)	0.024 (0.090)
Total Value	0.002** (0.0003)	0.003** (0.0006)	0.002 (0.0020)
Dummy (bonus=0.1)	$0.094^{\dagger}$ (0.049)		
Dummy (bonus=0.2)	0.207** (0.039)		
Observations	539	120	120

	Panel B: Total or Individual Contributions			
		Individual Contributions		
	Total Contributions (4)	Any Alternatives (5)	$r = 0$ vs. $r = 0, 0.1$ (6)	$r = 0.1$ vs. $r = 0.1, 0.2$ (7)
Dummy (Multiple Projects)	-18.02** (4.539)	-1.580** (0.449)	-4.195** (1.429)	-0.313 (0.604)
Total Value	0.159** (0.026)			
Own Value		0.356** (0.014)	0.346** (0.040)	0.330** (0.019)
Dummy (bonus=0.1)	32.06** (6.40)	3.206** (0.632)		
Dummy (bonus=0.2)	40.11** (6.53)	4.004** (0.634)		
Constant	168.60** (17.21)	4.20** (1.23)	$6.16^{\dagger}$ (3.66)	8.80** (1.56)
Observations	539	5390	1200	1200
R-squared	0.231	0.188	0.196	0.166

Notes: Random-effects regressions, with standard errors clustered by sessions; robust standard errors are reported in parentheses. Time trend (period) and treatment sequence controls included in all models. ** indicates coefficient is significantly different from zero at the .01 level; * at .05; † at 0.10.

tions when multiple projects are available to fund. From a different perspective, multiple projects can aggravate the problem of equilibrium coordination under no bonus conditions. This observation is consistent with findings from the literature on two-arm bandit problems (see Bergemann and Välimäki (2008) for a review of the economics strand of literature). Put crudely, project experimentation (contributions in our case) should be directed to projects with the highest expected reward. In our study, for projects without bonuses we have efficient and inefficient equilibria which implies lower expected returns compared to projects with bonuses provided that subjects attach a positive probability to inefficient equilibria. Thus, when confronted with alternatives subjects start first experimenting with projects that offer refund bonuses, i.e., higher expected rewards, which can explain our finding of lower contributions for projects without bonuses. At the same time, since expected equilibrium rewards are barely affected by the size of refund bonuses, there should be no difference in the levels of experimentation between projects that offer bonuses as we precisely observe in our experiment.

5.3 Individual Contributions, Conditional on Funding Success

The next set of empirical results concern the pattern of individual contributions as predicted by equilibria with a positive probability of provision. Accordingly, we restrict attention to the projects that were successfully funded. Hypothesis 3 postulates that individual continuation contributions g_i^T in the later phase of the period depend positively on the contributor's own valuation for the project, and negatively on their own previous contribution made up to that point in the period. This is because own previous and further contributions are perfect substitutes. The data support this hypothesis, as summarized in the next result. Hypothesis 4 is that individual continuation contributions depend negatively on the aggregate previous contributions of others, but only for the case of positive refund bonuses. For the zero-bonus case, previous contributions of others should have a neutral impact. The data support only the zero refund bonus part of this hypothesis.

Result 5. Individual continuation contributions in the later part of the contribution period depend positively on a contributor's value for the project, and negatively on own previous contributions. This contribution pattern holds for zero and positive refund bonus conditions, with and without alternative projects available for funding. A negative but statistically insignificant relationship exists between individual continuation contributions and previous contributions of others in the period.

Support. We wish to estimate how individual i's continuation contributions in period t, g_{it}^T, depend on own previous contributions up to that point in the period (g_{it}), the aggregate contributions of others up to that point (G_{-it}) and the individual's own value draw for that period (v_{it}). When assessing these relationships it is important to account also for the amount remaining to reach the target at that point, $R_t = C - g_{it} - G_{-it}$, where $C = 300$ is the threshold for funding. We therefore would like to estimate the following linear regression, which also includes a time trend and individual fixed effects to absorb systematic differences between subjects:

$$g_{it}^T = \beta_0(C - g_{it} - G_{-it}) + \beta_1 g_{it} + \beta_2 G_{-it} + \beta_3 v_{it} + \beta_4 t + \alpha_i + \epsilon_{it}$$

The key parameters of interest for evaluating Hypotheses 3 and 4 are β_1, β_2 and β_3. This equation cannot be estimated directly due to perfect colinearity, however, since the funding threshold $C = 300$ is a constant. So instead we estimate a transformed version,

$$g_{it}^T = \beta_0 C + (\beta_1 - \beta_0) g_{it} + (\beta_2 - \beta_0) G_{-it} + \beta_3 v_{it} + \beta_4 t + \alpha_i + \epsilon_{it}$$

The estimates from this transformed equation can be converted back into the original β_1 and β_2 terms using β_0, with corresponding adjustments to the standard errors.

Table 5 reports the results of this estimation exercise, with different treatment conditions reported in each column. The dependent variable is the individual subject's total contribution during the final 60 seconds of each 2-minute period. The subject's own and aggregate other contributions in the initial 60 seconds in the period are used to estimate β_1 and β_2. Similar results obtain when splitting the early and late parts of the period at the 30- or 90-second mark. The coefficient estimate on subjects' own project value (β_3) is always positive, as predicted. The top row indicates a strong and robust negative relationship between own previous contributions and later contributions (β_1), consistent with Hypothesis 3.

Table 5: Continuation Contributions - Second Half of Each Period (61-120s)

	No Alternative Projects			With Alternative Projects		
	$r = 0$	$r = 0.1$	$r = 0.2$	$r = 0$	$r = 0.1$	$r = 0.2$
β_1: Own Previous	-0.132**	-0.109*	-0.260**	-0.212**	-0.195**	-0.231**
Contributions (1-60s)	(0.037)	(0.061)	(0.096)	(0.078)	(0.067)	(0.057)
β_2: Others' Previous	-0.006	-0.041	-0.024	-0.009	-0.037	-0.028
Contributions (1-60s)	(0.049)	(0.076)	(0.122)	(0.108)	(0.093)	(0.079)
β_3: Own Value	0.123*	0.186*	0.203**	0.170*	0.225**	0.212**
	(0.047)	(0.060)	(0.038)	(0.073)	(0.035)	(0.035)
β_4: Period (t)	-0.013	0.173	0.051	-0.037	0.006	0.188
	(0.101)	(0.248)	(0.227)	(0.038)	(0.060)	(0.087)
β_0: Constant	0.072**	0.074**	0.072**	0.064**	0.072**	0.062**
(on $C = 300$)	(0.013)	(0.015)	(0.018)	(0.013)	(0.004)	(0.005)
Observations	350	280	370	370	610	720
R-squared	0.188	0.143	0.161	0.166	0.186	0.217
Individuals	40	40	40	80	80	80

Note: Only includes successfully funded projects. Individual fixed-effects regression, with standard errors clustered by sessions (reported in parentheses). ** indicates coefficient is significantly different from zero at the .01 level; * at .05.

The aggregate contributions of others in the early part of the period also have a negative coefficient estimates (β_2), but they are imprecisely estimated and are not significantly different from zero. Hypothesis 4 predicts no relationship for the treatments without a refund bonus r, and indeed the (β_2) coefficient estimates are closest to zero for the $r = 0$ treatments. But the support for Hypothesis 4 is mixed due to the failure to find a statistically significant relationship between the previous aggregate contributions of others and individual continuation contributions for the $r > 0$ treatments. At the same time, we also note that since the degree of strategic substitutability directly depends on the size of the bonus r (see (12)) it might have been particularly difficult to detect it given the small values of r chosen and our sample size.

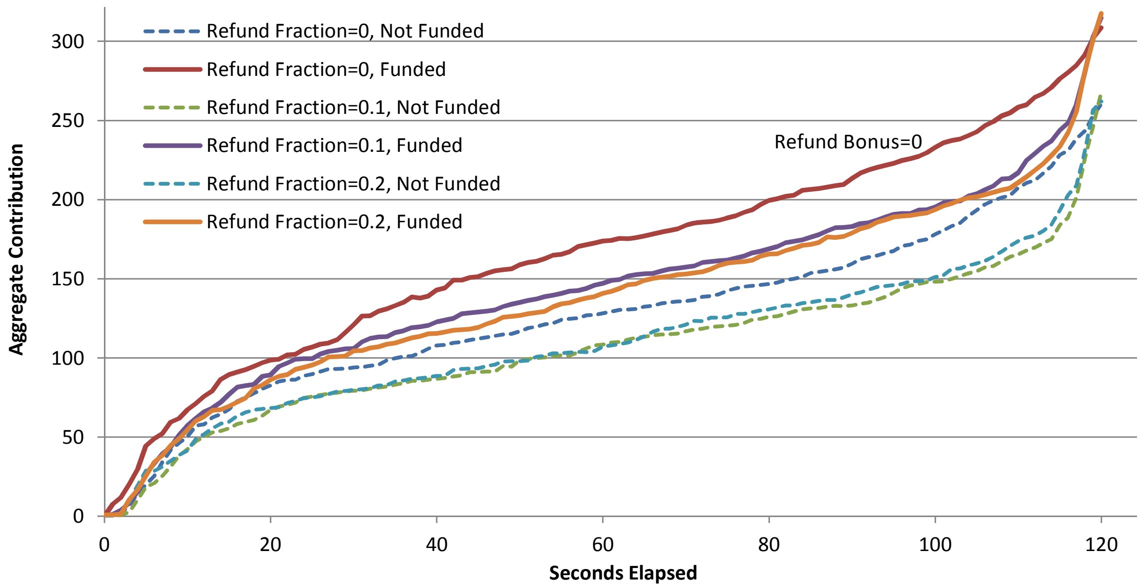

Figure 3: Cumulative Average Contributions (All Projects, No Alternative Project Available, by Funding Success)

5.4 Contribution Dynamics

Refund bonuses provide potential contributors with a positive return even when the provision point is not reached. Therefore, refund bonuses create an incentive to miss the contribution target, which is also behind the strategic substitutability between others' earlier contributions and own continuation contribution. This motivates our Conjecture that contributions accumulate more slowly with refund bonuses. As noted earlier, to make comparisons of equilibrium contributions across treatments, we restrict attention to successful fundraising campaigns.

Result 6. Within the continuous time interval for project contributions, conditional on successful fundraising, aggregate contributions accumulate more slowly when refund bonuses are available. This contribution pattern holds with and without alternative projects available for funding.

Support. Figures 3 and 4 illustrate how the cumulative average contributions rise across the 120-second fundraising window. The figures differentiate the successful (solid line) and unsuccessful (dotted line) campaigns. By design, the successful campaigns reach the threshold of 300, and the figures highlight how this occurs typically through a spike

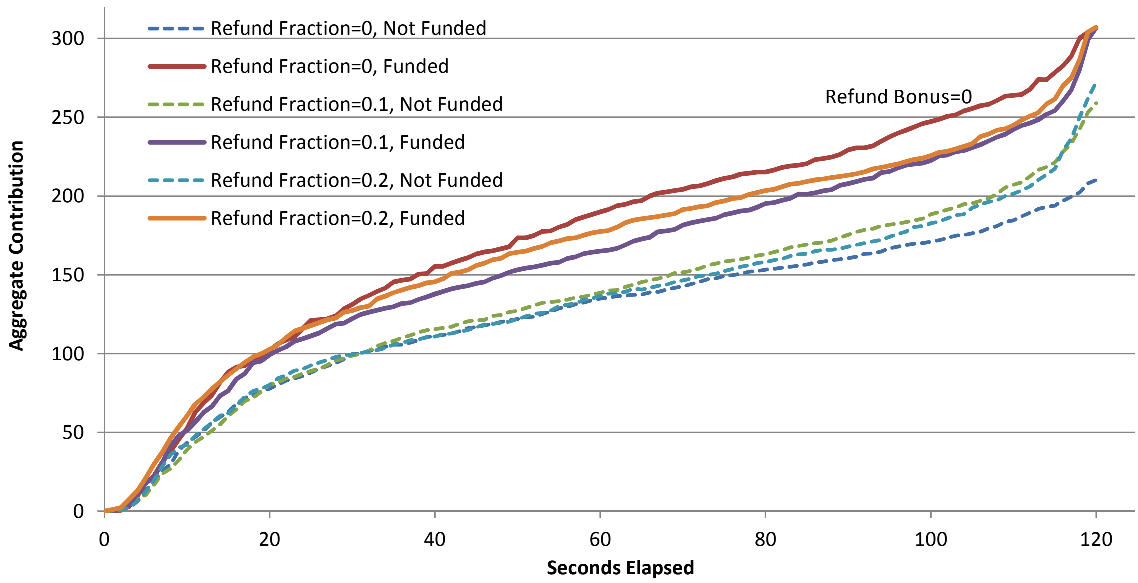

Figure 4: Cumulative Average Contributions (All Projects, With Alternative Project Available, by Funding Success)

of contributions in the final seconds. Therefore, this continuous time contribution mechanism still has a coordination challenge, since these final contributions are effectively made simultaneously. Prior to these very late contributions, the (red) top solid line for successful campaigns without a refund bonus lies above the cumulative contributions for the treatments with positive refund bonuses. This is particularly evident for Figure 3 in which no alternative projects are available to fund. With alternatives available (Figure 4), the gap is smaller and about 40 seconds are required before it emerges above the other treatments.

Table 6 reports a series of regressions to provide statistical support for Result 6. The dependent variable in these regressions is the cumulative, aggregate contributions made by all 10 group members through the first 60 seconds (Panel A) or through the first 90 seconds (Panel B) of the 120-second period. The omitted treatment condition is the case of no refund bonuses. The negative, and often statistically significant, coefficient estimates for the refund bonus treatment dummy variables indicate the lower cumulative contributions with refund bonus at these interim time points. Contributions are on average 10 to 15 percent lower with refund bonuses at these time points.[18] Note that this

[18] A similar set of regressions at the 30-second point also have negative coefficient estimates on the refund bonus dummies, but they are not statistically significant.

Table 6: Early Contributions for Successful Campaigns

	Panel A: Total Contributions through first 60 Seconds			
	No Alternative Projects		With Alternative Projects	
	(1)	(2)	(3)	(4)
Dummy (bonus=0.1)	-25.59		$-23.27^{\dagger}$	
	(22.83)		(12.42)	
Dummy (bonus=0.2)	$-32.63^{\dagger}$		-11.15	
	(17.07)		(12.93)	
Dummy (Any bonus> 0)		$-29.32^{\dagger}$		-17.04
		(17.33)		(11.09)
Period	-4.61**	-4.61**	-5.67**	-5.67**
	(1.42)	(1.41)	(0.99)	(1.01)
Constant	206.7**	206.7**	232.6**	232.9**
	(19.34)	(19.34)	(9.80)	(9.71)
Observations	100	100	170	170
R-squared	0.242	0.241	0.261	0.249

	Panel B: Total Contributions through first 90 Seconds			
	No Alternative Projects		With Alternative Projects	
	(5)	(6)	(7)	(8)
Dummy (bonus=0.1)	-30.82		-21.74*	
	(20.63)		(9.92)	
Dummy (bonus=0.2)	$-32.64^{\dagger}$		-13.54	
	(17.43)		(10.77)	
Dummy (Any bonus> 0)		-31.79*		$-17.56^{\dagger}$
		(15.40)		(9.63)
Period	-5.16**	-5.16**	-5.80**	-5.80**
	(1.25)	(1.24)	(0.95)	(0.96)
Constant	249.5**	249.5**	272.3**	272.5**
	(14.96)	(14.87)	(13.28)	(13.28)
Observations	100	100	170	170
R-squared	0.281	0.281	0.262	0.261

Notes: Only includes successfully funded projects. Random-effects regression, with standard errors clustered by sessions; robust standard errors are reported in parentheses. ** indicates coefficient is significantly different from zero at the .01 level; * at .05; † at 0.10 (all two-tailed tests).

comparison is being made for those fundraising campaigns that were ultimately successful.

Also notable in Table 6 is the strong and robust result that contributions are lower at these interim time points in later periods of the experiment. Early contributions decrease as contributors gain more experience, even for these successful campaigns, and the flurry of final-second contributions becomes even more pronounced in the later periods of the experiment.

6 Conclusion

The main objective of this work is to investigate whether refund bonuses have a potential in enhancing the present practice of crowdfunding for public goods. In theory refund bonuses can help mitigate the problem of equilibrium coordination by eliminating inefficient equilibria. We test the effects of refund bonuses in an experiment using a laboratory-based crowdfunding platform that features most main aspects of real-life crowdfunding platforms. Our main result is that refund bonuses help resolve the problem of equilibrium coordination when such coordination is exacerbated by confounding factors such as the presence of alternative projects. Furthermore, our findings also demonstrate that refund bonuses can lead to significant economic gains even after accounting for their costs. Overall, our findings provide further support for the case of attempting the modification of crowdfunding with refund bonuses in the field.

As mentioned earlier, here we explicitly do not study the question of sources for refund bonuses (but see footnote 5 for several examples of such sources). We recognize the importance of this question which, though, requires a fully fledged study of its own. Furthermore, such a study could also investigate the signaling role of refund bonuses. Specifically, refund bonuses and their size can credibly signal important aspects of the project, e.g., its value in the case of noisy private valuations, that can potentially help contributors better coordinate on efficient outcomes. The current study also considered only efficient projects, whose aggregate valuation exceeded costs. Future research can explore whether refund bonuses help (or hurt) in screening out inefficient projects that should not receive funding.

Our research shows the importance and effectiveness of incentives offered on the off-the-equilibrium path. Further research could also explore other designs of such incentives aimed at further efficiency gains. For instance, the time pattern of contributions documented in the final subsection suggests an alternative mechanism with time-varying refund bonuses that could more effectively promote contributions in practice. The current results indicate that contributions for successfully funded projects accumulate more quickly in the absence of refund bonuses. This pattern could be reversed by a new mechanism in which bonuses are only paid for contributions made during an early phase of the contribution window. This could raise initial phase contributions to a higher level; subsequently, later contributions during the period would not generate additional refund bonuses and the strategic complementarity of these contributions could push total contributions across the funding threshold.

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Appendix: Experiment Instructions

Introduction

This experiment is a study of group and individual decision making. The amount of money you earn depends partly on the decisions that you make and thus you should read the instructions carefully. The money you earn will be paid privately to you, in cash, at the end of the experiment. A research foundation has provided the funds for this study.

The experiment is divided into many decision "rounds." You will be paid based on your cumulative earnings across all rounds. Each decision you make is therefore important because it affects the amount of money you earn.

In each decision round you will be grouped with 9 other people, who are sitting in this room. You will make decisions privately, that is, without consulting other group members. Please do not attempt to communicate with other participants in the room during the experiment. If you have a question as we read through the instructions or any time during the experiment, raise your hand and an experimenter will come by to answer it.

Your earnings in the experiment are denominated in experimental dollars, which will be exchanged at a rate of 50 experimental dollars = 1 U.S. dollar at the end of the experiment. At the beginning of the experiment you are given 100 experimental dollars to start. You will add to this amount every round based on decisions you and others in your group make.

Overview

Every decision round you can allocate some experimental dollars to help fund one or two group projects that will benefit you and the other members of your group. If enough money is allocated to a project by all members of your group, the project is funded and you (and all other group members) will each receive an extra payment of some experimental dollars (as explained next). The amount of money, in total, that your group must allocate to fund any project is called the *Threshold*. This *Threshold* amount may be different in different rounds.

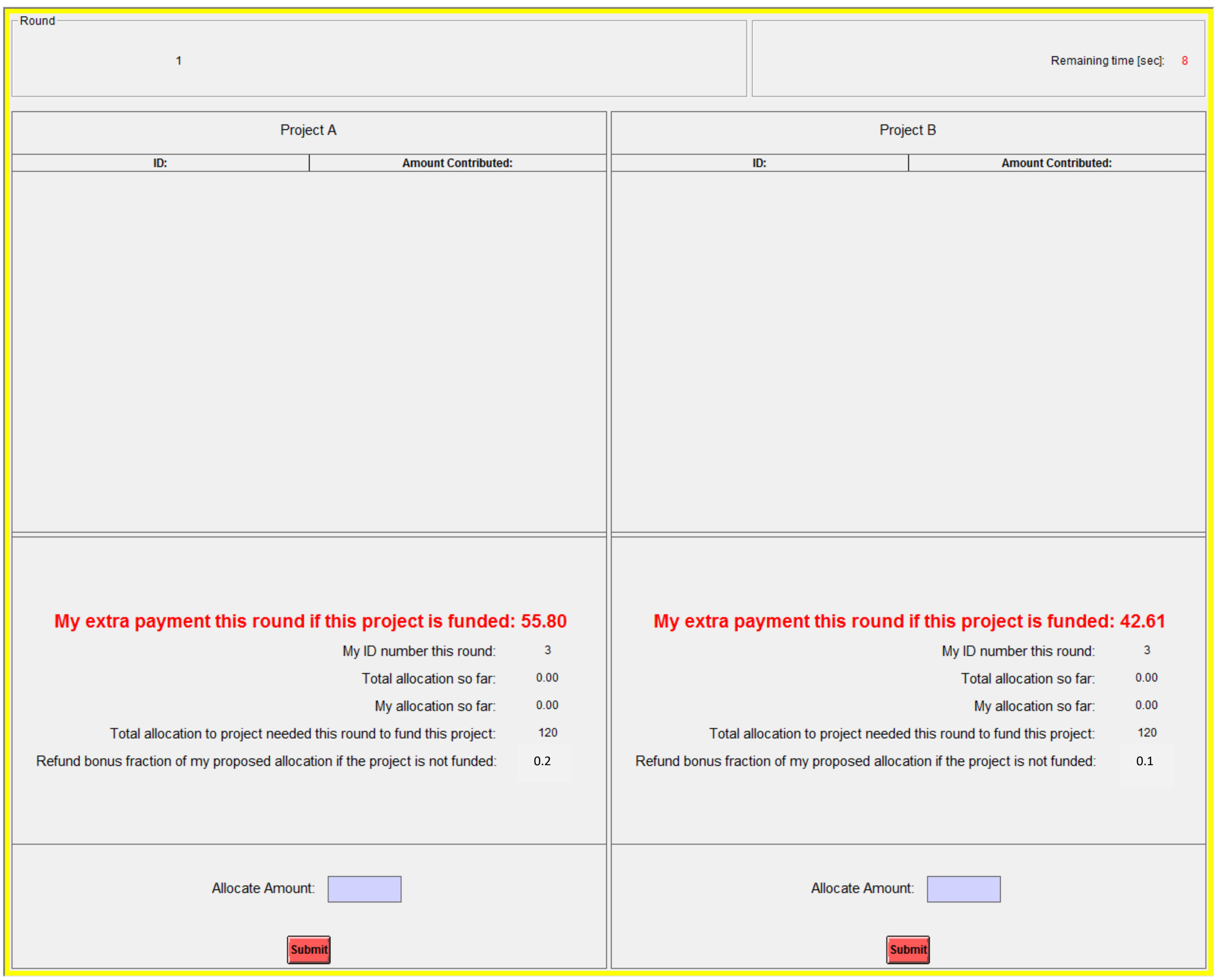
If insufficient money is allocated to a project by all members of your group, then those who tried to allocate money to a project will have their proposed allocation returned. Those individuals who tried to allocate money to a project may also receive a refund bonus. The amount of the refund bonus is a fraction of the proposed amount allocated to a group project.

Your value for the projects

You and everyone else in your group will receive an extra payment of experimental dollars if any project is funded. This amount is determined randomly for each person, for each project, in each round, drawn from the 8001 possible values 20, 20.01, 20.02, …, 99.98, 99.99, 100. Each of these values between 20 and 100 experimental dollars is equally likely to be chosen for each group member and project in each round. The likelihood that another group member draws any of these values is not affected by the value drawn by any other group member in that round, or in any previous or future rounds. Your values are your private information. You will know your own values, but you will not know the values drawn for any other group member, nor will others know your values.

Your allocation decision

The figure below presents an example screen for the case when two projects are both potentially funded. Everything on the left side of the screen refers to Project A and everything on the right side refers to Project B. When you want to make an allocation to help fund a project during a round you will indicate how much (in experimental dollars) you wish to allocate using the fields at the bottom of the screen. Any number between and including 0 up to the *Threshold* that the projects require is an acceptable allocation.



Proposed allocations can be made at any time while the two-minute countdown clock in a round (shown on the top right of the screen) is active. Your proposed allocation will immediately be displayed to all others in your group as soon as you click Submit, added to the list under either Project A or Project B along with your ID number. The ID numbers for everyone in the group will be randomly re-assigned each round. You can submit multiple allocations within the two-minute time period if you wish.

The lower part of the allocation screen shows the total allocation sum made by all group members, instantly updated following each new allocation. It also updates the total (summed) allocation made by you individually in the round so far. Your extra payment when either of the projects is funded is also shown in red, and note that these are different for Project A and Project B because they are randomly and independently drawn as explained above.

If the total amount of money that your group allocates to fund either project (or both projects) is equal to or greater than the *Threshold*, then you and each of the other group members all receive an extra payment for that project drawn between 20 and 100 as explained above. If the total amount allocated to a project strictly exceeds the *Threshold*, the extra amount above the *Threshold* will not be returned to anyone.

Computing the refund bonus

If the total amount of money that your group allocates to fund a project is less than the *Threshold*, then no group member receives an extra payment for that project. That group project is not funded. All people who allocated money to that project will have their proposed allocation amount returned. They may also receive a refund bonus that is some amount times their proposed allocation to the group project. For example, in the earlier example screen the indicated refund bonus fraction is 0.2 and the *Threshold* is 120. Suppose that you allocated X to the project, and in total all individuals in your group (including you) allocated Y to the project. When Y<120 (so that the threshold to fund the project and to receive the extra payment is not met), you will receive 0.2 times your proposed allocation X as an extra refund bonus.

Adding some completely hypothetical numbers to this example, suppose that you allocated X=20 and the other members of your group allocated 90 in total. Therefore Y=20+90=110<120. You would receive back the X=20 you tried to allocate to the project, and would also receive a refund bonus of (0.2)×20=4 experimental dollars. Notice that individuals who tried to allocate more to the project get a larger refund bonus. For example, a person who tried to allocate 40 in this hypothetical example would receive a refund bonus of (0.2)×40=8 experimental dollars.

End of the round

At the end of every decision round, as illustrated in the figure below your computer will display the total amount allocated to the group projects by members of your group. The results screen will also display whether the project was funded, the refund bonus you receive if the group project threshold is not met, and your earnings for the round. Your cumulative earnings will also be shown, and a table will also display the key results from every previous round.

Project A		Project B	
(1) My extra payment this round if this project is funded:	23.97	(1) My extra payment this round if this project is funded:	39.16
(2) Total allocation to project needed this round to fund this project:	120	(2) Total allocation to project needed this round to fund this project:	120
(3) Total allocation to this project:	122.00	(3) Total allocation to this project:	57.00
(4) My allocation to this project:	0.00	(4) My allocation to this project:	0.00
(5) Was this project funded this round:	Yes	(5) Was this project funded this round:	No
(6) Refund bonus fraction if this project is not funded:	0.2	(6) Refund bonus fraction if this project is not funded:	0.1
(7) My refund bonus if project was not funded:		(7) My refund bonus if project was not funded:	
(8) My earnings from this project this round:	23.97	(8) My earnings from this project this round:	0.00

Note: If project is funded, earnings(8) = my extra payment(1) - my allocation(4)

If project is not funded, earnings(8) = my allocation(4) x refund fraction(6) = refund bonus(7)

My earnings from both projects this round: 23.97

My cumulative earnings: 269.48

	Project A					Project B				
Period	**My Pay if funded (A)**	**Total Alloc. (A)**	**My Alloc. (A)**	**Funded? (A)**	**My Earnings (A)**	**My Pay if funded (B)**	**Total Alloc. (B)**	**My Alloc. (B)**	**Funded? (B)**	**My Earnings (B)**
1	55.80	122.17	0.00	Yes	55.80	31.06	98.80	11.55	No	3.47
2	84.74	137.55	6.00	Yes	84.74	81.37	119.42	5.00	No	1.50
3	23.97	122.00	0.00	Yes	23.97	39.16	57.00	0.00	No	0.00

<u>What might change in different rounds?</u>

The experimenter will make a verbal announcement when any payoff rules change during the experiment.

As already noted, the *Threshold* may be different across rounds or for different projects.

In some rounds the refund bonus fraction (0.2 in the earlier example) may be a different number, or may be 0 (giving NO REFUND BONUS) for one or both projects.

In some rounds there may be only one project to fund.

Summary

1. You will make allocation decisions in many decision rounds.
2. Group members' ID labels are randomly-determined each round, and therefore typically change from round to round. Each group always contains the same 10 members.
3. Group members make allocations to one or two group projects at any time (and as many times as they want) during the two minutes in a round.
4. If the total amount allocated in your group is ≥ *Threshold* for any project, you receive an extra payment. The other members of your group also receive extra payments.
5. The extra payments are drawn independently from the range between 20 and 100 experimental dollars, and each amount in this range is equally likely.
6. You should pay close attention to the "Total allocation so far" made to each project by the group. Any allocations above the *Threshold* needed to fund the project are wasted (never returned) and can only reduce your earnings.
7. If the total amount allocated to a project is < *Threshold*, everyone's proposed allocation to that project is returned. Everyone also receives a refund bonus that is equal to some fraction times his or her proposed allocation. (This fraction could be 0, providing NO refund bonus in some rounds for some projects.)
8. The refund fraction can be different for different projects.