Signaling Quality: How Refund Bonuses Can Overcome Information Asymmetries in Crowdfunding*

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Abstract

Crowdfunding can suffer from information asymmetry, leaving some investors disappointed with low-quality projects while other high-quality projects remain unfunded. We show that refund bonuses, which provide investors a payment if a fundraising campaign is unsuccessful, can signal project quality and help overcome the market failure in crowdfunding. Because strong projects have a lower risk of bonus payout, entrepreneurs with strong projects are more likely to offer bonuses. This signals high quality to investors, and due to their updated beliefs this drives investment toward such projects. An experiment provides supporting empirical evidence for the benefits of this signaling solution to the problems of information asymmetry in crowdfunding.

Keywords: Crowdfunding; threshold implementation; adverse selection; experiments. **JEL Codes**: C72; C90; D82; G23

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1 Introduction

Crowdfunding is a two-sided, many-to-many market, where entrepreneurs raise capital for their projects from a crowd of investors. In this market, the threshold implementation ("all-or-nothing") mechanism is typically employed, where a fundraising campaign is deemed successful only if the amount of capital raised reaches a pre-specified threshold. In the event the threshold is not reached, the provisionary investments are returned to their investors.

The threshold implementation mechanism has at least two problems. First, it is fraught with multiple equilibria and, thus, coordination problems. In particular, the zero investment outcome is an equilibrium even for socially valuable projects. The refund bonus extension proposed by Tabarrok (1998) and Zubrickas (2014) can eliminate equilibria in which socially valuable projects are not funded. Thus, refund bonuses resolve the coordination problem of the threshold implementation mechanism, which is experimentally demonstrated by Cason and Zubrickas (2017, 2019) and Cason et al. (2021).

The second problem with the threshold implementation mechanism is that it is subject to information asymmetry. Entrepreneurs know more about the quality of their projects than do investors. Overly optimistic or deceptive entrepreneurs may over-promise performance or underestimate price. Belavina et al. (2020) refer to this problem as performance opacity and they give examples from crowdfunding such as the Pebble watch, Zune drone and Coolest Cooler where the product, if delivered at all, either underperformed or was overpriced relative to what was promised. Belavina et al. (2020) propose several modifications to threshold implementation which can incentivize entrepreneurs to reveal more about true product performance.[1]

In this paper we modify threshold implementation with refund bonuses and show that it solves both problems. In particular, as we have shown before, refund bonuses increase the probability that socially valuable projects are funded. Moreover, new to this paper,

[1] Early stopping, for example, closes the campaign once the threshold is met. Early stopping, therefore, shifts an entrepreneur's return away from the pre-delivery stage where performance is uncertain and towards the post-delivery stage where performance can be measured thus incentivizing entrepreneurs who expect a robust post-delivery market.

we show that refund bonuses can also perform the transfer of information function and, thus, without intermediation, help to solve the problem of asymmetric information.

Under a refund bonus extension, entrepreneurs offer investors refund bonuses in the event of unsuccessful fundraising. If the investment threshold is not reached, investors receive a refund of their investment and also a refund bonus, such as 5% of their intended investment. Given an efficient project with no uncertainty, offering refund bonuses ensures successful fundraising because investing is a dominant strategy for investors (eliminating the need for actual bonus payments). With variable project quality and asymmetric information, we argue that the role of refund bonuses can extend beyond the resolution of coordination failures. Our analysis shows that entrepreneurs with lower-quality projects are less likely to offer refund bonuses because their risk of paying refund bonuses is higher than for entrepreneurs with high-quality projects. Therefore, the offer of refund bonuses serves as a credible signal of project quality, and investors act on this signal by investing more often in projects that offer refund bonuses.

Crowdfunding is an example of the larger category of decentralized finance. The defining feature of decentralized financial markets is their operation without intermediaries. Most notably, banks are an intermediary that helps to solve asymmetric information problems (Diamond 1984). The question of decentralized finance is thus, to what extent can other institutions substitute for banks? The principal functions of financial intermediation such as brokerage, exchange, depository, fiduciary, or securitization can now be facilitated by more cost-efficient technological solutions, including blockchains, but what about the transfer of information explanation of financial intermediation (Leland and Pyle, 1977; Diamond, 1984). Under asymmetric information decentralized financial markets may unravel and fail (Akerlof, 1970). A FinTech report by Statista (2021) notes, in particular, that despite very promising growth projections a major obstacle to the development of alternative financing is fraudulent activities (as the failure of FTX illustrates) or, put differently, asymmetric information about investment opportunities (also see Cumming et al., 2021). In this paper, we show that by improving information transfer refund bonuses can alleviate the problem of asymmetric information in the decentralized capital market of crowdinvesting.

In our model, entrepreneurs must raise a minimum amount of capital from investors for a project. Entrepreneurs know the quality of their project, but investors only receive noisy signals about quality. We assume signals are more likely to indicate a good project is good (or a bad project is bad), but signal noise is high enough so that there is market failure for traditional threshold implementation and, thus, good investment opportunities are foregone. We demonstrate that refund bonuses can resolve this market failure. Specifically, entrepreneurs with good projects always offer refund bonuses, while those with bad projects offer them randomly. This reduces noise for projects with refund bonuses, helping investors distinguish good from bad projects. The result is a 'hybrid' perfect Bayesian equilibrium with positive investment. In short, refund bonuses better harness the 'wisdom of the crowd' to turn an inefficient capital market for crowdinvesting into a functional one.

Based on our theoretical analysis, we formulate two hypotheses: (i) refund bonuses increase the rate of fundraising success, and (ii) entrepreneurs with bad quality projects are less likely to offer refund bonuses. The experimental results provide clear evidence for the implications of the model. Good quality projects are funded much more frequently when entrepreneurs can choose to offer bonuses. Entrepreneurs offer bonuses over twice as often for good than for bad projects, and investors respond by investing in projects offered with refund bonuses at more than triple the rate of projects without bonuses. The combination of entrepreneur and investor behavior allows endogenous refund bonuses to transfer information and leads to more successful fundraising for higher quality projects.

Related Literature. Our paper is most closely related to Belavina et al. (2020) and Strausz (2017) . Strausz (2017) argues that crowdfunding has an important advantage over intermediated finance–namely, the entrepreneur contracts with consumers directly and thus learns more about consumer demand before production–but crowdfunding suffers from moral hazard and asymmetric information problems, as previously discussed.[2]

[2]In Strausz (2017) and in reward-based crowdfunding more generally, investors have individual and deterministic valuations for the entrepreneur's project (typically about the development of a new product) but investors do not observe project costs. In our paper, investors' ex post valuations are common but there is ex ante uncertainty about them.

Belavina et al. (2020) and Strausz (2017) both discuss mechanisms to overcome some of these problems, most notably deferring entrepreneurial rewards to the post-delivery period. Our paper is largely similar in goal, but provides an alternative mechanism, refund bonuses. In our paper, we are explicitly interested in the outcome of market failure due to adverse selection and use this outcome as a benchmark in presenting our solution. Brown and Davies (2020) and Cong and Xiao (2023) are two recent theoretical studies of crowdinvesting that have a modelling framework close to ours. Unlike in our paper, though, in their studies no adverse selection exists on the entrepreneurial side of the market. See also Cumming et al. (2021) for a comprehensive review of the problem of asymmetric information and fraud in the literature on crowdfunding.

We also make a contribution to the finance literature by introducing a novel signaling mechanism. Two existing signaling mechanisms have found applications in crowdfunding: 1) signaling by investment in own equity (Leland and Pyle, 1977) and 2) signaling by collateral (Stiglitz and Weiss, 1981; Bester 1985). In the context of crowdfunding, under the first mechanism the threshold for capital to be raised by the entrepreneur can serve the signaling function, and under the second mechanism collateral takes the form of social (or alliance) capital. See Ahlers et al. (2015) for an extensive discussion of signaling in equity crowdfunding and for an empirical examination of the effectiveness of signals. While Ahlers et al. (2015) find some empirical support in favor of the first mechanism, they also acknowledge the problem of the credibility of signals in crowdfunding, which actually resemble "cheap talk." For instance, a lower threshold for capital does not necessarily imply that the entrepreneur commits more of their own funds to the project.

Our proposed signaling mechanism is credible for it bears a risk of costly refund bonus payout and this cost varies across project types. More generally, Spence (1977) showed that a warranty can be a signal of quality because the cost of a warranty is lower for firms with better quality products. Refund bonuses operate similarly because they are cheaper for entrepreneurs with better quality projects. As consumers buy the product with a warranty, so do investors invest in the project with refund bonuses because they expect the warranty will not be necessary and the refund bonus not paid.

Our paper is also related to the experimental literature on signaling and strategic information transmission. Much of this literature concerns pure cheap talk (i.e., non-payoff relevant communication) and often finds overcommunication of private information (see Blume et al., 2020 for a survey). Senders have a tendency to reveal too much information and receivers are frequently too trusting (Cai and Wang, 2006; Battaglini and Makarov, 2014). In environments with costly signaling, as in the present paper, results are often consistent with separating equilibria although signaling tends to be incomplete (Kübler et al., 2008; de Haan et al., 2011; Jeitschko and Normann, 2012). Our experimental results also indicate incomplete signaling, but this is qualitatively consistent with the hybrid perfect Bayesian equilibrium that is based on mixed strategies.

The remainder of the paper is organized as follows. Section 2 describes the model and the benchmark of market failure. In Section 3, we introduce the refund bonus extension, obtain our main theoretical result, and formulate empirical hypotheses. Section 4 presents a two-investor example of the model, which is the basis for the experiment. In Sections 5 and 6, we present our experimental design and results. The last section concludes the paper. All omitted proofs are in the appendix.

2 Benchmark model

An entrepreneur needs to raise capital $C > 1$ for a business project. There are N potential investors, each endowed with a non-divisible unit of capital. In this section, we consider the entrepreneur using the threshold implementation mechanism for fundraising. If the number of investors $n \leq N$ investing their capital into the project is at least C, then the fundraising campaign is successful and the investment return is θ. If fewer than C investors support the campaign, then it is not successful, the investments are refunded and the investment return is zero. Investors can also invest in an outside option with a safe return of $\overline{\theta} > 0$. An investor's utility from investment is determined by its expected return.

The entrepreneur and, respectively, his project can be one of two types, bad (B) or good (G). When supported by $n \geq C$ investors, the project of type $i \in \{B, G\}$ generates a gross profit of $\pi_i n$ with each of n investors obtaining investment return $\theta = \theta_i$ and the entrepreneur retaining the residual of $(\pi_i - \theta_i)n$. We normalize the entrepreneur's reservation profit to 0 and assume that a good project is more profitable; i.e., $\pi_G - \theta_G \geq \pi_B - \theta_B \geq 0$. We also assume that only good projects yield investment returns above the safe return or $\theta_B \leq \pi_B < \overline{\theta} < \theta_G \leq \pi_G$.

The type of the project is the entrepreneur's private information, about which an investor privately receives noisy signal x. Signal x takes one of two values $\{\theta_B, \theta_G\}$ so that if the project is of type $i \in \{B, G\}$, then αN investors receive signal $x = \theta_i$ and the remaining $(1 - \alpha)N$ receive $x = \theta_{-i}$, where $\alpha \in (0.5, 1]$. Hence, a signal is correct with probability $\Pr(x = \theta_i \,|\, \theta_i) = \alpha$ and false with probability $\Pr(x = \theta_{-i} \,|\, \theta_i) = 1 - \alpha$, which is common knowledge. We further assume (i) $(1 - \alpha)N \geq C$, that is, due to the signal noise, fundraising for a bad project can potentially attract enough support from investors with false signals; and (ii) $\alpha\theta_G + (1 - \alpha)\theta_B < \overline{\theta}$, i.e. the level of signal noise is sufficiently high so that the expected project investment return is below the return of the outside option.

After receiving private signals about the project, the investors simultaneously and independently of each other decide whether to invest their capital in the project or in the outside option. We are interested in the equilibrium profiles of decisions, where each investor's decision is optimal given the decisions of other investors. Restricting attention to symmetric equilibria where the investors holding the same information make identical decisions, we let $g(x) \in [0, 1]$ denote the probability of investing in the project after receiving signal x. The probability of investing in the outside option is then equal to $1 - g(x)$. We can prove the following auxiliary result about equilibrium investment decisions $\{g(\theta_G), g(\theta_B)\}$.

Lemma 1. *In equilibrium,* $g(\theta_G) < 1$ *and* $g(\theta_B) = 0$*.*

Proof. The assumptions of $\alpha\theta_G + (1 - \alpha)\theta_B < \overline{\theta}$ and $(1 - \alpha)N \geq C$ imply that pure strategy $g(\theta_G) = 1$ is not equilibrium because of successful fundraising for a bad project. Suppose that $g(\theta_G) \in (0, 1)$ in equilibrium. As the randomization implies indifference, for an investor with a good signal the expected return from project investment is equal to the return from the outside option. This in turn implies that an investor with bad signal $x = \theta_B$ will only invest in the outside option because of a lower expected return from project investment given a bad signal. Finally, if $g(\theta_G) = 0$ is equilibrium, then $g(\theta_B) = 0$ must be as well. $\square$

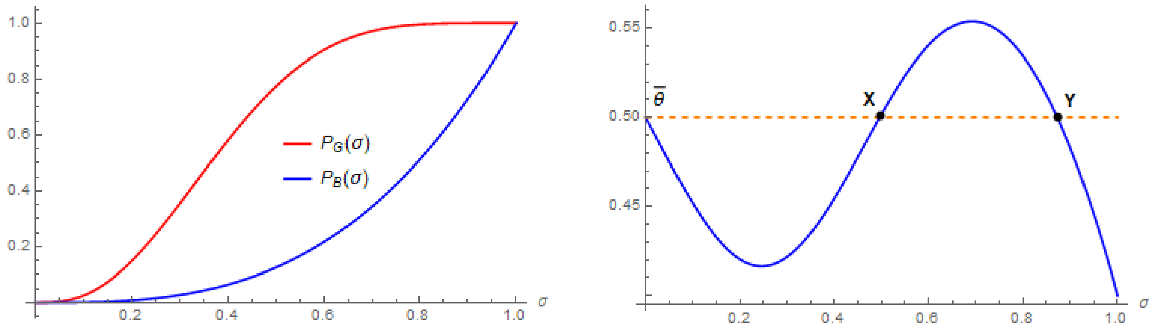
An implication of Lemma 1 is that the investment game is played only by investors with good signals, whose strategy we denote by $g(\theta_G) = \sigma$. The probability of successful fundraising for a good project and for a bad project is, respectively, equal to $P_G(\sigma) = 1 - F(C-1; \alpha N, \sigma)$ and $P_B(\sigma) = 1 - F(C-1; (1-\alpha)N, \sigma)$, where F is the cumulative distribution function of the binomial distribution. The expected payoff of an investor with a good signal from strategy σ is given by

$$U(\sigma) = \sigma \left[\alpha\, P_G(\sigma)\, \theta_G + (1-\alpha)\, P_B(\sigma)\, \theta_B\right] + (1-\sigma)\, \overline{\theta}. \tag{1}$$

As a consequence of the coordination problem created by the threshold implementation mechanism, there is one pure-strategy equilibrium where all investors with good signals invest in the outside option only, $\sigma = 0$. This is an equilibrium because an individual investor cannot alone affect the outcome of fundraising due to implementation threshold $C > 1$. Depending on the noise level α, there can be mixed-strategy equilibria. At low levels of noisiness (i.e., for large α) there are fewer investors with false signals and, hence, the probability of successful fundraising for a bad project diminishes more quickly than the probability of successful fundraising for a good project as σ decreases (see Figure 1a). Hence, for $\sigma < 1$ we can have an expected payoff higher than the payoff from the outside option as illustrated in Figure 1b. The mixed-strategy equilibria are then determined by the solutions to $U(\sigma) = \overline{\theta}$ so that the expected payoff from each investment option is the same. In Figure 1b, the mixed-strategy equilibria are given by the intersection points, X and Y, of the expected payoff curve with the horizontal line representing the payoff from the outside option.

For higher levels of noisiness there may be no other equilibria than the pure strategy

Figure 1: Crowdfunding outcomes at low levels of noise

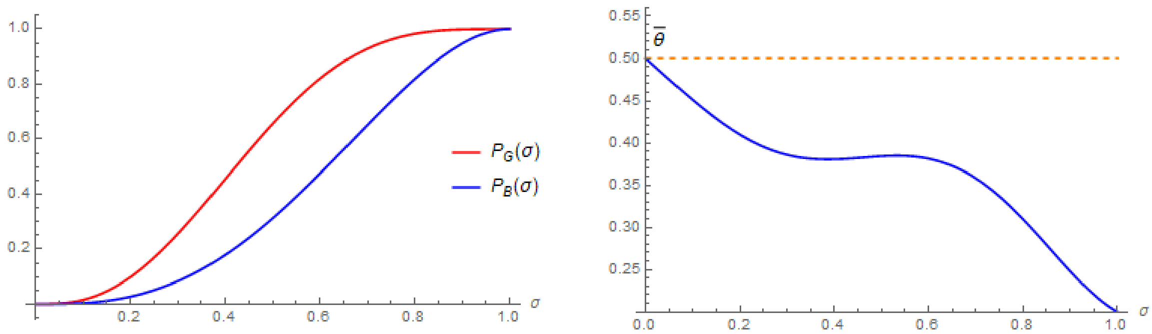


(a) Success probability (b) Investor expected payoff

Note: The parameter values used are $N = 10$, $C = 3$, $\alpha = 0.7$, $\theta_G = 1$, $\theta_B = -1$, $\overline{\theta} = 0.5$.

equilibrium of $\sigma = 0$. In Figure 2 we plot the success rates of fundraising and investors' expected payoff for the same specification as in Figure 1 but with $\alpha = 0.6$. As panel (b) shows, with more noise investors' expected payoff never rises above the payoff from the outside option because the success rate for bad projects is sufficiently high. Despite economic gains from good projects ($\theta_G > \overline{\theta}$), asymmetric information about project quality can result in market failure in decentralized financial markets.

Figure 2: Crowdfunding outcomes at high levels of noise



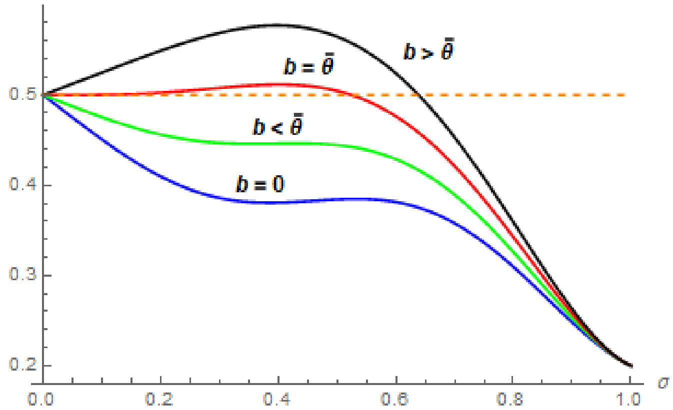
(a) Success probability (b) Investor payoff

Note: The parameter values used are $N = 10$, $C = 3$, $\alpha = 0.6$, $\theta_G = 1$, $\theta_B = -1$, $\overline{\theta} = 0.5$.

Henceforth we will focus on the case of market failure, which for this context we define as

Definition (Market failure). *There is no investment strategy $\sigma > 0$ such that $U(\sigma) \geq \overline{\theta}$ for any investment return $\theta_i \leq \pi_i$, $i \in \{B, G\}$.*

Figure 3: Expected payoff and refund bonus



Note: Refund bonus b values are $\{0.5\overline{\theta},\, \overline{\theta},\, 1.5\overline{\theta}\}$; other parameter values as in Figure 2.

Put differently, we impose that the expected return from project investment does not exceed the return from the outside option even when investment return θ_i is at its upper bound π_i for each project type $i \in \{B, G\}$.

3 Refund bonuses

We next introduce a refinement to the threshold implementation mechanism aimed at mediating the problem of asymmetric information and, subsequently, averting market failure.[3] Before investors make their investment decisions, the entrepreneur can commit to pay refund bonus b to the participating investors in the event of unsuccessful fundraising. In particular, if $n < C$ then the investors receive not only their investments back but also refund bonuses. We restrict the attention to refund bonuses of fixed size b as, e.g., imposed by the fundraising platform. Furthermore, we require the size of refund bonuses be less than the investment return from a good project, $b < \theta_G$, to exclude investors' behavior solely aimed at obtaining refund bonuses, which cannot be equilibrium.

The result of Lemma 1 extends to the case with refund bonuses as the outside-option investment remains optimal for investors with bad signals in equilibrium. The expected

[3]See Tabarrok (1998), Zubrickas (2014), and Lattimer and Zubrickas (2023) for the equilibrium coordination function of refund bonuses, and Cason and Zubrickas (2017, 2019) and Cason et al. (2021) for empirical evidence on the efficacy of this function in a public goods crowdfunding context without entrepreneurs or equilibrium market failure.

payoff from mixed strategy σ for an investor with a good signal becomes

$$U^b(\sigma) = \sigma \left\{\alpha \left[P_G(\sigma)\, \theta_G + (1 - P_G(\sigma))b\right] + (1 - \alpha) \left[P_B(\sigma)\, \theta_B + (1 - P_B(\sigma))b\right]\right\} + (1 - \sigma)\, \overline{\theta}.$$

Graphically, as shown in Figure 3, refund bonuses shift the expected payoff schedule of investors with good signals upwards. For bonuses above the outside-option return ($b \geq \overline{\theta}$) there is a unique mixed-strategy equilibrium candidate. (With refund bonuses $b > \overline{\theta}$, $\sigma = 0$ cannot be optimal.)

With refund bonuses the entrepreneur's expected payoff is given for a project of good and bad type, respectively, by

$$\Pi_G(\sigma, b) = (\pi_G - \theta_G) \sum_{n=C}^{\alpha N} n\, p(n, \alpha N, \sigma) - b \sum_{n=1}^{C-1} n\, p(n, \alpha N, \sigma) \tag{2}$$

$$\Pi_B(\sigma, b) = (\pi_B - \theta_B) \sum_{n=C}^{(1-\alpha)N} n\, p(n, (1 - \alpha)N, \sigma) - b \sum_{n=1}^{C-1} n\, p(n, (1 - \alpha)N, \sigma), \tag{3}$$

where $p(.)$ is the probability mass function of the binomial distribution. The first term of each expression indicates the expected profit when fundraising is successful and the second term is the expected cost of refund bonus payments when fundraising is unsuccessful. Note that refund bonus payments are more likely and more expensive for bad projects as $1 - P_B(\sigma) > 1 - P_G(\sigma)$ and $n\, p(n, \alpha N, \sigma) > n\, p(n, (1 - \alpha)N, \sigma)$ for $n < C$. Hence, because of the variation in costs across project types, refund bonuses can perform a signaling function for good entrepreneurs to separate from bad entrepreneurs, which is behind our main result presented below.

The proposed threshold implementation mechanism with refund bonuses creates a two-stage game between the entrepreneur and the investors with imperfect information. In the first stage the entrepreneur chooses whether to offer refund bonuses, and in the second stage the investors choose whether to invest in the entrepreneur's project. We will consider the perfect Bayesian equilibrium of this game, where the investors form beliefs about the type of the project upon observing the entrepreneur's first-stage decision. Based on the entrepreneur's play, we can distinguish three possible equilibrium candidates: (i) separating equilibrium – only one type of the entrepreneur offers refund bonuses, (ii) pooling equilibrium – the entrepreneur of each type type offers refund bonuses, and (iii) hybrid equilibrium – one type offers refund bonuses whereas the other type offers them at random. Next, we prove that

Theorem 1. *Let the threshold implementation mechanism result in market failure. With the refund bonus extension, there exists a hybrid Perfect Bayesian equilibrium where investors invest with a positive probability. There is no other equilibrium where investors invest with a positive probability.*

Proof. See the appendix. □

The theorem demonstrates that the extension of the threshold implementation mechanism with refund bonuses can help resolve the problem of market failure in decentralized financial markets. Refund bonuses can serve as a signaling device for good entrepreneurs to distinguish themselves from bad entrepreneurs who are less likely to offer refund bonuses.[4] Even though the separation of types is only partial, the offer of refund bonuses reinforces investors' own private signals, which leads to positive investment levels in equilibrium. We do not observe a full separation of types because if refund bonuses were offered only by good entrepreneurs, then all investors would choose to invest in projects with refund bonuses, prompting bad entrepreneurs to offer refund bonuses as well. Lastly, a pooling equilibrium with positive investment levels is impossible because some individual rationality condition is bound to be violated.

Based on the theoretical predictions of the model, we formulate the following hypotheses, which we test in the experiment.

Hypothesis 1. *The offer of refund bonuses increases the rate of fundraising success.*

Hypothesis 2. *Entrepreneurs with bad projects are less likely to offer refund bonuses.*

[4]Importantly, the entrepreneurs' *choice* to offer refund bonuses, and not the mere existence of the bonus, is key for information transmission from entrepreneurs to investors. The experimental design tests this by employing a control treatment with random bonuses to contrast with chosen, endogenous bonuses.

4 Two-investor example

This section presents a two-investor example of the model, which is the basis of our experimental design. This example presents an experimentally tractable environment that captures the main assumptions and predictions of the model. There are $N = 2$ potential investors and the support of both investors is needed for the entrepreneur's fundraising campaign to be successful (i.e., $C = 2$). If the project is good, its return to an investor is $\theta_G = 3$ and if it is bad, its return is $\theta_B = -1$, i.e., the investment is lost. The return of investment in an outside option is $\overline{\theta} = 1.5$. The entrepreneur's net total profit from successful crowdfunding is given by $\widehat{\Pi} = 2$ and is independent of the project's type. The entrepreneur is also endowed with $e = 1.5$ that can be used for incentive schemes.

The entrepreneur knows the type of the project, but the investors are uninformed about it unless they receive a private signal. If the project is bad, then each investor independently from one another can receive a signal with probability $s_B = 0.25$, which informs the investor that the project is bad with certainty. If the project is good, then the investors receive no signal but can expect that the project is bad or good with equal probability. To ensure the conditional probability $\Pr(\theta = \theta_G \,|\, \text{No signal}) = \Pr(\theta = \theta_B \,|\, \text{No signal}) = 0.5$, we require the prior probability η that the project is good satisfy the Bayes' rule condition $\eta/(\eta + (1-\eta)(1-s_B)) = 0.5$.

In the benchmark case of no refund bonuses, the investors make their investment decisions after potentially receiving private signals. An informed investor knows the project is bad with certainty and invests in the outside option. And so does an uninformed investor because the expected return from the project is at most $0.5\theta_G + 0.5(s_B \times 0 + (1-s_B)\theta_B) = 1.125$ which is less than the certain return of $\overline{\theta} = 1.5$. Hence, because of bad projects and asymmetric information we have a market failure in the decentralized finance market despite the high return of the good project $\theta_G = 3 > \overline{\theta} = 1.5$.

Suppose that before investors' make their investment decisions the entrepreneur can promise to pay investors refund bonus $b = 1$ in the event of unsuccessful fundraising. We note that by setting $b < \overline{\theta} = 1.5$ we retain the zero investment equilibrium and, subsequently, the investment coordination problem. Following the proof of Theorem 1, we can show that the resultant two-stage game does not have separating equilibrium where only the good entrepreneur offers refund bonuses and uninformed investors invest in the project with refund bonuses. The bad entrepreneur can deviate by offering refund bonuses and make an expected positive profit of $(1 - s_B)^2\widehat{\Pi} - 2s_B(1 - s_B)b = 0.75$. Nor can there be pooling equilibrium with non-zero investment where both good and bad entrepreneurs offer refund bonuses. A high chance of lost investment ensures that the expected investment return for uninformed investors cannot exceed the return of the outside option.[5]

Hence, as in Theorem 1, the game has only one perfect Bayesian equilibrium with non-zero project investment levels, which takes a hybrid form. The good entrepreneur always offers refund bonuses whereas the bad entrepreneur offers bonuses with probability γ, and the uninformed investors invest in the project that offers refund bonuses with probability σ and they do not invest in the project that does not offer refund bonuses. Probabilities γ and σ are found from two conditions on the equilibrium play of the bad entrepreneur and uninformed investors. Randomization implies that the bad entrepreneur's expected profit when offering refund bonuses is equal to the reservation profit of 0,

$$(1 - s_B)^2[\sigma^2\,\widehat{\Pi} - 2\sigma(1 - \sigma)b] - 2s_B(1 - s_B)\sigma b = 0,$$

from which we find $\sigma = 2/3 = 0.67$.

An uninformed investor's expected payoff from investing in the project that offers refund bonuses is given by

$$U_{rb} = \mu(\gamma)[\sigma\theta_G + (1 - \sigma)b] + (1 - \mu(\gamma))[(1 - s_B)(\sigma\theta_B + (1 - \sigma)b) + s_B b],$$

where $\mu(\gamma) = \eta/(\eta + (1 - \eta)(1 - s_B)\gamma)$ is the investor's posterior belief that the project with refund bonuses is good. Randomization implies that $U_{rb} = \overline{\theta}$, from which we find $\gamma = 5/9 = 0.55$.

[5] There can be pooling equilibria where both types of entrepreneurs offer or do not offer refund bonuses but investors do not invest.

5 Experimental Design

Subjects were divided into entrepreneur and investor roles. Investors make two binary decisions each round – whether to invest a unit of capital ($1.00 in the experiment) into two projects offered by two entrepreneurs. They could invest in zero, one, or two projects. The use of multiple projects is intended to capture a key aspect of crowdinvesting in practice, where potential investors can choose among multiple projects. Multiple projects also create a more challenging coordination problem for investors when choosing which projects to support (Corazzini et al., 2015; Cason and Zubrickas, 2019). But since each project is offered by a different entrepreneur this does not change the equilibrium. Two investors make their investment decisions for the two projects simultaneously; that is, without any knowledge of the other's investments. Projects required both investors to invest in order to be developed (i.e., to be successfully crowdfunded).

As described earlier, projects could be either good or bad quality. If both investors invest in a good quality project, they earned a $3 return on their $1 investment. If both investors invest in a bad quality project, they each lose their $1 investment. A unit of capital not invested in a project earned a safe outside option return of $1.50. Thus, in each round each investor could earn a risk-free return of $3 by not investing in either project, or up to $6 by investing in two good quality projects along with the other investor.

When a project was bad quality, investors received an independent signal that it was definitely bad quality with a one-quarter (25%) likelihood. The instructions describe this as a "negative report." For bad quality projects they received no report the other three-quarters of the time, and they never received any kind of report for good quality projects. The underlying prior probability of a good quality project was fixed at 0.42857, so the instructions (see Appendix A) could accurately inform investors that "If you do not receive a negative report for an invention, then the invention is equally likely to be good or bad quality" by a simple application of Bayes rule.

As just indicated, projects were framed as "inventions" in the experiment. Earnings for investors when they were the only investor in a project depended on whether that project offered a refund bonus. Each session began with rounds in which no refund bonuses were possible. In this case, sole investors simply received back their \$1 investment amount and the project was not developed. The second part of each session included a longer sequence of rounds in which refund bonuses were possible. A project offering a refund bonus, which was prominently displayed on the investors' decision screens, paid a \$1 bonus to a sole investor. They also received back their \$1 investment, leading to a \$2 total payoff from the failed investment attempt.

The treatments differed in how the refund bonus offer was determined. In the **Endogenous Bonus (EB)** treatment, entrepreneurs chose whether or not to offer a refund bonus after they learned the quality of their project.[6] Thus, they could offer a refund bonus to provide a signal of their project's quality. By contrast, in the **Random Bonus (RB)** treatment, each project was randomly assigned a refund bonus with equal likelihood, independent of the project's quality. This control treatment eliminated the potential signaling role for the refund bonus, while still presenting investors with opportunities to receive refund bonuses. This is an important part of the experimental design, since refund bonuses raise expected returns. A control treatment without any bonus offers could overstate the bonuses' impact on investment rates. Whenever the \$1 refund bonus was paid, it was paid by the entrepreneur out of their per-round endowment of \$1.50 (to avoid negative earnings).[7]

All sessions included 60 total rounds of stationary repetition, beginning with 20 initial rounds without refund bonuses followed by 40 rounds of either the EB or RB treatment (varied between sessions). Long sequences of repetition are common in the experimental literature on signaling to allow for learning (e.g., Cooper et al., 1997). Subjects changed entrepreneur and investor roles, spending exactly half of the rounds in each role. Role switching, which is common in signaling experiments (Jeitschko and Normann, 2012), occurred in 5-round blocks; i.e., subjects were always in one role for five consecutive rounds, before potentially switching to the other role for the next five rounds. Groups always consisted of two entrepreneurs and two investors. To limit repeated game incentives,

[6] Entrepreneurs were framed as "inventors" in the instructions.

[7] In the Endogenous Bonus treatment the realized frequency of bonus offers was 0.488 (937 out of 1920 projects). This is not significantly different from the 0.5 rate imposed exogenously in the Random Bonus treatment (Wilcoxon signed-rank test p-value $= 0.281$, $n = 8$ independent sessions)

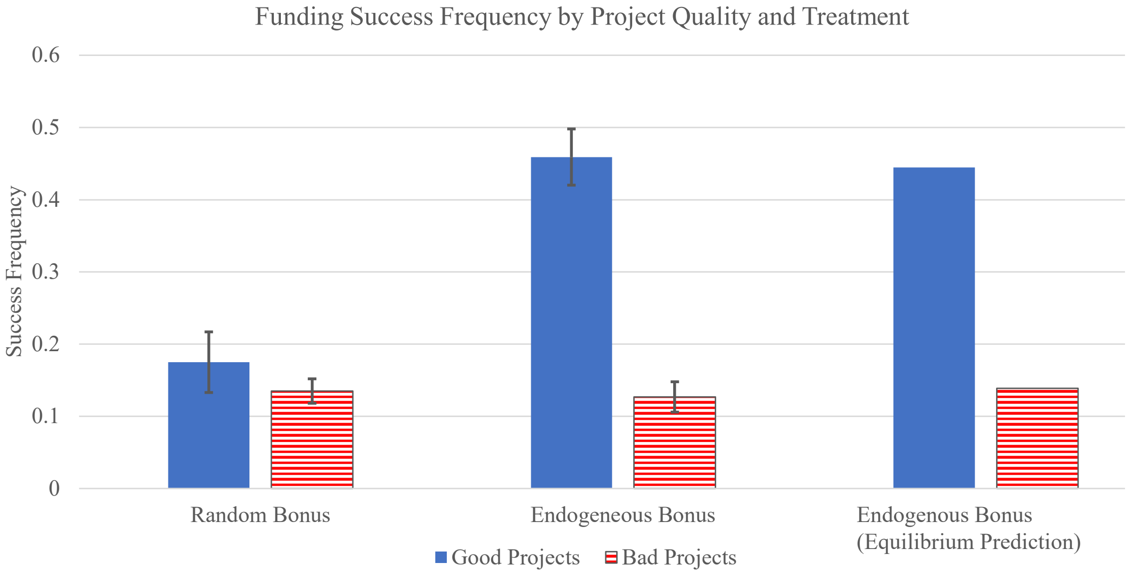
the four subjects assigned to each group randomly changed each round from a larger matching group of 12 total subjects.

The experiment reports data from a total of 168 subjects, divided into 8 independent 12-subject matching groups for the EB treatment and 6 matching groups for the RB treatment. We oversampled the EB treatment because our main hypotheses concern differences in choices and outcomes within this treatment, and because only the EB treatment included entrepreneur decisions. A power analysis, conducted following the collection of data from the first 4 groups, indicated that this sample size would provide at least 85% power for all but one of our hypotheses using an $\alpha = 0.05$ significance level.

All sessions were conducted at the Vernon Smith Experimental Economics Laboratory at Purdue University, with experimental software implemented using oTree (Chen et al., 2016). Subjects were undergraduate students, recruited across different disciplines at the university by email using ORSEE (Griener, 2015). No subject participated in more than one session. Typically sessions included two, 12-subject matching groups.

At the beginning of each session subjects received a hardcopy of the instructions shown in Appendix A, and these were read aloud by a computerized voice. This was accompanied by an automated slide presentation projected in the lab to highlight key points, payoffs and decision screens. Subjects answered eight comprehension quiz questions at the conclusion of the instructions, earning $1 for every correct answer. The Part 2 instructions (which added the possibility of the refund bonus) were distributed and read aloud in a similar computerized presentation at the conclusion of Part 1. Two (four) rounds from Part 1 (Part 2) were randomly chosen for payment at the conclusion of the session. Total earnings averaged US$25.35 per subject, with an inter-quartile range [$22.00, $28.38]. Sessions lasted about 60 minutes each, including the time taken for instructions and payment distribution.

Figure 4: Funding Success Frequency by Project Quality and Treatment



Note: Error bars display standard error of the mean.

6 Experiment Results

We begin by considering the most important outcome variable, the frequency of successful project funding. Figure 4 and Table 1 display the funding rates for good and bad projects, separately for the EB and RB treatments. Good projects are funded more frequently in EB than RB, giving a clear indication that the bonus offer appears to fulfill its signaling role as in the hybrid equilibrium.

Result 1. *Good quality projects are successfully funded more frequently in the EB treatment where entrepreneurs can choose whether to offer refund bonuses compared to the RB treatment where the assignment of refund bonuses is random.*

Support: Figure 4 and Table 1 indicate that good projects are funded more than two and a half times more frequently in the EB than the RB treatment. The success rates for the 8 EB groups all exceed the success rates for the 6 RB groups, so a nonparametric Wilcoxon rank-sum test based on the 14 independent session averages strongly rejects the null hypothesis of equal success rates for good quality projects (p-value < 0.001).

The middle parts of Table 1 and Figure 4 indicate that bad projects are successfully funded at much lower rates than good projects, and at similar rates in both treatments.

Table 1: Funding Success Frequency

	Random Bonus (RB)	Endogenous Bonus (EB)
Good Projects (pooled)	0.175	0.459
	(0.042)	(0.039)
Good Projects (with bonus)	0.292	0.616
	(0.079)	(0.043)
Good Projects (no bonus)	0.065	0.076
	(0.028)	(0.019)
Bad Projects (pooled)	0.135	0.127
	(0.017)	(0.021)
Bad Projects (with bonus)	0.211	0.310
	(0.035)	(0.037)
Bad Projects (no bonus)	0.061	0.038
	(0.025)	(0.015)
All Projects (pooled)	0.153	0.280
	(0.026)	(0.021)
All Projects (with bonus)	0.248	0.518
	(0.049)	(0.035)
All Projects (no bonus)	0.064	0.049
	(0.025)	(0.015)

Note: Entries display mean successful funding rates across sessions, with standard error of the mean in parentheses. Funding success occurs when both investors choose to invest.

Moreover, for the EB treatment overall funding rates are similar to equilibrium predictions – the rate of 0.459 compared to 0.444 predicted with good projects, and the rate of 0.127 compared to 0.139 for bad projects.[8] These funding rates for good and bad projects within the EB treatment are significantly different (Wilcoxon signed-rank test p-value < 0.01, $n = 8$ independent sessions).

The hybrid equilibrium also makes specific predictions about the funding success rates for good and bad projects in the EB treatment *when a bonus is offered*. This is 0.444 for good projects and 0.25 for bad projects. The observed rates are somewhat higher (0.616 and 0.310, respectively, as shown in Table 1). Nevertheless, they are significantly

[8] In equilibrium entrepreneurs with good projects always offer bonuses and investors who are offered a bonus and do not receive a negative report invest with probability 2/3. Therefore, since success requires both investors, it occurs with probability (2/3)*(2/3)=4/9≈0.444 in equilibrium. Entrepreneurs with bad projects offer bonuses with probability 5/9 in equilibrium, and investors receive negative reports (and thus do not invest) with probability 1/4 for bad projects. Therefore, funding for bad projects is successful with probability (5/9)*[(3/4)*(2/3)]*[(3/4)*(2/3)]=5/36≈0.139.

Table 2: Frequencies that Entrepreneurs Offered Bonuses and Investors Invested

Entrepreneurs		Investors		
Project	Offer Bonus	Project	Invest RB	Invest EB
Good	0.700 (0.032)	With Bonus	0.594 (0.062)	0.791 (0.023)
Bad	0.306 (0.025)	Without Bonus	0.245 (0.061)	0.234 (0.034)

Note: RB stands for the random bonus treatment and EB for the endogenous bonus treatment. Entries display mean rates across sessions, with standard error of the mean in parentheses. Investment rate is only for cases in which investors did not receive a negative report.

different according to a Wilcoxon signed-rank test (p-value < 0.01, $n = 8$ independent sessions).

These funding success rates derive from a combination of investors' investment choices and entrepreneur's decisions about whether to offer a refund bonus, which we turn to next. Table 2 displays the frequency of these choices pooled across all sessions.[9] The leftmost columns indicate that entrepreneurs offered bonuses at different rates for the two project qualities, which is our next main result.

Result 2. *Entrepreneurs offer refund bonuses more frequently for good quality projects than for bad quality projects.*

Support: The 70 percent rate of bonus offers for good quality projects is significantly greater than the 31 percent rate for bad quality projects (Wilcoxon signed-rank test p-value < 0.01, $n = 8$). This frequency of refund bonus offers is lower than in the hybrid equilibrium, however, which is 55.6 percent for bad quality projects and 100 percent for good quality projects.

In the RB treatment, by design bonuses are offered for all projects with equal likelihood, and this is independent of project quality. Therefore, unlike in the EB treatment where the bonus is a (noisy) signal of quality, the bonus cannot provide any quality infor-

[9]The indicated investment frequency excludes the cases where an investor received a negative report that a project was definitely bad quality. Investors (mistakenly) invested in only 17 out of 1421 these cases (one percent), indicating a relatively low baseline error rate for these clearly dominated choices.

mation in the RB treatment. In equilibrium, risk neutral or risk averse investors should not invest in projects in the RB treatment regardless of the bonus offer, since the total expected return, including the \$1 endowment, is $(0.5 \times 4) + (0.5 \times 0) = \$2$ if the other investor invests, and it is \$2 or \$1 if the other investor does not invest, depending on whether a bonus is offered. In both cases these expected total returns fall below the safe outside option of \$2.50 from not investing. But the higher return of \$2 rather than \$1 when the bonus is offered makes investment relatively more attractive with a bonus, even when the bonus does not convey information about product quality.

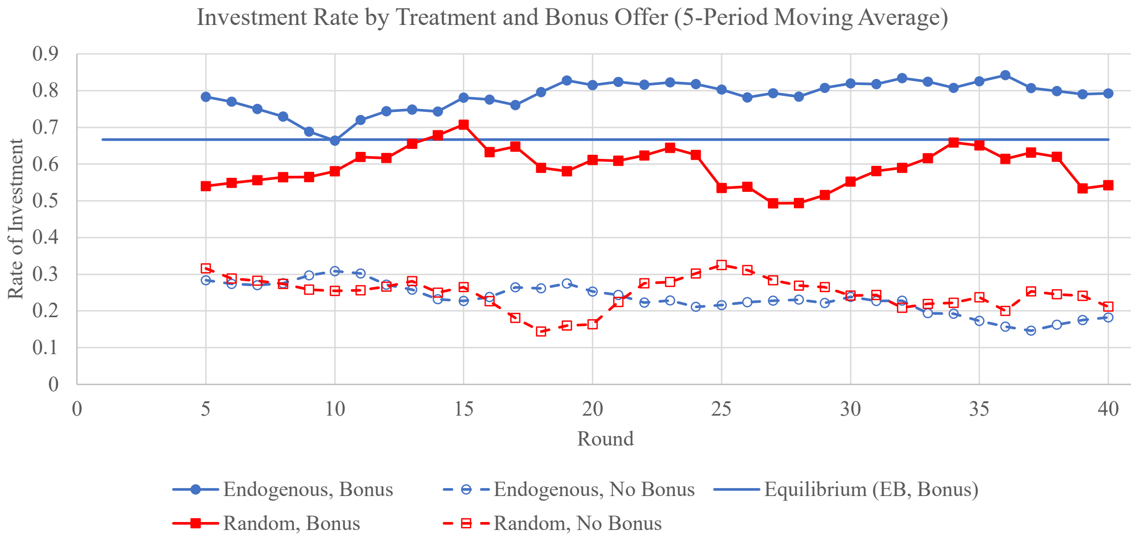
The right part of Table 2, and the time series shown in Figure 5, indicates that investors invest too frequently relative to the equilibrium predictions, for all treatments and bonus offer conditions. Nevertheless, as the next result summarizes, they invest more frequently exactly when they should – when a bonus is offered in the EB treatment, where the bonus provides an indication of project quality.

Result 3. *(a) Investors invest more frequently in projects that offer a refund bonus than those that do not in the EB treatment; and (b) for projects that offer a refund bonus they invest more frequently in the EB treatment than the RB treatment.*

Support: Part (a) involves a within-treatment comparison of the investment rate with a bonus offer (average = 0.791) and without (average = 0.234) within the EB treatment. This difference is highly significant (Wilcoxon signed-rank test p-value < 0.01, $n = 8$ independent sessions). Part (b) compares the EB investment rate (average = 0.791) to the RB investment rate with a bonus offered (average = 0.594). Although the investment rate in RB is surprisingly high, almost no overlap exists between the distribution of investment rates across sessions in the two treatments so the difference is highly significant (Wilcoxon signed-rank test p-value < 0.01, $n_1 = 8$, $n_2 = 6$ independent sessions). Note in Figure 5 that the three time series, except for the Endogenous Bonus case, exhibit a modest decline across rounds, in the direction of the equilibrium of zero investment.[10]

[10] The negative time trends in both cases without a bonus are statistically significant based on a random effects logit regression of investment on round number (p-value < 0.05). For the cases with a bonus offer, the negative time trend in the RB treatment is not statistically significant, and the positive trend in the EB treatment is marginally significant (p-value = 0.074). At the individual level, over twice as many subjects decrease their average investment rates in the last 20 compared to first 20 rounds in the

Figure 5: Investment Rates by Treatment and Bonus Offer



Notes: Investment rate calculated only for cases in which investors did not receive a negative report. Equilibrium prediction for all Random Bonus and No Bonus cases is zero investment.

In summary, the experimental results provide strong support for Hypotheses 1 and 2. The data indicate that crowdfunding is more successful when entrepreneurs can choose whether or not to offer refund bonuses, compared to a baseline condition where bonuses are offered randomly. Success rates are modestly elevated relative to equilibrium point predictions, but treatment differences are all statistically significant and in agreement with theory. Entrepreneurs do not offer bonuses for good projects as frequently as predicted in equilibrium, but investors tend to invest more frequently than predicted. The combination of these offsetting deviations from the equilibrium predictions leads the overall funding success to be very similar to equilibrium in the EB treatment.

Table 3 summarizes the average earnings of investors and entrepreneurs for both treatments, depending on their decisions. The failure of entrepreneurs to offer bonuses whenever they have a good project is clearly a mistake, as they earn significantly more on average when offering bonuses (\$2.39) than when not offering (\$1.65) (Wilcoxon signed-rank test p-value < 0.01, $n = 8$). In this respect the entrepreneurs are not playing an empirical best response to investor behavior. Entrepreneur earnings are not significantly different when offering the bonus (\$1.64) or not (\$1.58) when they have a bad project

Random/Bonus and the Endogenous/No Bonus treatments; specifically, 72 subjects decrease compared to 33 subjects who increase investment frequency across these two conditions pooled.

Table 3: Mean Earnings for Entrepreneurs and Investors

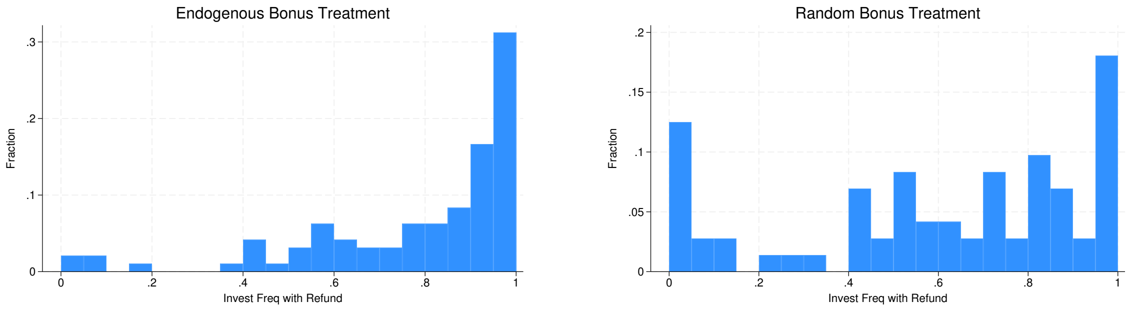
	Entrepreneurs' earnings		
Project	Bonus Offered	No Bonus Offered	Equilibrium
Good	2.39 (0.12)	1.65 (0.04)	1.94
Bad	1.64 (0.10)	1.58 (0.03)	1.50
	Investors' earnings		
Project	Invest RB	Invest EB	Not Invest / Equilibrium
Bonus Offered	1.99 (0.10)	2.86 (0.10)	2.50
No Bonus Offered	1.20 (0.12)	1.17 (0.06)	2.50

Note: RB abbreviates the random bonus treatment and EB for the endogenous bonus treatment. Entries display mean earnings in US dollars per period per round across sessions, with standard error of the mean in parentheses. They include the per-period, per-project endowments of \$1 for investors and \$1.50 for entrepreneurs. Investment earnings are only for cases in which investors did not receive a negative report.

(Wilcoxon p-value = 0.547). This is consistent with the mixed strategy equilibrium, in which entrepreneurs should always offer bonuses for good projects and to mix between offering bonuses or not for bad projects. Overall, average entrepreneur earnings exceed the level expected in equilibrium, both for good and bad projects (Wilcoxon p-value < 0.05 in both cases). This suggests that entrepreneurs' incentive to participate in this funding mechanism could actually exceed the incentive based on only equilibrium calculations.

Earnings for investors are not consistent with equilibrium, however, and their over-investment in the RB treatment and when no bonus is offered is puzzling. They should not invest in these three cases, and indeed their average earnings are always significantly lower than the safe \$2.50 earned from not investing (all Wilcoxon p-value < 0.05). Only in the case where the bonus is offered endogenously are earnings (average = \$2.86) greater than \$2.50 (Wilcoxon p-value < 0.01). Investors should actually mix in this case in equilibrium, but if they are risk neutral they should always invest based on the average earnings realized from investment.

Figure 6: Investment Frequency by Subject when Refund Bonus is Offered



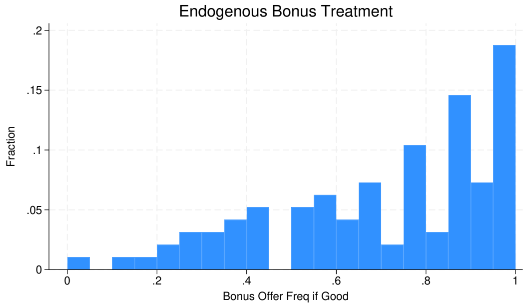
(a) Endogenous Bonus (b) Random Bonus

Note: Investment frequency excludes cases in which investors received a negative report.

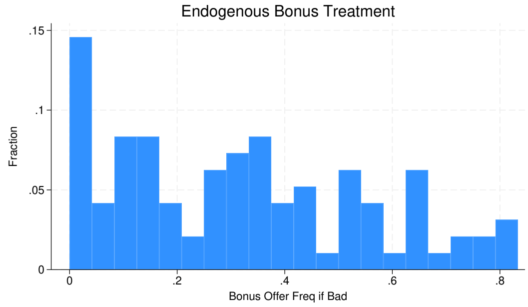
Investors are clearly not making deterministic best responses considering these average payoffs. The greater investment rate in the RB treatment when a bonus is offered (59.4 percent) relative to not offered (24.5 percent) shown in Table 2, however, is consistent with noisy best responses. The investment frequency is considerably lower in the no-bonus case in which expected payoffs are much lower. That is, investors mistakenly invest more frequently when the payoff consequences of this error are lower. Moreover, investment rates are similar without bonuses in both the EB (23.4 percent) and RB (24.5 percent) treatments, as are the low average earnings from investment ($1.17 and $1.20, respectively). These patterns are consistent with noisy choice as originally formulated by Luce (1959) and they are a foundation of quantal response equilibrium (Goeree et al., 2016).

In closing we note that the overall average investment frequency shown in Figure 5 and the bonus offer rates reported in Table 2 obscure considerable subject heterogeneity. This variability across subjects is documented in Figures 6 and 7, which display the frequency distribution across individual subjects for investment rates (when the bonus is offered) and the entrepreneur bonus offer rates, respectively. In the EB treatment nearly half of the subjects invest at least 90 percent of the time when the refund bonus is offered. Few individuals invest at the hybrid equilibrium mixed strategy rate of 0.667. In the RB treatment the investment rate across individuals is bimodal and widely dispersed, in stark contrast to the equilibrium investment rate of 0.

Figure 7: Bonus Offer Frequency by Subject and Project Type



(a) Good Projects



(b) Bad Projects

Entrepreneurs bonus offer rates are also widely dispersed (Figure 7). Only about a quarter offer bonuses for good projects more than 90 percent of the time, although in equilibrium they should always offer a bonus for good projects. Most entrepreneurs offer bonuses for bad projects at rates below the equilibrium frequency of 0.556, with a substantial number offering bonuses less than 20 percent of the time.

7 Conclusion

Crowdfunding and the larger field of decentralized finance have given investors new options for funding projects. Crowdfunding has advantages in testing demand and building community before production. But crowdfunding raises issues of asymmetric information and trust. The success of crowdfunding platforms around the world indicates that the advantages outweigh the costs, in at least some cases. But increasing the size of the market will require new innovations. Intermediated finance, primarily banks, have a long history of practice while the institutions of decentralized finance like the threshold implementation mechanism are new. Realizing the full promise of decentralized finance requires progress in governance and technology.

In this paper, we present and test a novel solution to the problem of asymmetric information and adverse selection in crowdfunding. We demonstrate that refund bonuses, designed to resolve the investment coordination problem, can also perform the important function of information transfer. The main idea is that the offer of refund bonuses can reinforce the wisdom of the crowd up to the level needed for successful and efficient fundraising. Specifically, because good quality projects have a lower risk of bonus payout, entrepreneurs with good quality projects are more likely to offer refund bonuses. Hence, the offer of refund bonuses signals high quality to investors, reinforcing their beliefs and driving investment toward such projects. The results of our experiment provide supporting evidence of this proposed signaling solution and the specific steps through which it works.

The proposed solution is a simple extension of the threshold implementation mechanism and, thus, easily implementable in practice. Future research efforts could be directed at conducting larger scale experiments or field studies to further evaluate the solution's real-world viability and refine its implementation. Key questions remain regarding how to optimize the design for different contexts. What threshold maximizes participation without generating entrepreneurial moral hazard? What bonus size and timing maximizes success rates? Managerial guidelines and best practices on these practical considerations will facilitate greater adoption of crowdfunding and decentralized finance.

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Appendix: Proof of Theorem 1

First, consider the possibility of separating equilibrium. If only the good entrepreneur offers refund bonuses, then all investors will choose to invest in projects that offer refund bonuses. Yet, with all investors investing, it cannot be equilibrium for the bad entrepreneur to abstain from offering refund bonuses. For a similar reason there is no equilibrium where the bad entrepreneur offers refund bonuses while the good entrepreneur does not. Hence, separating equilibrium cannot exist.

Second, consider the possibility of pooling equilibrium where the entrepreneur of each type offers refund bonuses and the investors with good signals invest with a positive probability $\sigma \in (0, 1)$. The offer of refund bonuses implies a non-negative profit $\Pi_i(\sigma, b) \geq 0$ for each type $i \in \{B, G\}$, while mixed strategy σ implies the expected investor payoff equal to safe return $\overline{\theta}$, i.e., $U^b(\sigma) = \overline{\theta}$. (Pure strategy $\sigma = 1$ cannot be in equilibrium because of Lemma 1.) By the definition of market failure we have that $\overline{\theta} > \alpha\pi_G + (1 - \alpha)\pi_B$. Then, we have $U^b(\sigma) > \alpha\pi_G + (1 - \alpha)\pi_B$ or

$$\alpha(y_G(\sigma) - \pi_G) + (1 - \alpha)(y_B(\sigma) - \pi_B) > 0,$$

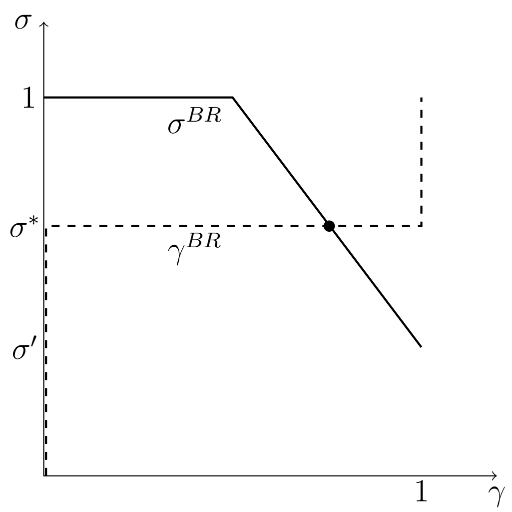
where $y_i(\sigma) = P_i(\sigma)\theta_i + (1 - P_i(\sigma))b$ is the expected investment return from the project of type $i \in \{B, G\}$. For the last inequality to hold, we must have $y_i(\sigma) > \pi_i$ for some type $i \in \{B, G\}$, which in turn implies a strictly negative profit $\Pi_i(\sigma, b)$. Hence, pooling equilibrium with a positive investment level does not exist because at least one entrepreneur type is bound to have a negative profit.

Third, consider the hybrid equilibrium candidate, where the good entrepreneur offers refund bonuses with certainty but the bad entrepreneur with probability γ. The bad entrepreneur's expected profit is equal to $\gamma\Pi_B(\sigma, b)$ (we recall that the reservation profit is 0). For small values of investors' strategy σ the profit from the project is negative, $\Pi_B(\sigma, b) < 0$, which implies $\gamma = 0$ as the bad entrepreneur's best reply against such values of σ. Specifically, we obtain from the definition of $\Pi_B(\sigma, b)$ in (3) that

$$\Pi_B(\sigma, b) < (\pi_B - \theta_B)P_B(\sigma)(1-\alpha)N - b(1 - P_B(\sigma)),$$

where the right-hand side is less than 0 for small values of σ because $P_B(\sigma) \to 0$ with $\sigma \to 0$. At the same time, we have $P_B(\sigma) \to 1$ for $\sigma \to 1$ (because of the assumption $(1-\alpha)N \geq C$) and, hence, $\lim_{\sigma \to 1} \Pi_B(\sigma, b) > 0$. Then, by continuity there is $\sigma^* \in (0, 1)$ such that $\Pi_B(\sigma^*, b) = 0$. Figure A1 plots the graph of the bad entrepreneur's best response γ^{BR} (dashed line).

Figure A1 : Entrepreneur and investor best responses



Upon observing the offer of refund bonuses, investors with good signals update their beliefs μ that the project is good to

$$\mu(\gamma) = \frac{\alpha}{(1-\alpha)\gamma + \alpha}. \tag{4}$$

The investors' expected payoff is then equal to

$$\widetilde{U}(\sigma, \gamma) = \sigma \left\{ \mu(\gamma)\, y_G(\sigma) + (1 - \mu(\gamma))\, y_B(\sigma) \right\} + (1-\sigma)\, \overline{\theta}.$$

Let $\sigma^{BR}(\gamma)$ denote the investors' best reply against the bad entrepreneur's strategy γ. At the values of γ close to 0 so that $\mu(\gamma) \to 1$, the expected payoff $\widetilde{U}$ increases in σ

because of $b < \theta_G$, implying that $\sigma^{BR}(0) = 1$ or that it is optimal for investors to invest with certainty in the project offering refund bonuses. Next consider the investors' best reply against $\gamma = 1$. If $\sigma^{BR}(1) \equiv \sigma' < \sigma^*$, then the hybrid equilibrium is determined by the intersection of the best-reply graphs as shown in Figure A1. Therefore, next we consider the possibility of $\sigma' \geq \sigma^*$. It must be that the investors' expected payoff satisfies $\widetilde{U}(\sigma', 1) > \overline{\theta}$ as otherwise $\sigma' = 0$ is the best reply. Then, the bad entrepreneur's profit at σ' is positive as $\Pi_B(\sigma', b) \geq \Pi_B(\sigma^*, b) = 0$, which implies the existence of pooling equilibrium (both types of the entrepreneur offer refund bonuses with certainty and the investors invest with probability σ'). This is, however, not possible as demonstrated earlier. Hence, we have $\sigma' < \sigma^*$, which proves the existence of hybrid equilibrium with a positive level of investment.

Appendix: Experiment Instructions

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 so 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.

This part of the experiment is divided into 20 decision "rounds." You will be paid based on your earnings in 2 of the 20 rounds of this part (randomly drawn at the end). Each decision you make is therefore important because it has a chance to affect the amount of money you earn.

In each decision round you will be grouped with 3 other people, who are sitting in this room. Group members will change randomly each round. You will make decisions privately, 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.

After reading these instructions and instructions for the other parts you will complete comprehension quiz questions and earn $1 for every correct answer.

Overview

In every decision round you will be either an investor or an inventor. Each group has 2 investors and 2 inventors. Inventors are assigned an invention each round. Every invention can be good or bad, which is determined randomly and independently of the quality of other inventions and other rounds. In a decision round, both inventions could be good, both could be bad, or only one might be good. The inventions are arbitrarily labeled circle and square.

Inventors know their inventions' good or bad quality, but investors do not. Investors only sometimes learn whether an invention is bad quality before investing. Investors choose each round whether to invest in developing none, one or both inventions.

If both of the investors decide to invest in an invention, then it is developed and the inventor receives a monetary payment (as explained later). The investors receive a monetary payment only if the invention is good quality, otherwise they lose the money they invested. If only one investor invests in an invention, then then it is not developed and the investor who tried to invest will have their investment money returned.

When you are an investor

At the start of each round you begin with $2 (and so does the other investor) and you can invest $1 in each of the two inventions. If the invention turns out to be good, and if both investors invest in it, your $1 investment quadruples to a $4 total return. But if the invention turns out to be bad, and if both investors invest in it, you lose your investment. If only you (and not the other investor) invest in a specific invention, then not enough money is raised to develop it but you receive back your investment. The table below summarizes your potential total earnings from investment.

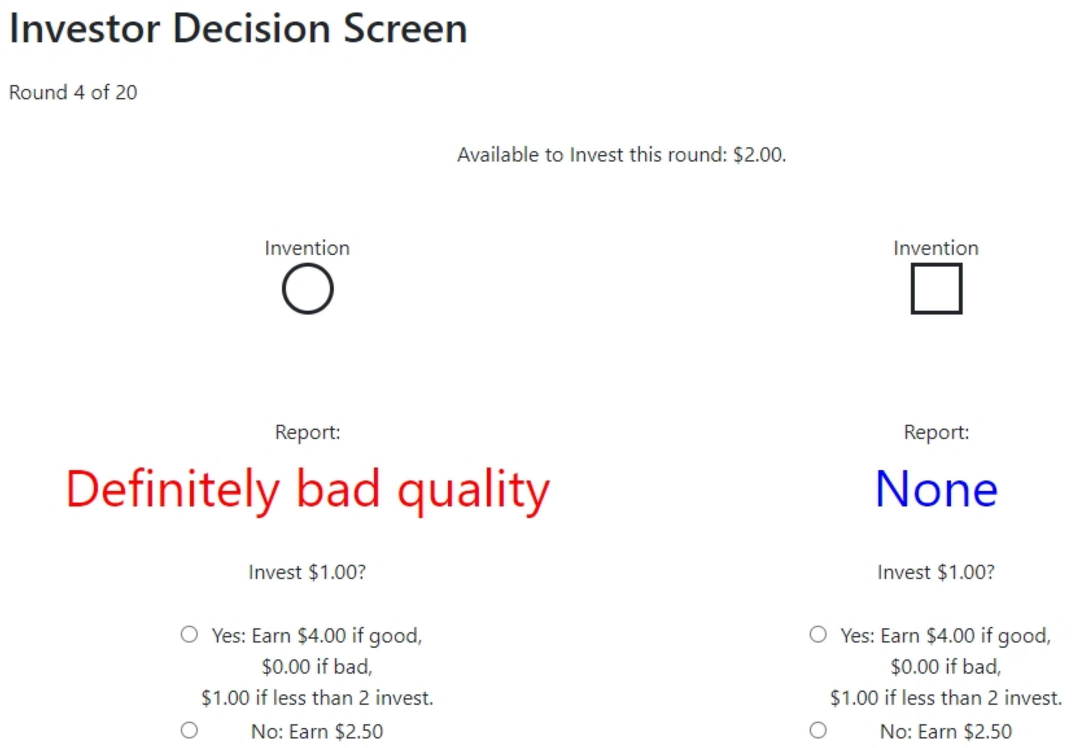
Your total earnings from each potential $1 investment

	Good invention	Bad invention
Only you invest	$1.00	$1.00
Both invest	$4.00	$0.00

Remember that each round all investors can invest in zero, one or two inventions, so you can potentially earn double the amounts shown in the table. Any dollar that you *do not* invest in an invention automatically increases to $2.50.

While at the start of each round the quality of an invention is only known by the inventor, you may occasionally receive a negative report for some invention(s). If you do not receive a negative report for an invention, then the invention is equally likely to be good or bad quality. If you receive a negative report for an invention, then the invention is definitely bad quality.

After receiving reports, if any, both investors make their investment decisions at the same time, using the decision screen shown below, and they do not learn about other's investment choices until the end of the round.



When you are an inventor

In half of the rounds in this part of the experiment you will have the role of investor. But in the other rounds you will have the role of inventor. In every round as inventor, you will begin with a $1.50 endowment and will be assigned an invention, the quality of which is randomly determined each round and nobody can influence it.

If your invention is bad, there is a one-quarter (25%) chance that each investor will receive a negative report indicating that the invention is definitely bad quality, but a three-quarters (75%) chance of no report at all. Exactly which of the investors receive reports is random, determined independently from person to person and from round to round. For good quality inventions, investors never receive any kind of report.

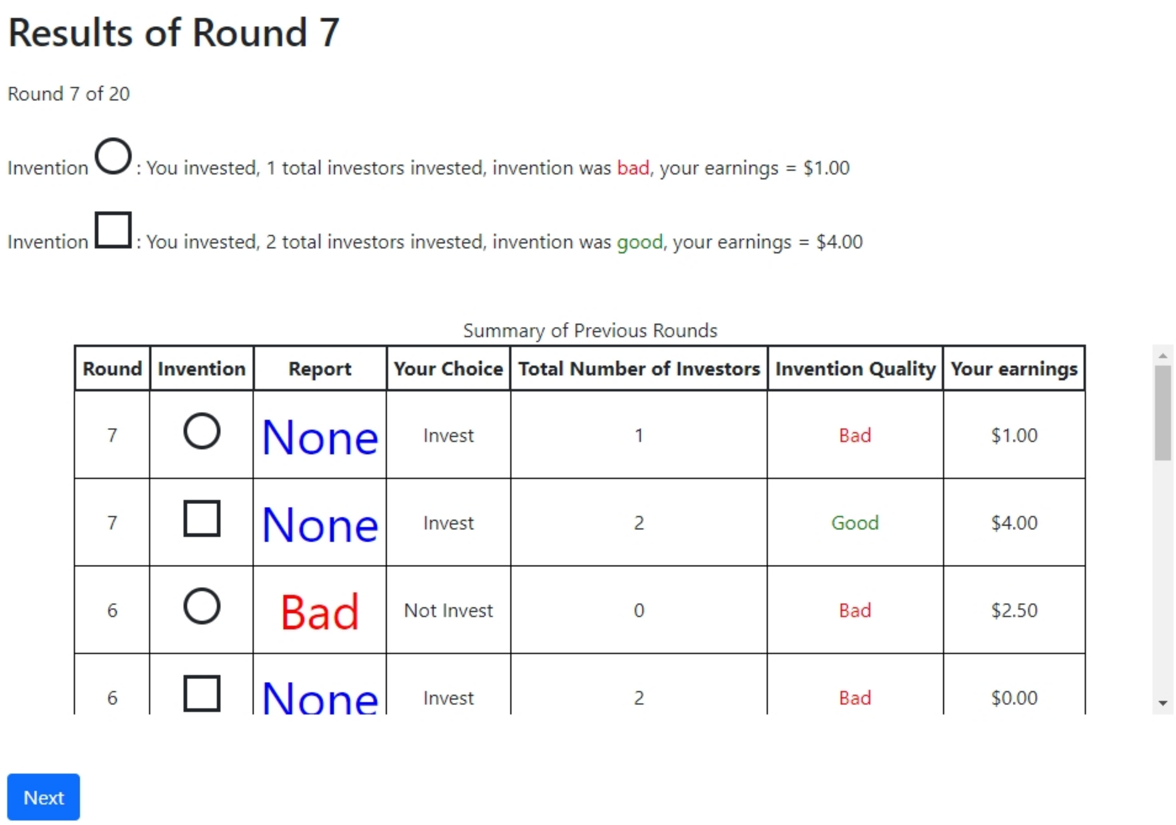
Your earnings will depend on how many investors invest in your invention. If your invention has 2 investors, then you earn $2.00 irrespective of the quality of your invention.

If your invention attracts only 1 or 0 investors, then you earn \$0 for that round. You also keep the \$1.50 endowment.

At the start of each round of this part of the experiment the inventors will learn the quality of their invention and will wait for the investors to make their investment decisions.

End of the round

At the end of every decision round, as illustrated in the figure below, your computer will display the total number of investors for each invention. The results screen will also display whether both investors invested to develop the invention, your decisions made in the round, and your earnings for the round. A table will also summarize the results from every previous round.



Results of Round 7

Round 7 of 20

Invention ○ : You invested, 1 total investors invested, invention was bad, your earnings = $1.00

Invention □ : You invested, 2 total investors invested, invention was good, your earnings = $4.00

Summary of Previous Rounds

Round	Invention	Report	Your Choice	Total Number of Investors	Invention Quality	Your earnings
7	○	None	Invest	1	Bad	$1.00
7	□	None	Invest	2	Good	$4.00
6	○	Bad	Not Invest	0	Bad	$2.50
6	□	None	Invest	2	Bad	$0.00

Next

Summary

1. Each group contains 4 members. Group members change randomly each round.
2. In half of the rounds you will have the role of an investor, and you and the other investor will make investment decisions for two inventions of, in most cases, unknown quality.
3. For an invention to be developed, both investors need to invest in it. If only 1 investor invests in an invention, then it is not developed and the investor who tried to invest receives their investment back.
4. An invention can be either good, or bad quality. If an invention is bad, each investor, independently of one another, can receive a negative report about it with a one-quarter chance.
5. If an investor does not receive any report about an invention, then the invention is equally likely to be good or bad quality.
6. In half of the rounds you will have the role of inventor. Inventors receive monetary payments that depend on the number of investors in their invention.

Note: The following instructions were distributed on separate pages after the completion of Part 1.

Regular text is for the Endogenous Bonus treatment. Alternative text used for the Random Bonus treatment is shown in bold.

NEW INSTRUCTIONS FOR PART 2

This part of the experiment is divided into 40 decision "rounds." You will be paid based on your earnings in 4 of these 40 total rounds (randomly drawn at the end). Each decision you make is therefore important because it has a chance to affect the amount of money you earn. As in the earlier part, in each decision round you will be grouped with 3 other people, who are sitting in this room, and the composition of your group changes randomly from round to round.

Overview of changes – the Refund Bonus

This part of the experiment is very similar to the previous part. The only difference is the refund bonus, which is an extra payment that can be offered by the inventor to those investors who tried to make an investment when insufficient money was raised. In particular, when only one investor invests in an invention, the investor will not only have their investment returned as before but will also receive the refund bonus offered by the inventor. The decision whether to offer a refund bonus or not is made by each inventor before investors make their investment decisions. **Alternative for Random Bonus: Whether or not an inventor offers a refund bonus is determined randomly, with each inventor having an equal and independent (50/50) chance of being assigned a refund bonus.**

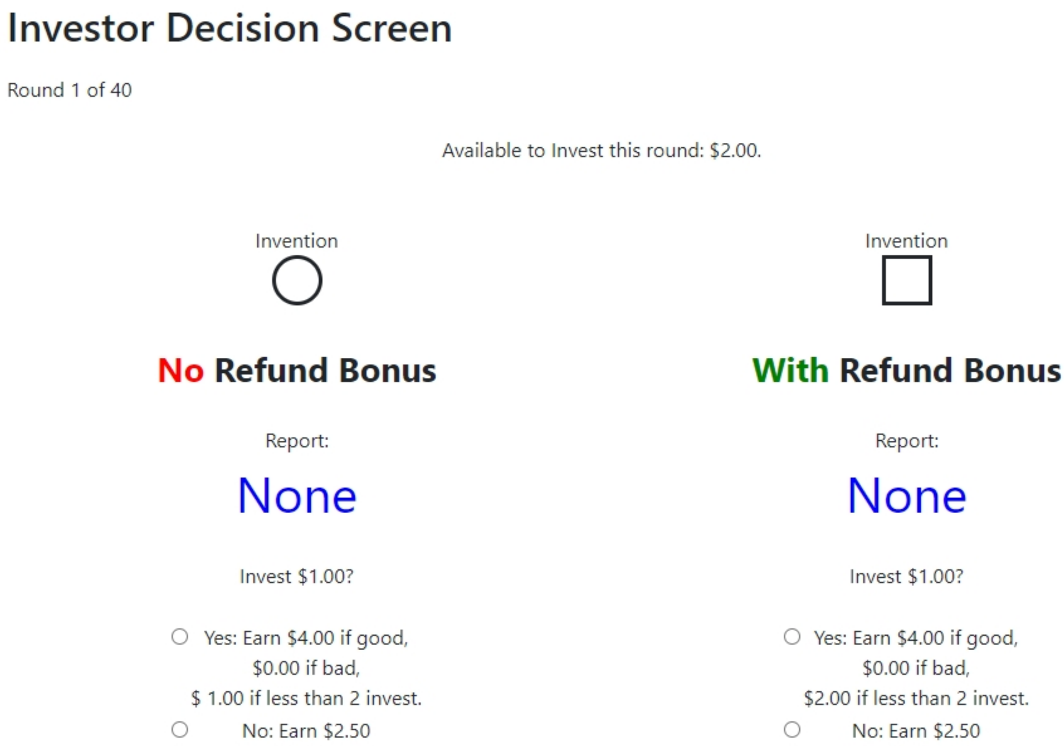
When you are an investor

If an invention does not offer a refund bonus, your investment earnings remain the same as before.

If an invention offers a refund bonus, your investment earnings change only when you are the only investor. If only you invest in a specific invention, not enough money is raised to develop it and you will receive back your $1 investment plus a refund bonus of $1 for the total return of $2.00. The table below summarizes your potential investment earnings depending on whether the invention is good or bad and on whether the $1 refund bonus is offered or not. Differences due to the refund bonus are highlighted in color.

Your total earnings from each potential $1 investment

	No Refund Bonus		With Refund Bonus	
	Good invention	Bad invention	Good invention	Bad invention
Only you invest	$1.00	$1.00	$2.00	$2.00
Both invest	$4.00	$0.00	$4.00	$0.00



Remember that each round all investors can invest in zero, one or two inventions, so you can potentially earn double the amounts shown in the table. The investors' decision screen clearly indicates which inventions offer a refund bonus, as shown above.

As before, any dollar that you *do not* invest in an invention automatically increases to \$2.50. You may occasionally receive a negative report about a bad quality invention.

When you are an inventor

In half of the rounds in this part of the experiment you will have the role of investor. But in the other rounds you will have the role of inventor. After you learn the quality of your invention, you choose whether or not you wish to offer **Alternative for Random Bonus: When you learn the quality of your invention, you will also learn whether or not you have been randomly selected to offer** a refund bonus of \$1 to be paid in situations where only one investor invests in your invention as described earlier. The refund bonus would be paid out of your \$1.50 endowment.

If your invention has 2 investors, then you earn \$2.00 irrespective of the quality of your invention and keep the \$1.50 endowment. But if you choose to offer **Alt: ... your**

invention offers a refund bonus, and only 1 investor invests in your invention, you must pay that investor a refund bonus of $1 out of your $1.50 endowment. The table below summarizes your potential earnings from invention.

Your total earnings from invention (including $1.50 endowment)

	No Refund Bonus	With Refund Bonus
0 Investors	$1.50	$1.50
1 Investor	$1.50	$0.50
2 Investors	$3.50	$3.50

Remember that if your invention is bad, there is a one-quarter (25%) chance that each investor, independently of one another, will receive a negative report indicating that the invention is definitely bad quality. You do not determine invention quality, or who might receive a negative report.

At the start of each round the inventors will learn the quality of their invention and will then decide whether to offer the refund bonus with their invention. **Alt: ... whether their invention offers a refund bonus.** They then wait for the investors to make their investment decisions.

Summary

1. If only 1 investor invests in an invention, the investor who tried to invest receives their investment back. If a refund bonus is offered, they will also receive a refund bonus of $1 as shown in Table 2.

2. Inventors receive monetary payments that depend on the number of investors in their invention, and whether their invention offers a refund bonus.

3. Inventors decide whether to offer a refund bonus for their invention after they learn the quality of their invention.

4. **Alternative for Random Bonus: Whether or not an invention pays a refund bonus is randomly determined, with an equal (50/50) chance of being assigned a refund bonus.**