Crowdfunding as a Vehicle for Raising Capital and for Price Discrimination

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ABSTRACT

Crowdfunding campaigns are traditionally used as a means for entrepreneurs to raise capital to fund the development of new products. We show that crowdfunding may serve an additional purpose of acting as a platform to allow entrepreneurs to successfully implement price discrimination. The entrepreneurs’ ability to implement such price discrimination depends on the extent to which they are eager to raise capital through the crowdfunding campaigns. Specifically, we show that enhanced consumer surplus extraction through price discrimination is feasible when the total consumer surplus that the project generates is relatively small, when the development cost of the project and the financing costs through traditional funding sources are relatively low, and when the extent of heterogeneity in the consumer population is relatively high. We also provide insights regarding the entrepreneur’s choice of the funder reward and campaign goal, two tools that can enable her to achieve the dual objective of raising funds for the campaign and implementing price discrimination.

Keywords: Crowdfunding; Price Discrimination; Game Theory

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INTRODUCTION

Online crowdfunding provides an alternative way for entrepreneurs to finance the development and production of new products without the need of traditional financial intermediaries. While crowdfunding has been around since the first entrepreneur solicited friends and family for funding, the Internet has expanded the accessible “crowd” from friends and family to individuals all over the world. Allowing these consumers-turned-investors to support the development of a product that they like, crowdfunding platforms bring together entrepreneurs looking to finance a product with individuals who have funds to provide to the project.

The popularity of crowdfunding websites has attracted entrepreneurs from all walks of life. Actors, directors, and writers have taken to crowdfunding platforms to fund new creative projects. Famous chefs have used crowdfunding to raise funds for new restaurants. Aspiring techies have pitched new apps and product ideas that they assure will increase quality of life. Kickstarter, one of the leading crowdfunding platforms, claims that since its establishment in 2009 more than 9.6 million people have pledged over $2 billion to fund over 93,000 creative products using its services (Kickstarter 2015a). The crowdfunding industry as a whole keeps growing; funding grew 167% in 2014, up from $6.1 billion in 2013, and is expected to continue to grow to $34.4 billion in 2015 (Massolution 2015).

While crowdfunding as a fundraising vehicle is not limited to commercial products, our focus is on campaigns used for development of commercial products. Many crowdfunding websites such as Kickstarter limit themselves to funding for the development of creative projects. However, many of these projects turn into commercial products. In fact, of the 50 highest funded projects on Kickstarter, 49 represent products that have since been or are expected to
become commercialized (Kickstarter 2015b). Projects on Kickstarter’s “most funded” page include a second season of a critically acclaimed webseries, an immersion circulator that is used to cook sous vide, and a game console that is built on Android open source technology. In 2014, business and entrepreneurship had the leading share of funding volume on crowdfunding websites (Massolution 2015).

Many entrepreneurs utilize crowdfunding to finance new product ideas because traditional financial intermediaries such as banks and venture capitalists find their ideas to be too risky. However, as crowdfunding gains in popularity, entrepreneurs who would have traditionally sought funding from these intermediaries look instead to the crowd to finance a project. In addition, while several types of crowdfunding exist (rewards, patronage, lending, and equity), our model’s focus is on rewards based crowdfunding. (For more information on the other types of crowdfunding see Mollick (2014).) This is the model used by the leading creative project crowdfunding website Kickstarter. Rewards based crowdfunding is especially important from a marketing perspective because it taps consumers for funding, as opposed to traditional investors, through the design of the reward.

An important reason why rewards based crowdfunding has been successful is the existence of high valuation consumers who wish to ensure that their preferred products are produced and become available on the market. Entrepreneurs that use the services of crowdfunding platforms employ campaign goals to motivate such consumers to make pledges. These consumers are aware that unless the campaign goal to finance their preferred product is reached the product might never be produced. Crowdfunding campaigns also offer pecuniary rewards (e.g., a digital download of a crowdfunded album’s first single) that further incentivize the funders. When the early pledges of such consumers in the campaign exceed the reward that
the entrepreneur promises to pay them when the project is complete, these consumers with higher valuation for the product pay de-facto a higher price for it than those having lower valuation. Hence, crowdfunding has the potential to serve as a price discrimination device. This was likely the case for the team behind the movie Blue Mountain State who was able to use crowdfunding to raise $40 from each of 836 backers in exchange for the digital download of the movie and some product affiliated gifts (Falconer 2015).

However, the primary goal of crowdfunding campaigns is for entrepreneurs to raise capital to fund the development of new products. Many times campaigns offer entrepreneurs the opportunity to save significant amounts in financing costs. As a result, entrepreneurs may end up providing very generous rewards to funders in order to incentivize them to submit high pledges in the campaign. If, as a result, funders’ pledges fall short of such generous rewards, high valuation consumers end up paying a lower (rather than a higher) price in comparison to low valuation consumers. In such instances, crowdfunding fails as a price discrimination device. In this research we investigate conditions under which a crowdfunding campaign can, indeed, be used as a device to extract additional surplus from high valuation consumers. We also examine the entrepreneur’s choice of the pecuniary funder reward and campaign goal, two instruments that the entrepreneur can use to achieve the dual objective of raising funds to finance the project while successfully implementing price discrimination between high valuation and low valuation consumers.

Our model consists of two stages. In the first stage, the entrepreneur chooses the two instruments of the campaign: the campaign goal and the pecuniary funder reward geared towards incentivizing high valuation consumers to pledge in the campaign. At this stage, she can also offer other types of rewards of very little pecuniary value. Rewards such as inclusion in a social
club (access to information about the product), receiving a bumper sticker with the logo of the new product, or other forms of expressing “thank you” for the contribution. In the second stage, funders decide on the level of their contributions. We assume that only when the total funds raised in the campaign exceed the campaign goal can the entrepreneur and platform keep the contributions of funders. Otherwise, all contributions are returned to funders. (This is the rule used by Kickstarter.)

We distinguish between two types of funders. “Fans of the product”, who have very high valuation for the product that can ultimately be produced, and other funders who have a variety of reasons for backing the campaign, not necessarily related to their high valuation for the product. This second type may include funders who are altruistic in nature and whose motivation is to help the entrepreneur realize her dream. They may also be funders that like the idea of the project without actually planning to become consumers of the product. Examples may include environmentalists supporting “green” projects even if they do not plan to be consumers of the final product when it becomes available. We refer to and model the second type of funders as “random” funders, given the difficulty in identifying and predicting their behavior in the campaign. In contrast, we model “fans of the product” as strategic funders who choose their pledges strategically in response to the two instruments of the campaign, the campaign goal and the pecuniary funder reward, selected in the first stage. In their decision, strategic funders consider their expected surplus from consuming the product, the instruments set by the entrepreneur (campaign goal and funder reward), and the possibility to “free ride” on contributions of other funders (both strategic and random).

At the completion of the campaign if the aggregate contributions (i.e., sum of the pledges of strategic funders and random donations) exceed the campaign goal and if the total funding the
entrepreneur can raise (consisting of contributions from funders and the loan the entrepreneur can procure from outside funding sources) is sufficient to cover the development cost of the project, the product is produced and is sold to the consumer population. If the product is produced the entrepreneur distributes the pecuniary reward to the strategic funders.

We find that when the entrepreneur is very eager to raise funds through the crowdfunding campaign her ability to implement price discrimination between high and low valuation consumers is hindered. She is more eager to raise such funds when the total surplus from completion of the project is significant or when the development cost of the project and financing costs through traditional funding sources are high. In this case, the entrepreneur offers a more generous funder reward in order to encourage higher pledges from strategic funders and increase the likelihood, therefore, of a successful campaign and sufficient capital for the execution of the project. However, such a high reward limits the ability of the entrepreneur to successfully extract extra surplus from “fans of the product”.

In contrast, when the entrepreneur expects large contributions from “random” funders the relative importance of strategic funders in generating capital declines. This facilitates the entrepreneur to offer strategic funders a smaller reward. Similarly, when strategic funders’ valuation of the product is significantly higher than the price they anticipate to pay for it (namely, when their anticipated consumption benefits are high), they are highly motivated to contribute to the campaign as is, and the entrepreneur can cut the reward offered to strategic funders. This increases the entrepreneur’s ability to use crowdfunding as a means of price discrimination and to extract additional surplus from “fans of the product” in comparison to uniform pricing.
The entrepreneur can optimally choose the level of the campaign goal to supplement the choice of pecuniary funder reward. In this regard, the entrepreneur weighs two counteracting effects. On the one hand, lowering the campaign goal raises the odds that the less demanding goal can be reached and contributions raised in the campaign can be retained by the entrepreneur. On the other hand, a low campaign goal implies that strategic funders are less motivated to submit high pledges as they anticipate that the less demanding goal can be easily reached by contribution made by other funders. A lower campaign goal implies also that a bigger share of the development costs has to be financed via costly traditional funding sources.

We demonstrate that the entrepreneur has an incentive to raise the goal when she expects small contributions from random funders or when it becomes more expensive to fund the product through outside funding (borrowing from a bank). In such instances, it becomes more important for the entrepreneur to highly motivate strategic funders and obtain a bigger share of the development cost from the crowdfunding campaign. In contrast, when the entrepreneur can keep a bigger share of the campaign’s contributions, she is more determined for the campaign to be successful, and decreases, therefore, the campaign goal in order to increase the likelihood of a successful campaign. However, even when lowering the campaign goal the entrepreneur does not necessarily lower it that much to ensure that the goal can always be met. Instead, the entrepreneur finds it optimal to risk an unsuccessful campaign in order to more highly motivate strategic funders to submit high pledges, thus saving on capital costs and facilitating improved price discrimination among consumers.

Of particular interest, we also find that the entrepreneur will always set the campaign goal below the level that allows her to cover completely the development cost of the product. As a result, the entrepreneur chooses to sometimes procure a portion of the development costs via
traditional funding (i.e., a loan from the bank). While raising the campaign goal can help the entrepreneur to motivate more aggressive pledge behavior it also exposes her to the risk of a failed campaign when funds are insufficient to meet the more demanding goal. Given that the entrepreneur can also use the funder reward as an instrument to motivate strategic funders and given that a traditional outside funding source is available to the entrepreneur, she chooses the goal to be strictly lower than the level that allows her to cover the entire development cost.

Our research also illustrates the difference between crowdfunding and traditional vehicles that have been suggested in the literature in order to implement price discrimination. In this literature, the success of vendors to segment the market and practice price discrimination primarily depends on the extent of heterogeneity in the consumer population.

With crowdfunding, while the success of price discrimination still depends on the extent of heterogeneity among consumers, it also depends on a variety of other variables. These variables determine how eager the entrepreneur is to obtain funding from the campaign to finance the project in comparison to how eager fans are to ensure that the product becomes a reality. Successful price discrimination between high and low valuation consumers is more likely with crowdfunding if fans are relatively more eager for the product to become available than the entrepreneur is about covering most development costs from the campaign. In our model, fans are more eager when they expect only small contributions from random funders and therefore have fewer opportunities to free ride. The entrepreneur is less eager when the new venture generates a relatively small total consumer surplus or when development cost of the project and financing costs through traditional funding sources are relatively low. In this case, the entrepreneur has reduced incentives to motivate strategic funders, and therefore, offers them only a modest reward. This permits her to extract greater surplus from funders via their early pledges.
Our research is related to several streams of literature. First is the literature on price discrimination. This literature examines different devices that can be used to price discriminate between segments of consumers such as coupons (e.g., Narasimhan 1984), bundling (e.g., Adams and Yellen 1976) and quality pricing (Mussa and Rosen 1979). We introduce in this paper a novel device that can help entrepreneurs to benefit from price discrimination while raising funds for their projects. Crowdfunding is most similar to advance purchase discounts (e.g., Dana 1998, Nocke et al. 2011) typically used in pricing of service products (e.g., in hotel industry) in that both use time as the means to segment the consumers. The main difference between the two is the segment to which higher prices are charged. In advance purchase discounts consumers who buy late pay higher prices because they have higher valuations. In crowdfunding, however, high valuation funders whose early pledges exceed the campaign reward effectively pay higher prices than those who wait for the product to be available on the market.

Another related literature is on fundraising of a discrete public good (e.g., Cadsby and Maynes 1999, Menezes et al. 2001, Palfrey and Rosenthal 1984 and 1988) in which case these goods are provided only if a distinct funding threshold is met. In our paper, as well, there is a funding goal which must be met before the entrepreneur receives the funders’ contributions. It can then use these contributions to develop the product. However, in our paper the funding goal is set endogenously by the entrepreneur, whereas in this literature it is exogenously determined by the cost of the good. As well, the entrepreneur can set an additional campaign incentive (i.e., campaign reward) to further motivate funders to contribute to the campaign.

There is an emerging literature on crowdfunding. Most of the research in this area, however, is empirical (e.g., Agrawal et al. 2015, Mollick 2014, Ward and Ramachandran 2010).
The empirical literature supports the claim that funders are strategic and pay attention to various campaign variables when choosing to donate. For instance, Mollick (2014) provides evidence that perceived project quality affects the success of the campaign.

Hu, Li, and Shi (2015) use analytical modeling to explore crowdfunding. They examine the manner in which a project creator offers different product options in a crowdfunding campaign. Each of the product alternatives in Hu et al. (2015) corresponds to a different level of reward that the creator offers in exchange for a particular pledge level requested from buyers. The authors find that price discrimination with a menu of products can be more profitable than uniform pricing. A novel finding of their paper is that in comparison to a traditional product line design setting, the qualities of the products are less differentiated in crowdfunding. We also examine the possibility that crowdfunding can facilitate price discrimination. However, we focus on investigating whether the need of entrepreneurs to raise funds in the campaign may limit their ability to practice price discrimination. We incorporate, therefore, in the model development costs of the project and financing costs from traditional funding sources in order to evaluate how the instruments of the campaign (funding reward and campaign goal) and the entrepreneurs’ ability to practice price discrimination depend upon such costs. In contrast to the product line design in Hu et al. (2015), in our setting there is only one basic product and one reward level. Price discrimination is successful if fans of the product, via their early pledges, pay de-facto a higher price than low valuation consumers.

**MODEL**
Consider an entrepreneur with an idea for a new product. The entrepreneur seeks funding to cover the development cost $K$ of the new product. To this end, she tries to raise capital for her project by tapping the crowd on a platform. When creating the crowdfunding campaign, the entrepreneur has two strategic decisions she must make. First, she must set a campaign goal $F$ for the aggregate contributions. Only if aggregate contributions exceed this goal the campaign is considered successful. If these contributions fall short of the goal, the campaign is declared unsuccessful and they are returned to the funders.

Second, the entrepreneur makes the strategic choice of the level of the promotional funder reward $\Delta$ to be awarded to funders whose contribution exceeds a certain predetermined threshold. The funder reward corresponds to the future transfer of funds between the entrepreneur and the funders if the new product is successfully developed. Given that many rewards in crowdfunding campaigns are tied to the production of the product (e.g., a pre-order of the product or a digital copy of the first single on an album) we assume that the funder reward is given to backers only after production occurs. We also assume that concerns regarding her reputation prevent the entrepreneur from reneging on the promised reward once the product is produced. Indeed, empirical evidence shows that most entrepreneurs deliver on their promised rewards upon successful production of their products (Mollick 2014).

In order for production to take place, the entrepreneur must raise enough funds to cover the cost $K$ of developing the product. If the funds available to the entrepreneur exceed the development cost, the entrepreneur incurs the development cost and the product is produced. Products produced are sold to consumers and rewards are distributed to backers of the crowdfunding campaign. Without loss of generality we assume that other than the development cost $K$, the entrepreneur incurs no additional production costs.
We allow for the entrepreneur to have access to traditional sources of funding in addition to funds raised in the crowdfunding campaign. Increasingly entrepreneurs are utilizing crowdfunding websites to finance only part of the development cost of their projects, hoping that successful campaigns attract traditional investors to complete the investment necessary to cover the entire cost of the projects (Geigner 2013). To account for this possibility, we consider an environment where the entrepreneur may have access to funding sources other than the crowd. We model the possible outside funding source that is available as a lender that may provide funds to the entrepreneur at an interest rate $s$.

We assume that when the entrepreneur approaches the lender with news of a successful crowdfunding campaign, she can definitely secure funds from the lender to cover the shortfall between the contributions collected in the campaign and the development cost. In contrast, a failed campaign may signal lack of demand for the product or a risky investment. Further, such a failure may raise a “red flag” regarding the managerial skills of the entrepreneur. Her failure to attain the goal of the campaign may be interpreted by the lender as inability to set realistic objectives. Therefore, an entrepreneur who approaches the lender with news of a failed campaign faces uncertainty regarding her ability to obtain funding from the lender. We model this uncertainty by assuming that following a failed campaign the lender approves a loan to the entrepreneur with probability $q < 1$. In case of a failed campaign, however, the entrepreneur has to secure a loan of $K$ because she cannot keep any portion of the contributions when the goal of the campaign is not met.

In addition, we assume that raising sufficient capital to cover the development cost of the product does not necessarily guarantee that the product will become a reality. Because entrepreneurs may run into difficulties while developing the product or may make poor estimates
of the cost of the project, it is sometimes the case that an entrepreneur is unable to introduce the product in the marketplace or may be unable to deliver the promised quality level (e.g., may have to renege on certain features) even after she collects sufficient funds to cover its anticipated cost. An investigative article found that out of the top 50 projects on Kickstarter, at the time of the article 15 projects had not been delivered to their backers as promised (Pepitone 2012).

Therefore, we introduce a probability that is associated with the technical success of the product which we denote by $p < 1$. This probability is known to the entrepreneur, consumers who plan to pledge in the campaign, and the platform.

If the entrepreneur is able to develop and produce the product, she sells it as a monopolist. This assumption is reasonable as many crowdfunding projects are for new products that are intended to ultimately serve niche markets: an electric skateboard, a 3D printer pen, a farm-to-table organic restaurant, etc.

The entrepreneur’s new product appeals to two types of consumers. The first type consists of $n$ high valuation consumers having the reservation price $r_H$. We refer to these high valuation consumers as “fans of the product”. Because all fans of the product share the same valuation in our formulation, the entrepreneur chooses a single minimum threshold that entitles funders to receive the pecuniary reward. The entrepreneur sets it equal to the pledge level selected by strategic funders at the equilibrium, $D$. Any pledge equal or above this threshold is eligible for the reward.

The bulk of the market comprises of consumers who have much lower valuation for the product. There are $m$ consumers in the second group and their valuation is $r_L < r_H$. We assume that if the product is successfully developed the entrepreneur finds it optimal to set the price of the product at $r_L$ because the segment of low valuation consumers is so big, that it makes it
profitable for the entrepreneur to set the price to ensure that the entire market is covered (i.e., all 
\( n + m \) consumers are served). We assume that the low valuation segment of consumers is 
unaware of the campaign. In the Appendix we relax this assumption and allow for a portion of 
these consumers to be aware of the campaign.

There are two types of funders whose contributions the entrepreneur can attract through 
the crowdfunding platform. Strategic funders are the “fans of the product” who choose their 
pledges \( D_l \) (or \( D \) at the symmetric equilibrium) strategically to maximize their expected payoff. 
This expected payoff depends upon the fans’ expected surplus from consuming the product and 
the promotional funder reward \( \Delta \) that they receive if they make a pledge and the product is 
successfully developed. The expected payoff depends also on the threshold total contribution 
level \( F \) and any expected contributions from other funders which together determine the 
likelihood of the successful completion of the project.

The second type of funders consists of random funders who make contributions either 
because of altruistic reasons or because they like the project but do not necessarily plan to 
become consumers of the product. We assume that the pledges submitted by random funders do 
not qualify them for the reward \( \Delta \). Instead, they receive rewards of very little pecuniary value. 
Examples may include being a member of a social “founders club”, receiving a bumper sticker 
with the logo of the new product, or receiving other tokens of appreciation for the contribution. 
We designate the aggregate level of random donations by \( x \) and assume that \( x \) is stochastically 
determined according to a uniform distribution over the support \( [0, \bar{x}] \). Moreover, we assume 
that each of these donations is so small that it falls short of any threshold level that would qualify 
the random funder for the pecuniary reward or that the random funder opts to receive no reward. 
Indiegogo is one crowdfunding website that facilitates inferring some information regarding the
size of the segment of funders who do not anticipate receiving any significant reward in return for their contribution. This website posts the pledge level submitted by each funder as well as the number of funders who opt to receive no reward for their contribution. Based on information regarding two campaigns that were ongoing on October 9, 2015, this segment of what we designate as random funders appears to be quite substantial. In the case of Dipper Audio Necklace that was 63% funded on this day, about 40 out of a total of 128 funders (about 30%) did not anticipate any pecuniary reward. In the case of Wine Down SF that was 48% funded on this day, 10 out of 62 backers (about 16%) did not expect any such reward.

Notice that in addition to raising funds and thereby saving on capital costs, the crowdfunding campaign can enable the entrepreneur to price discriminate between fans of the product and lower valuation consumers. Because pledges are paid with certainty in the campaign and the reward is paid only with some probability if the product becomes available in the market, price discrimination can be implemented if $(D - p\Delta) > 0$, namely if the pledge exceeds the expected future reward paid upon completion of the product. In this case, high valuation consumers pay de-facto a higher price than low valuation consumers (i.e., they pay in expectation $D + p( r_L - \Delta)$ whereas the lower valuation consumers pay in expectation $pr_L$).

The crowdfunding platform is tasked with bringing together funders and entrepreneurs. For its service of bringing together the two populations, the platform keeps a percentage of the aggregate contributions. We designate by $\alpha$ the percentage of the aggregate contributions that the entrepreneur can keep. (For campaigns on Kickstarter, this is between 90-92% including 5% Kickstarter fee and 3-5% processing fees).

We model the crowdfunding campaign as a two stage game. In the first stage, the entrepreneur sets the levels of the campaign goal $F$ and the funder reward $\Delta$. In the second stage,
strategic funders decide how much to pledge $D_i$ and nature determines the realization of the donations raised randomly $x$. At the completion of the campaign if the aggregate funds raised (i.e., pledges of strategic funders and random donations) exceed the campaign goal, and if the total funding the entrepreneur can raise (including the possible loan the entrepreneur can get from the lender) are sufficient to cover the development cost $K$, the product has the potential to be produced. Once sufficient funds are raised, the product will be produced with probability $p$. If the product becomes available, it is sold to $m+n$ consumers and the reward $\Delta$ is distributed to the $n$ strategic funders.

**ANALYSIS**

**Pledge Behavior of the Strategic Funders**

To obtain subgame perfect equilibrium, we start by considering the second stage when strategic funders choose their pledges. Strategic funders are aware of the fact that the entrepreneur has access to an outside funding source and consider this when choosing how much to pledge. They know, therefore, that as long as the crowdfunding campaign is successful ($\left(\sum_{i=1}^{n} D_i + x\right) \geq F$), the entrepreneur will be able to secure any additional funds needed to cover the development cost of the project through outside funding. However, strategic funders know that with probability $(1 - p)$, the entrepreneur may not be able to produce the product as planned. This exposes the funders to the risk of losing their investment (pledge) without obtaining the promised benefits from consumption of the product and the funder reward. Additionally, because strategic funders know that the project may be fully funded even when the crowdfunding campaign is unsuccessful (with probability $q$ when $\left(\sum_{i=1}^{n} D_i + x\right) < F$), they may have muted incentives to
contribute to the campaign, as they expect positive odds for the product to be available even in the absence of their contributions. Specifically, they anticipate that with some probability the project will be executed even when they reduce their contributions and the goal of the campaign is not met.\(^3\)

The above discussion leads to the following expression for the expected utility of strategic funder \(i\):

\[
EU_i = \int_{F-D_i}^{\bar{F}} \left( p(r_H - r_L + \Delta) - D_i \right) f(x) \, dx + pq \int_{0}^{F-D_i} \left( r_H - r_L \right) f(x) \, dx.
\]

The first integral of (1) is the expected net payoff of the funder when the goal of the campaign is met. With probability \(p\) the product is produced as planned and the funder receives the funder reward \(\Delta\) and proceeds to buy the product yielding a consumption net benefit of \(r_H - r_L\). However, the funder must pay his pledge \(F\) upfront, when the goal of the campaign is met, even if the product is never produced. The second integral is the strategic funder’s net payoff when the campaign fails, in which case he can benefit from consuming the product with some probability \(pq\) that is strictly less than one (\(q\) is the probability that the entrepreneur can receive funding from the outside source given a failed campaign and \(p\) is the probability that the product will be produced given sufficient funding). Strategic funder \(i\) chooses his pledge level \(F_i\) to maximize (1). Strategic funders face a tradeoff when choosing \(F_i\). A higher pledge level increases the probability that the campaign will be successful and the product will be produced, but decreases funder \(i\)’s welfare when the campaign is successful.

Note that in modeling the behavior of strategic funders we assume that they have the freedom to optimally set their pledge level. Essentially we assume that the crowdfunding platform follows a Name Your Own Price (NYOP) model instead of a Posted Price (PP) model, where the pledge level necessary to receive a certain reward would be dictated by the platform.
The reason we make this assumption is consistent with the mechanics of Kickstarter in which after selecting a reward the funder gets to choose his exact contribution level. Additionally, one can observe that there is heterogeneity in the pledge levels submitted by participants on crowdfunding campaigns even when expecting an identical reward in return for the pledge. Such heterogeneity implies that each funder chooses to name a different price for a given reward, an outcome consistent with the NYOP model. Further, it turns out that the NYOP model yields simpler derivations than the PP model without qualitatively changing the main results of the paper. In particular, the effect of changes in the instruments of the campaign ($F$ and $\Delta$) on the pledge level submitted by strategic funders is similar under the PP and the NYOP models. The Appendix includes the derivation of the behavior of strategic funders under the PP model. Using (1) and solving for the symmetric pledge strategy yields the behavior reported in Lemma 1.

**Lemma 1**

*The pledge behavior of each strategic funder can be expressed as follows:*

$$D = \frac{p((1-q)(r_H - r_L) + \Delta) + F - \bar{x}}{n+1}.$$  

The equilibrium pledge increases when the spread in the valuations of the product in the consumer population, as measured by $(r_H - r_L)$ is higher. This difference in valuations determines the future surplus from consumption that “fans of the product” can expect. Note that the expected future consumption surplus declines when the probability of technical success of the product $p$ is lower, thus reducing the incentive of funders to contribute to the campaign. Similarly, strategic funders reduce their contribution when the probability $q$ that the entrepreneur can obtain outside funding after a failed campaign $q$ is higher. The equilibrium pledge increases
when either one of the two instruments that the entrepreneur chooses is bigger (either the funder reward $\Delta$ or the campaign goal $F$), when surplus from consumption $(r_H - r_L)$ is higher, when the maximum random donation $\overline{X}$ is smaller, and when the number of strategic funders $n$ is smaller.

As the surplus from consumption $(r_H - r_L)$ increases, strategic funders increase their pledge in order to raise the probability that they will be able to consume the product in the future (we refer to this as the “consumption effect”). As the funder reward $\Delta$ increases, strategic funders pledge more to increase the probability that they will be able to receive the bigger reward. The increase in the pledge level in both of these instances depends, however, on the probability $p$ that the product will be produced because funders receive no consumption or reward benefits when the product is not produced. When the campaign goal $F$ increases, the likelihood of a successful campaign declines, and it is less likely that the product will be produced. Strategic funders try to reverse this possibility by increasing their pledge. We refer to the effect of changes in the levels of the instruments $\Delta$ and $F$ as the “instrument effect”. Note that in our environment the effect of either instrument on the pledge behavior of strategic funders is identical. The pledge function depends simply on the sum of the two instruments. When either the maximum level of random donations $\overline{X}$ increases or the number of strategic funders $n$ increases each strategic funder has stronger incentives to “free ride” on the contributions of other funders, thus reducing his willingness to pledge himself (we refer to this as the “free riding effect”). The comparative statics we obtain from (2) would remain unchanged if we assumed that the pledge level is set by the platform instead of chosen optimally by strategic funders (see Appendix.)

The Entrepreneur’s Choice of the Campaign Goal and Reward
In the first stage the entrepreneur chooses the two campaign instruments $\Delta$ and $F$ to maximize her expected profit. When choosing these instruments, the entrepreneur tries to attain the dual objective of motivating more aggressive pledge behavior by strategic funders and of aligning more closely the payments of different consumer groups with their willingness to pay for the product. By offering strategic funders the opportunity to submit pledges in the campaign the entrepreneur can extract additional surplus from fans of the product. Moreover, higher pledges allow the entrepreneur to save on capital costs.

Whenever aggregate contributions exceed the campaign goal $F$, the entrepreneur is able to keep her fraction of the revenue from the campaign (given the equilibrium pledges of strategic funders this fraction amounts to $\alpha(nD + x)$). The actual execution of the project takes place, however, only when the entrepreneur is able to raise enough money to cover the development cost $K$. As mentioned earlier, because successful campaigns are interpreted by outside investors as a positive signal of demand for the product we assume that if the goal of the campaign is met the entrepreneur can raise any remaining funds necessary to cover the development cost $K$ through an outside funding source at interest rate $s$. In addition, recall that with probability $q$ the product may still be produced even after a failed campaign. Given the equilibrium pledge strategy $D$ of each strategic funder, the expected profit of the entrepreneur can be expressed by the following piecewise profit function:

$$
(3) \quad E\pi_E =
\begin{cases}
\omega + \int_{\alpha - nD}^{\alpha nD} [p(n + m)r_L + (\alpha(nD + x) - pm\Delta - K) - s(K - \alpha(nD + x))] f(x)dx \\
\quad \quad + \int_{\bar{x}}^{\alpha nD} [p(n + m)r_L + (\alpha(nD + x) - pn\Delta - K)] f(x)dx & \text{if } F < \frac{K}{\alpha} \\
\omega + \int_{F - nD}^{\bar{x}} [p(n + m)r_L + (\alpha(nD + x) - pn\Delta - K)] f(x)dx & \text{if } F \geq \frac{K}{\alpha}
\end{cases}
$$
where $\omega = q \int_0^{F-nD} [p(n + m)r_L - (1 + s)K] f(x) dx$.

The expected profit expression depends on whether the campaign goal is set below or above $K/\alpha$, which we refer to as the gross-cost of the project. The first term $\omega$ appears in the expected profits of the entrepreneur irrespective of whether the campaign goal is set below or above the gross-cost of the project. It measures the expected payoff of the entrepreneur when the campaign fails. In this case, if the lender is willing to make a loan to the entrepreneur (happens with probability $q$) the entrepreneur will cover the development cost by borrowing the entire funds from the lender at an interest rate $s$. She will earn, therefore, the difference between expected revenues $p(n + m)r_L$ and the overall cost of $(1 + s)K$ of financing the project.

The remaining terms depend on whether the entrepreneur chooses the campaign goal below or above the gross-cost of the project $K/\alpha$. If the goal is chosen below the gross-cost two possibilities may arise. The first possibility is that the campaign is successful but insufficient funds are available to cover the entire cost of the project. In this case, the entrepreneur has to borrow the shortfall $(K - \alpha(nD + x))$ and pay the interest rate $s$ on these funds. The second term of the expected profits when $F < K/\alpha$ corresponds to this possibility. The second possibility is that the campaign has raised sufficient funds to cover the entire development cost, in which case the entrepreneur does not need to borrow any additional funds. The third term of the expected profits when $F < K/\alpha$ corresponds to this possibility. Note that the product will be produced as promised with probability $p$ irrespective of whether sufficient funds to cover the entire cost have been raised in the campaign, implying that the entrepreneur has to pay the funder reward in each of these two possibilities only when the product is indeed produced. When the goal is chosen above the gross-cost of the project, whenever the campaign is successful it also generates sufficient funds to cover the entire development cost. As a result, the entrepreneur does
not need to borrow any additional funds in this case. The second term of the expected profits when \( F \geq K/\alpha \) corresponds to this event.

The entrepreneur chooses the instruments \( \Delta \) and \( F \) to maximize her expected profit in (3) subject to the constraint that the optimal pledge strategy of each strategic funder is given by (2). A higher campaign goal \( F \) encourages the strategic funders to contribute more to the campaign in order to increase the likelihood of reaching the higher goal as well as extracting additional surplus from strategic funders. However, this higher goal decreases the probability of a successful campaign and thus the potential for the entrepreneur to earn profits by selling the product in the market.

Similarly, a larger reward \( \Delta \) incentivizes strategic funders to make more aggressive pledges but reduces the profit of the entrepreneur when she is able to produce the product. A larger \( \Delta \) may help the entrepreneur extract surplus from funders because it induces the strategic funder to contribute more to the campaign, however a larger \( \Delta \) can effectively decrease the realized price that strategic funders must pay for the product because it results in a larger transfer of funds from the entrepreneur to the funders.

We first derive the optimal funder reward \( \Delta \) for a fixed value of \( F \) and calculate the elicited pledge \( D^* \) given the optimal funder reward \( \Delta \). Both the funder reward \( \Delta \) and aggregate strategic pledges \( nD^* \) are fully characterized in the Appendix (see equations A.4 and A.5). It is interesting that the expression for the optimal funder reward remains the same irrespective of whether the campaign goal is set above or below the gross-cost of the development. Because the funder reward has to be paid to strategic funders if the product becomes available in either of these two cases, the entrepreneur chooses its value to be the same regardless of whether \( F < \)
\( K/\alpha \) or \( F \geq K/\alpha \). We report comparative statics for the optimal value of the funder reward \( \Delta \) in Proposition 1.

**Proposition 1**

*For a fixed value of \( F \), the optimal value of the funder reward \( \Delta \):*

(i) Increases when the total surplus generated by the project (as measured by the difference between the expected total willingness to pay of consumers and the development cost, \( p(nr_H + mr_L) - K \)) is bigger and when either the maximum level of random donations \( \bar{X} \) or the gap in valuations \( r_H - r_L \) are smaller.

(ii) Increases when the campaign goal \( F \) is raised and when the interest rate \( s \) increases.

(iii) Increases with the sharing rule \( \alpha \).

When the project generates a larger surplus the entrepreneur is more highly motivated to execute the project, and therefore, offers a larger reward to strategic funders in order to ensure that sufficient capital to cover the development cost becomes available. In this case, the entrepreneur has greater interest in raising enough capital to produce the product than extracting surplus from the strategic funders, which limits her ability to price discriminate (i.e., a larger \( \Delta \) reduces the effective price premium paid by the strategic funders for the product \( D - p\Delta \)).

In contrast, when the entrepreneur expects high levels of random donations, the relative importance of strategic funders in generating capital declines, and the entrepreneur offers them a smaller reward. Even though free riding from strategic funders becomes more prevalent in this case, the entrepreneur is actually able to extract more surplus from each funder because she does not need to rely as much on the reward to motivate these funders.
Similarly, when the benefit that “fans of the project” derive from the product \((r_H - r_L)\) is higher, they are highly motivated as is, and the entrepreneur cuts the reward offered to strategic funders. This again leads to favorable conditions for extracting consumer surplus from strategic funders enhancing the entrepreneurs’ ability to price discriminate.

Raising the campaign goal requires the entrepreneur to raise the funder reward in order to provide extra incentives to strategic funders to increase their contribution and ensure that the more demanding goal is met. This result demonstrates the two counteracting effects on the ability of the entrepreneur to extract surplus from fans of the product when raising the campaign goal. From (2) raising the goal motivates strategic funders to pledge more aggressively. However, given that it also reduces the likelihood that the more demanding goal can be met it requires the entrepreneur to reward strategic funders more generously in order to reduce the likelihood of a failed campaign.

As the interest rate \(s\) increases, the entrepreneur increases the reward because it becomes costlier to finance the project through loans. The entrepreneur is intent, therefore, of raising more funds in the crowdfunding campaign by providing extra rewards to funders. This, once again, shows that the need to finance the product by using the crowdfunding campaign as a means of raising capital may weaken the ability of the entrepreneur to use the campaign as a device to successfully implement price discrimination between high and low valuation consumers.

The effect of the sharing rule \(\alpha\) on the funder award is implied by the fact that when the entrepreneur is entitled to a bigger share of the product’s revenue she is more highly motivated to increase the likelihood that the project is executed. As a result, she offers strategic funders a more generous reward to ensure that they submit higher pledges. While a larger reward \(\Delta\) is
typically associated with a muted ability to extract surplus from consumers, a higher $\alpha$ also allows the entrepreneur to keep a larger share of each of the contributions made by strategic funders.

Having established the optimal funder reward as a function of $F$ as given in Proposition 1, we now turn to the derivation of the optimal campaign goal $F$. We start by considering the region $F \geq K/\alpha$. After substituting $\Delta$ and $nD^*$ back into the objective of the entrepreneur (3), we take the derivative of the entrepreneur’s expected profits when $F \geq K/\alpha$ with respect to $F$ and obtain:

$$
\frac{\partial E\pi_{Fz}}{\partial F} = \frac{-(1-\alpha)[(1-q)(p(nr_H+mr_L)-K)+Ksq-(1-\alpha)F+X]}{X(2n+2-\alpha)} = \frac{(1-\alpha)[X+nD^*-F]}{X} < 0.
$$

The last inequality follows because $X + nD^* - F > 0$ is necessary to ensure that there is a positive probability that the campaign is successful for some realization of the random variable $x$. Proposition 2 is a direct result of the sign of (5).

**Proposition 2**

The entrepreneur will never find it optimal to set the campaign goal $F$ above the gross-cost threshold $K/\alpha$.

Recall that $F$ and $\Delta$ are substitutable instruments in affecting the pledge of a strategic funder in (2) because the equilibrium pledge depends on the sum of these two variables. However, raising the campaign goal in the region $F \geq K/\alpha$ in order to motivate more aggressive pledge behavior may be risky for the entrepreneur because a higher goal reduces the probability of a successful campaign and the likelihood that the product is ever produced. Hence, in this
region the entrepreneur is more inclined to utilize the instrument $\Delta$ to motivate higher pledges while keeping the campaign goal as low as possible (i.e., $F = K/\alpha$.)

Next we consider the region $F < K/\alpha$. Designating by $E\pi(F)$ the expected payoff of the entrepreneur as a function of the campaign goal, it is easy to see from the objective function of the entrepreneur in (3) that:

\[
E\pi(F)_{|F < \frac{K}{\alpha}} = E\pi(F)_{|F = \frac{K}{\alpha}} - \frac{a\pi F}{2X}.
\]

Taking the derivative of the right hand side of (6) with respect to $F$ while using (5) yields that

\[
\frac{\partial E\pi_{|F < \frac{K}{\alpha}}}{\partial F} = \frac{-(1-\alpha)[(1-q)(p(nr_H+mr_L)-K)+Ksq-(1-\alpha)F+\bar{X}]}{X(2n+2-\alpha)} + \frac{a\pi}{X} \left(\frac{K}{\alpha} - F\right).
\]

Differentiating the right hand side of (6) with respect to $F$, once again, yields:

\[
\frac{\partial^2 (E\pi_{|F < \frac{K}{\alpha}})}{\partial F^2} = \frac{(1-\alpha)^2}{X(2n+2-\alpha)} - \frac{a\pi}{X}.
\]

This second order derivative of the profit function is negative if $T \equiv 2\alpha(1 + s + ns) - \alpha^2(1 + s) - 1 > 0$, in which case the objective of the entrepreneur is a concave function of $F$.

This latter condition for concavity is very likely to be satisfied for reasonable values of the parameters of the model.\textsuperscript{4} Assuming that concavity holds we can set the derivative in (6) equal to zero and solve for $F$ to obtain the solution:

\[
F^* = \frac{(2n+2-\alpha)sK-(1-\alpha)[(1-q)(p(nr_H+mr_L)-K)+Ksq+\bar{X}]}{2\alpha(1+s+ns)-\alpha^2(1+s)-1}.
\]

This solution should satisfy the constraint that $nD^* \leq F^* \leq K/\alpha$ to ensure that it falls in the feasible region. The lower bound on $F^*$ is necessary to ensure that the probability of a successful campaign does not exceed 1 and the upper bound is necessary given the result reported in Proposition 2.
Proposition 3

(i) The entrepreneur chooses the campaign goal $F = F^*$ at the interior of the region $\left( nD^*, \frac{K}{\alpha} \right)$:

If either the development cost of the product or the maximum level of random giving is relatively high (when $K > K_{LB}$ or $\bar{X} > \bar{X}_{LB}$, where $K_{LB}$ and $\bar{X}_{LB}$ are defined in the Appendix.)

(ii) The entrepreneur chooses the campaign goal $F = nD^*$:

If either the development cost of the product or the maximum level of random giving is relatively low (when $K < K_{LB}$ or $\bar{X} < \bar{X}_{LB}$).

(iii) The entrepreneur never chooses the campaign goal so that $F = \frac{K}{\alpha}$.

When the development cost $K$ is relatively high or when the maximum level of random donations $\bar{X}$ is relatively high the entrepreneur chooses the campaign goal to be strictly smaller than $K/\alpha$ and bigger than $nD^*$, implying that the campaign may sometimes be unsuccessful (i.e., when $nD^* + x < F$ ) and even when it is successful the entrepreneur finances only part of the development cost with funds raised from the campaign and part with outside funding (i.e., when $F < nD^* + x < K/\alpha$). In this situation, the entrepreneur is willing to risk an unsuccessful campaign in order to receive additional funds from the strategic funders that can enable her to save on capital costs and price discriminate better. Further, by raising the campaign goal (i.e., setting it over $nD^*$), she can reduce the incidence of free riding by strategic funders who may think their contributions are not needed for the campaign to be successful.
When the development cost $K$ is very low or when the maximum level of random donations $\bar{X}$ is relatively modest part (ii) of the Proposition states that the entrepreneur chooses $F$ at the minimum feasible level to ensure that the campaign is always successful; specifically, because $F = nD^*, nD^* + x$ is always bigger than $F$. When $K$ is relatively small there is no need to raise a lot of funds given the low level of development cost. As a result, the entrepreneur does not have to raise the goal above the minimum in order to motivate strategic funders to raise their pledges. Similarly, when $\bar{X}$ is relatively small strategic funders have reduced incentives to “free ride” on random donations, given that these donations are relatively small. As a result, strategic funders are motivated to submit high pledges even when the goal is set at the lowest possible level.

According to part (iii) of the Proposition the entrepreneur does not choose the goal so high to ensure that she never utilizes the outside funding source. Because of the availability of this source the entrepreneur is never so desperate to guarantee that the entire amount of the development cost is raised in the campaign. A direct inspection of the expression derived for $F^*$ in (9) yields the comparative statics reported in Corollary 1.

**Corollary 1**

When $nD^* < F^* < \frac{K}{\alpha}$, the campaign goal is an increasing function of $K, s, and q$ and it is a decreasing function of $\bar{X}, nr_H + mr_L, p,$ and $\alpha$.

When more funds are required to execute the project (higher $K$) or when it becomes more expensive to finance the development cost with outside funding (higher $s$), the entrepreneur raises the goal in order to more highly motivate the strategic funders and obtain a
bigger share of the development cost from the crowdfunding campaign. When the probability $q$ of outside funds becoming available even after a failed campaign is higher the entrepreneur is less concerned about the consequences of raising the campaign goal. Even if this higher goal is not met outside funds are still likely to be available in this case. When the importance of strategic funders to the entrepreneur declines because the random donations are more significant ($\overline{X}$ is bigger) the entrepreneur reduces the campaign goal because motivating strategic funders is less important to her in this case. When the total consumer surplus is bigger the entrepreneur increases the funder reward $\Delta$ in order to generate higher pledges from strategic funders. Given that $\Delta$ and $F$ are substitute instruments in motivating the strategic funders the entrepreneur can reduce the level of the campaign goal when $nr_H + mr_L$ increases or when the probability $p$ that a funded campaign turns into a finished product increases. When the entrepreneur obtains a bigger share of the product’s revenue (when $\alpha$ is bigger) she is more determined for the campaign to be successful. She reduces, therefore, the campaign goal in order to increase the likelihood that the lower goal is reached.

**Price Discrimination with Crowdfunding**

We have argued that crowdfunding may play a dual role for the entrepreneur. While serving the basic function of raising funds to finance the new venture it may also serve as an effective price discrimination device if it can facilitate extraction of additional surplus from “fans of the product” in comparison to uniform pricing. Enhanced surplus extraction arises at the equilibrium if the expected funder reward $p\Delta$ falls short of the share of the equilibrium pledge of each strategic funder that the entrepreneur can retain, namely $aD^*$. However, because of her need to raise capital it is unclear whether the entrepreneur can necessarily extract extra surplus from
“fans of the product”. In Proposition 4 we assume that the conditions supporting an interior solution for \( F \) are valid (i.e., at \( nD^* < F = F^* < K/\alpha \)), and we investigate circumstances under which enhanced consumer surplus extraction is possible, namely the share that the entrepreneur keeps from a contribution is bigger than the reward she must pay to a strategic funder, in case the project is successfully completed (\( \alpha D^* > p\Delta \)).

**Proposition 4**

The entrepreneur can extract additional surplus from “fans of the product” in comparison to uniform pricing provided that:

\[
p(1 - q)(r_H - r_L) > \frac{\frac{z(a[(1-q)p(nr_H + mr_L) + \bar{X}] - K[1 - aq - aqs])}{2a(1+s+ns) - \alpha^2(1+s) - 1} + \frac{z(a[(1-q)p(nr_H + mr_L) + \bar{X}] - K[1 - aq - aqs])}{2a(1+s+ns) - \alpha^2(1+s) - 1}}{2a(1+s+ns) - \alpha^2(1+s) - 1},
\]

where the right hand side of (10) is strictly positive.

The fact that the right hand side of (10) is positive implies that for crowdfunding to support price discrimination the extent of heterogeneity in the population, as measured by the gap in valuations \( (r_H - r_L) \) has to exceed a certain threshold. This extent of heterogeneity determines the strategic funder’s net consumption benefit from submitting a pledge. Because another important objective of the campaign besides surplus extraction is to raise funds, fans of the project have to be especially enthusiastic about the product to enable the entrepreneur to extract additional surplus from them in comparison to uniform pricing.

Condition (10) in Proposition 4 is more likely to hold the bigger the extent of heterogeneity in the consumers’ valuations of the product \( (r_H - r_L) \), the smaller the maximum level of random donations \( (\bar{X}) \), and the smaller the total consumer surplus \( (nr_H + mr_L) \). In these instances the entrepreneur provides a modest funder reward to strategic funders because her
negotiating position relative to that of strategic funders improves. For instance, when the gap \( r_H - r_L \) is relatively big strategic funders are motivated anyhow to submit high pledges even when the funder reward is relatively modest. Similarly, when random donations are relatively small (\( \bar{X} \) is relatively small), strategic funders have reduced incentives to “free ride” on funding by others, thus permitting the entrepreneur to reduce the funding reward and extract greater surplus from strategic funders. When \( nr_H + mr_L \) is small, the entrepreneur has reduced incentives to motivate strategic funders to submit high pledges, and she offers them, therefore, a smaller reward.

Note that the values of \( K \) or \( s \) have an ambiguous effect on the ability of the entrepreneur to extract additional surplus from fans because the right hand side of (10) may increase or decrease with \( K \) or with \( s \). To explain the ambiguity, consider, for instance, an increase in the development cost \( K \). On the one hand, when \( K \) increases, the net value of the project declines and the entrepreneur is less eager, therefore, to execute the project. On the other hand, a bigger value of \( K \) implies that the entrepreneur is more eager to raise funds in order to save on financing costs. In particular, when financing cost \( s \) is sufficiently high so that \([1 - aq - aqs] < 0\), as \( K \) increases it becomes more difficult for the entrepreneur to extract additional surplus from fans of the project because the right hand side of (10) increases. The argument is reversed if \( s \) is sufficiently small.

The result reported in Proposition 4 vividly illustrates the difference between crowdfunding and traditional vehicles that have been suggested in the literature in order to implement price discrimination. In the literature on quality differentiation, for instance, the success of vendors to segment the market and practice price discrimination primarily depends on the extent of heterogeneity in the consumer population (the spread \( r_H - r_L \) in our model).
crowdfunding, while the success of price discrimination still depends on the extent of heterogeneity among consumers, it also depends on a variety of other variables. These variables determine how eager the entrepreneur is to obtain funding from the campaign to finance the project in comparison to how eager fans are to ensure that the product becomes a reality. Successful price discrimination between high and low valuation consumers is more likely with crowdfunding if fans are relatively more eager for the product to become available than the entrepreneur is about covering most development costs from the campaign.

One example in which price discrimination was likely achieved was the campaign for the movie Blue Mountain State. In the campaign, the project creator offered funders a digital download of the movie as well as some small affiliated gifts in exchange for a contribution equal to or higher than $40. The project creator was likely able to price discriminate in this case because the movie was based upon a cult television series with a niche, yet eager fan base. On the other hand, the campaign for the Pono Music Player (a high-resolution portable digital music player) offered the music player in exchange for a $300 contribution (PonoMusic Team 2015). Because the music player would later go on to retail at $399, the entrepreneur probably had to entice the “fans of the product” to contribute by giving them a generous reward. This was possibly the case because the music player had high development costs and high financing costs given the risk facing startups in the digital music market that is dominated by big established companies such as Apple and Sony. It was also likely that “fans of the product” had only a marginally higher valuation for the product than the bulk of the market that the Pono Music Player would eventually serve. In addition, because award-winning musician Neil Young provided the vision behind the campaign, it is likely that the “fans of the product” anticipated to
free ride on a large group of followers of the musician (in our model a big population of random funders).

**CONCLUDING REMARKS**

Crowdfunding is traditionally used by entrepreneurs to raise funds necessary to develop and produce a product. Such funds allow the entrepreneurs to save on capital costs. In this research we discuss how this capital raising role affects another possible role for crowdfunding. Specifically, when the early pledges of funders in a campaign exceed the expected reward the entrepreneur promises to pay them when the project is complete, consumers with high valuation for the product effectively pay a higher price for it than those having lower valuations. Hence, crowdfunding can also be used as a price discrimination device to extract a larger amount of surplus from consumers.

We show that an entrepreneur’s ability to implement such price discrimination is higher, when her need to raise funds through the crowdfunding campaign is less pronounced. Specifically, we show that enhanced surplus extraction through price discrimination is feasible when the total consumer surplus that the project generates is relatively small, when the development cost of the project and financing costs through traditional funding sources are relatively low, and when the extent of heterogeneity in the consumer population is relatively high.

Our analysis also helps us to derive interesting insights regarding the entrepreneur’s choice of the funding goal. We find that the entrepreneur will always set the campaign goal below the level that allows her to cover the development cost of the product. As a result, the
entrepreneur chooses to sometimes procure a portion of the development costs via traditional funding (i.e., a loan from the bank.) While raising the campaign goal can help the entrepreneur to motivate more aggressive pledge behavior it also exposes her to the risk of a failed campaign when funds are insufficient to meet the more demanding goal. Given that the entrepreneur can also use the funder reward as an instrument to motivate strategic funders and given that a traditional outside funding source is available to the entrepreneur, she chooses the goal to be strictly lower than the level that allows her to cover the entire development cost. Our results also show that the entrepreneur may sometimes choose to risk an unsuccessful campaign in order to motivate more aggressive pledge behavior from funders. Higher pledges allow the entrepreneur to save on capital costs and to also support improved price discrimination. Further, by setting the campaign goal at a higher level she can reduce the incidence of free riding of funders who may think their contributions are not needed for the campaign to be successful.

We limit our current research to platforms that choose to return the contributions to funders when the campaign goal is not reached. While this refund rule is practiced by some of the most prominent crowdfunding platforms, including Kickstarter, other crowdfunding platforms follow modified refund rules. For instance, Indiegogo allows the entrepreneur to keep a share of the contributions even if the campaign goal is not reached. This refund rule raises the risk of funders losing their contributions without receiving any pecuniary benefits in return. However, Indiegogo is also utilized for charity projects and this rule may be better suited for projects with no development costs. Further research is necessary to address the implications of using different refund rules when the goal of the campaign is not met.

We model the outside funding source available to the entrepreneur in the form of a lender. We could have alternatively modelled it as a venture capitalist that obtains an equity
share in return for the funds invested in the company. Whereas interest payment is the cost of borrowing from the bank in our formulation, the loss of equity is the cost of raising funds from a venture capitalist. In addition, in our framework, the lender’s interest rate is determined exogenously and is independent of the contributions raised in the crowdfunding campaign. However, it is possible that the lender offers a lower interest rate to entrepreneurs who are able to raise a bigger share of the required capital through the crowdfunding campaign, possibly because the larger contributions serve as a signal of a project that is less risky to finance. Incorporating such considerations may be worthwhile extensions of our current investigation.

In our model we do not allow for any transmission of information between the entrepreneur and the funders or communication amongst the funders themselves. Funders may be self-incentivized to tell others about a project in order to encourage more contributions, so that the campaign goal is reached. Accounting for these social effects may be an interesting extension to the present study.
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**FOOTNOTES**

1 We attempt to distinguish between contributions made by strategic funders from contributions made by random funders by referring to the former as pledges and the latter as donations.
\( \bar{X} \) can be interpreted as a proxy for both the expected amount of funds that can be raised from random funders and for the overall level of uncertainty facing the entrepreneur and strategic funders regarding the availability of funds.

3 We assume that the entrepreneur’s expected benefit from producing the product always exceeds the incurred financing and development costs 
\[ p(n + m)r_L - K(1 + s) \geq 0. \]

4 For instance, if the sharing rule assumes a value of \( \alpha = 0.9 \) (Kickstarter’s approximate payment including processing fees is between 8-10%) and the cost of borrowing is \( s > 0.05 \) (for risky loans), then \( T > 0 \) for all \( n \geq 1 \).

5 If we relaxed the assumption that outside funding is always available following a successful campaign it would be possible that the goal of the campaign would be set at the level of the gross cost requirement. However, according to Proposition 2 it would never exceed this level.

6 For instance, the team behind Coolest Cooler (a high tech cooler) promised to give backers who contributed $165 their very own Coolest Cooler which had an estimated market price of $300 (Grepper 2015).

7 While the movie has not yet reached the market, it can be expected that the movie will debut at a price that is less than $40 (Falconer 2015).
The arguments for the proofs of the Lemmas and Propositions are outlined in the main text. In this appendix we provide technical details of the proofs.

**Explanation of Strategic Funder i’s Objective Function Given in (1)**

Solving the integral in (1) given the uniform distribution of random donations yields:

\[
EU_i = (p(r_H - r_L + \Delta) - D_i) \left[ \frac{X-(F-D_i-\sum_{j \neq i} D_j)}{X} \right] + qp(r_H - r_L) \left( \frac{F-D_i-\sum_{j \neq i} D_j}{X} \right).
\]

**Proof of Lemma 1**

Second stage pledge of strategic funder \( i \) is obtained by maximizing (1) which yields the following first order condition:

\[
(A.1) \quad \frac{\partial EU_i}{\partial D_i} = \frac{F-X-D_i-\sum_{j \neq i} D_j}{X} + \frac{(p(r_H-r_L+\Delta)-D_i)}{X} - \frac{q(r_H-r_L)p}{X} = 0.
\]

Evaluating (A.1) at the symmetric equilibrium \( D_i = D_j = D \) and solving it for \( D \), we get the second stage equilibrium pledge strategy as given in (2) in the Lemma. Note the condition (A.1) is sufficient for maximization because \( \frac{\partial^2 EU_i}{\partial D_i^2} < 0 \).

**Behavior of Strategic Funders if Crowdfunding Platform Used the Posted Price Model**

If the platform dictated the pledge level \( D \) necessary to receive the reward \( \Delta \) it would choose it at the highest level that induces the funder to participate in the campaign instead of simply waiting for the product to become available in the future. Specifically, \( D \) would satisfy the equation:
\[(p(r_H - r_L + \Delta) - D) \frac{X-(F-nD)}{X} + qp(r_H - r_L) \frac{F-nD}{X} = p(r_H - r_L) \frac{X-(F-(n-1)D)}{X} + q \frac{F-(n-1)D}{X}\], where the LHS of the above equation corresponds to the payoff of a strategic funder who participates in the campaign and the RHS corresponds to his payoff if he stays out and waits for the product to become available. The above equation yields a quadratic equation in \(D\). Solving it for \(D\) in terms of the two instruments \(\Delta\) and \(F\) yields:

\[D = \frac{R + \sqrt{R^2 + 4np(\bar{X}-F)}}{2n},\] where \(R \equiv [F + np\Delta + (r_H - r_L)p(1 - q) - \bar{X}]\).

Similar to the comparative statics obtained from equation (2), it is easy to show that the “Posted Price” \(D\) is an increasing function of the instruments \(\Delta\) and \(F\) (similar “instrument effect” as with NYOP) and a decreasing function of \(\bar{X}\) and \(n\) (similar “free riding” effect as with NYOP).

Because the effect of the instruments of the campaign on the behavior of strategic funders is qualitatively similar under both the NYOP and PP models, we do not anticipate that our predictions will be significantly affected. However, the simpler derivations under NYOP allow us to obtain closed form solutions for the optimal level of the instruments and to more clearly demonstrate the tradeoff between the fund raising and price discrimination objectives of crowdfunding.

**Explanation of Entrepreneur’s Objective Function Given in (3)**

Solving the integral in (3) given the uniform distribution of random donations yields:

\[E\pi_E = \]
Proof of Proposition 1

The entrepreneur’s choice of funder reward is derived by optimizing (3) which yields:

\[
\begin{align*}
\omega + [p(n + m)r_L + (anD - pn\Delta - K)] \left( \frac{\kappa F}{\bar{x}} \right) + \alpha(1 + s) \left( \frac{(\kappa - n\Delta - (F - n\Delta))^2}{2\bar{x}} \right) \\
+ [p(n + m)r_L + (anD - pn\Delta - K)] \left( \frac{\bar{x} - (\kappa - n\Delta)}{\bar{x}} \right) + \alpha \left( \frac{\bar{x}^2 - (\kappa - n\Delta)^2}{2\bar{x}} \right) \\
\omega + [p(n + m)r_L + (anD - pn\Delta - K)] \left( \frac{\bar{x} - (F - n\Delta)}{\bar{x}} \right) + \alpha \left( \frac{\bar{x}^2 - (F - n\Delta)^2}{2\bar{x}} \right)
\end{align*}
\]

if \( F < \frac{\kappa}{\alpha} \)

\[
\begin{align*}
\omega + [p(n + m)r_L + (anD - pn\Delta - K)] \left( \frac{\bar{x} - (F - n\Delta)}{\bar{x}} \right) + \alpha \left( \frac{\bar{x}^2 - (F - n\Delta)^2}{2\bar{x}} \right)
\end{align*}
\]

if \( F \geq \frac{\kappa}{\alpha} \)

where \( \omega = q[p(n + m)r_L - (1 + s)K] \left( \frac{F - n\Delta}{\bar{x}} \right) \).

Using (2) in (A.2) and (A.3) and solving each equation for \( \Delta \) yields the following funder reward:

\[
\Delta = \frac{(n+1)(1-q)(p(nr_H + mr_L) - K)}{pn(2n+2-a)} - (1 - q)(r_H - r_L).
\]

Note that conditions (A.2) and (A.3) are sufficient for maximization because \( \frac{d^2E\pi_E}{d\Delta^2} < 0 \).

The following aggregate pledge is obtained by substituting (A.4) in (2):
\[ (A.5) \quad nD^* = \frac{(1-q)(pn_H + mn_L) - K + qsK + (2n+1)F - (2n+1-\alpha)\bar{X}}{2n+2-\alpha}. \]

The comparative statics reported in the Proposition are obtained by differentiating \( \Delta \) in (A.4) with respect to the parameters of the model.

**Proof of Proposition 2**

The proof straightforwardly follows from the arguments made before the Proposition in the main text.

**Proof of Proposition 3**

Define

\[ K_{LB} \equiv \frac{a \left( (1-q)p(n_H + m_L) - \bar{X} \left[ (2n+1-\alpha) - \left( \frac{(1-\alpha)^2}{as} \right) \right] \right)}{[1-\alpha q - aqs]}, \quad K_{UB} \equiv \frac{a \left( (1-q)p(n_H + m_L) + \bar{X} \right)}{[1-\alpha q - aqs]}, \]

\[ \bar{X}_{LB} \equiv \frac{as(1-q)p(n_H + m_L) + sqsK + sK(as + aq-q)}{as(2n+1-\alpha) - (1-\alpha)^2}. \]

(i), (ii). From (A.5) \( F^* > nD^* \) if and only if:

\[ (A.6) \quad F^* > \frac{(1-q)(pn_H + mn_L) - K + qsK - (2n+1-\alpha)\bar{X}}{(1-\alpha)}. \]

Substituting \( F^* \) from (9) in (A.6) yields:

\[ \frac{(2n+2-\alpha)sK - (1-\alpha)(1-q)(pn_H + mn_L) - K + sqs + \bar{X}}{2a(1+s+ns) - \alpha^2(1+s) - 1} \geq \frac{(1-q)(pn_H + mn_L) - K + qsK - (2n+1-\alpha)\bar{X}}{1-\alpha}, \]

which implies:

\[ (A.7) \quad as(1-q)p(n_H + m_L) - (1-\alpha q - aqs)sK - \bar{X}(as(2n + 1 - \alpha) - (1-\alpha)^2) < 0. \]

(A.7) holds if \( 1 - \alpha q > aqs \) and \( K > K_{LB} \) or if \( 1 - \alpha q < aqs \) and \( \bar{X} > \bar{X}_{LB} \), where \( K_{LB} \) and \( \bar{X}_{LB} \) are defined above. On the other hand if \( 1 - \alpha q > aqs \) and \( K < K_{LB} \) or if \( 1 - \alpha q < aqs \) and
and $\bar{X} < \bar{X}_{LB}$, then $F^* \leq nD^*$. Because the probability of a successful campaign cannot exceed one, $F^* = nD^*$ in these cases, as given in part (ii) of the Proposition.

From (9) $F^* < \frac{k}{a}$ if and only if:

$$\frac{(2n+2-a)sK-(1-a)[(1-q)(p(nr_H+mr_L)-K)+Ksq+\bar{X}]}{2\alpha(1+s+ns)-\alpha^2(1+s)-1} < \frac{K}{\alpha},$$

which simplifies to:

(A.8) \quad \alpha [(1-q)p(nr_H + mr_L) + \bar{X}] - (1 - \alpha q - aqs)K > 0.

(A.8) holds if $(1 - \alpha q) > aqs$ and $K < K_{UB}$, where $K_{UB}$ is defined above. On the other hand if $(1 - \alpha q) < aqs$, then (A.8) always holds as the first term in the inequality is positive.

Finally, to ensure that a successful campaign is possible $nD^* + \bar{X} > F^*$ should hold. This implies from (A.5) and that

$$\frac{(1-q)(p(nr_H+mr_L)-K)+qsk+(2n+1)F^*-(2n+1-a)\bar{X}}{2n+2-\alpha} + \bar{X} > F^*,$$

which reduces to:

(A.9) \quad F^* < \frac{(1-q)(p(nr_H+mr_L)-K)+qsk+\bar{X}}{(1-\alpha)}.

Substituting (9) into (A.9) yields:

$$\frac{(2n+2-a)sK-(1-a)[(1-q)(p(nr_H+mr_L)-K)+Ksq+\bar{X}]}{2\alpha(1+s+ns)-\alpha^2(1+s)-1} < \frac{(1-q)(p(nr_H+mr_L)-K)+qsk+\bar{X}}{(1-\alpha)},$$

which implies:

(A.10) \quad [2n + 2 - \alpha] \left[ \alpha s \left( (1-q)p(nr_H + mr_L) + \bar{X} \right) + sK(aqs + \alpha q - 1) \right] > 0.

When $(1 - \alpha q) < aqs$, (A.10) always holds. On the other hand when $(1 - \alpha q) > aqs$, (A.10) holds if $K < K_{UB}$.

(iii) From (A.5) the condition $nD^* + \bar{X} > F$ at $F = \frac{K}{\alpha}$ yields:
\[
\frac{(1-q)(p(nr_H + mr_L) - K) + qsK + (2n+1)\frac{K}{\alpha} - (2n+1-\alpha)\bar{X}}{(2n+2-\alpha)} + \bar{X} > \frac{K}{\alpha},
\]

which reduces to:

(A.11) \[K < \frac{a[(1-q)p(nr_H + mr_L) + \bar{X}]}{(1-aq-\alpha s)} = K_{UB} \]

However, it is established above that when \((1 - aq) > aqs\) and \(K < K_{UB}, F^* < \frac{K}{\alpha}\) and when \((1 - aq) < aqs\) it is always the case that \(F^* < \frac{K}{\alpha}\). Since the expected profit of the entrepreneur is continuous at \(F = \frac{K}{\alpha}\), it follows that the entrepreneur never sets its funding goal at this level.

**Proof of Proposition 4**

From (A.4), (A.5) and (9), \(\Delta < \alpha D^*\) if and only if the condition (10) given in the proposition holds.

**A Portion \(\beta\) of Low Valuation Consumers are Aware of the Campaign**

Upon inspection of equation (1) it is clear that low valuation consumers would join the campaign only if \(p\Delta - D > 0\) because the expression \((r_H - r_L)\) would disappear in their maximization problem. Moreover, if such consumers were free to submit any pledge level in order to qualify for the reward, they would submit a lower pledge than the pledge that high valuation consumers choose. However, given that the entrepreneur selects the threshold pledge to qualify for the reward at the level equal to the pledge of high valuation consumers, if low valuation consumers wish to receive the reward they have to match the pledge submitted by the high valuation consumers. Define by \(\hat{n} = n + \beta m\), then optimizing the expected utility of “fans of the project” while accounting for the bigger population of participants in the campaign, yields the same expression as (2) with the only difference being that \(\hat{n}\) replaces \(n\) in the equation. Modifying the
payoff function of the entrepreneur to account for the new pledge behavior and the bigger number of participants, we obtain that for a fixed campaign goal, the optimal reward level is equal to:

$$\Delta = \frac{(\hat{n}+1)(1-q)(p(\hat{n}r_H+(n+m-\hat{n})r_L)-K) + (\hat{n}+1)qsK + F(\alpha\hat{n}+1+\tilde{n})-(\hat{n}+1-a)c} {p\hat{n}(2\hat{n}+2-a)} - (1-q)(r_H - r_L).$$

Optimizing with respect to $F$ with the new expressions for $D$ and $\Delta$, yields the interior solution $F^*$ as follows:

$$F^* = \frac{(2\hat{n}+2-a)sK-(1-a)[(1-q)(p(\hat{n}r_H+(n+m-\hat{n})r_L)-K) + KsN + \tilde{x}]} {2a(1+s+\tilde{n}s) - a^2 (1+s)-1}.$$ 

Note that the expressions for the optimal $\Delta$ and $F^*$ are very similar to those derived in the main text with the only changes being that $\hat{n}$ replaces $n$ and $[\hat{n}r_H + (n + m - \hat{n})r_L]$ replaces $[nr_H + mr_L]$. 

Given that low valuation consumers who are aware of the campaign join in when the entrepreneur cannot practice price discrimination, next we investigate whether the entry of such participants in this case may actually benefit the entrepreneur. We assess this question by deriving the expression for $(p\Delta - \alpha D)$, namely the expression for the gap between the expected reward and the share of the contribution retained by the entrepreneur. When the entrepreneur cannot use the campaign as a vehicle for price discrimination we know that this gap is positive. 

$$ (p\Delta - \alpha D) = \frac{s(a[(1-q)p(\hat{n}r_H+(n+m-\hat{n})r_L)+\tilde{x}] - K[1-\alpha q-\alpha qs])} {2a(1+s+\tilde{n}s) - \alpha^2 (1+s)-1} - p(1-q)(r_H - r_L).$$ 

It is easy to show that the above expression is a decreasing function of $\hat{n}$. Hence, the bigger the portion $\beta$ of low valuation consumers who are aware of the campaign, the smaller the gap $(p\Delta - \alpha D)$ is, thus benefitting the entrepreneur. It is unclear whether this smaller gap raises the expected profits of the entrepreneur because the reward has to be paid out to a bigger number of participants in the campaign ($\hat{n}$ instead of $n$). However, when the decline in the gap $(p\Delta - \alpha D)$
is sufficiently big to compensate for the bigger number of strategic funders who receive awards in access of their pledge the profits of the entrepreneur may actually increase.
To crowdfund or not to crowdfund? The informative role of reward-based crowdfunding*

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To crowdfund or not to crowdfund? The informative role of reward-based crowdfunding

Abstract

Reward-based crowdfunding can provide entrepreneurs information regarding future demand for their products. Such information is valuable, especially for entrepreneurs who need additional funding from a Venture Capitalist (VC), because a successful crowdfunding campaign can help convince the VC to finance the project. A failed campaign, however, will send a negative signal that is likely to eliminate the entrepreneur’s chances of obtaining subsequent VC funding. Because the entrepreneur can always approach professional investors without running a crowdfunding campaign, it is important that she weighs the informational benefits of running a campaign against the adverse consequences of failing in the campaign. This paper investigates the incentives of an entrepreneur to run a reward-based crowdfunding campaign in an environment where VC’s supplemental capital is needed to commercialize the entrepreneur’s new product. In case the entrepreneur decides to run a campaign, we examine how the entrepreneur chooses the campaign instruments. We also investigate the preference of the VC in favor of running crowdfunding campaigns. Our findings suggest that the likelihood of obtaining VC funding is higher under crowdfunding if the prior expectations regarding the future prospects of the project are relatively poor. However, given the risk of campaign failure, we also find that the entrepreneur chooses in favor of crowdfunding only if the campaign is sufficiently informative in comparison to the VC’s independent research. Finally, our analysis shows that the entrepreneur and VC do not always agree on the desirability of running a crowdfunding campaign, with the VC being less likely to prefer crowdfunding.

Keywords: reward-based crowdfunding, information acquisition, new products, venture capital.
1 Introduction

Crowdfunding is a novel method for raising capital to finance new projects, allowing founders of entrepreneurial, cultural, or social projects to solicit funding from many individuals, i.e., the crowd, in return for future rewards or equity (Mollick, 2014). In reward-based crowdfunding, in exchange for funding, the entrepreneur promises to provide the funder a reward, which often takes the form of the completed product if it is successfully produced in the future (Gorman 2012, Steinberg 2012, Snow 2014). In contrast, in equity-based crowdfunding, funding is provided in exchange for an equity stake in the startup (Belleflamme et al. 2014). Crowdfunding has rapidly gained in popularity, with about $16 billion raised across the globe in 2014 and an estimated growth of up to $34 billion in 2015 (Barnett 2015). Kickstarter, a leading platform for reward-based crowdfunding worldwide, has launched more than 200,000 crowdfunding campaigns, with 36% successfully funded by more than 9 million individuals.

The primary function of any type of crowdfunding campaign is to raise capital to cover a portion of the development cost of new projects. However, reward-based crowdfunding can offer additional benefits to entrepreneurs in the form of facilitating product line design (Hu et al. 2015) or providing a vehicle to price discriminate between high valuation consumers, who are attracted to pledge in the campaign, and low valuation consumers (Bender et al. 2015). Another possible role of reward-based crowdfunding, which is the focus of this paper, is to provide a vehicle for entrepreneurs to gather information regarding the future demand for the product. Given that the reward is often tied to the product itself, reward-based crowdfunding is likely to attract some consumers to pledge in the campaign. These consumers, referred to as backers, may be interested in experimenting with early prototypes of the product, in learning about its characteristics, and possibly via their pledge, in gaining early access to the product when it becomes available. Because reward-based crowdfunding requires backers to put down money for a product that has yet to be produced, and because backers tend to be drawn from the population of potential consumers, the number of backers and the overall level of capital raised may serve as an early indication of the enthusiasm for the product (Agrawal et al. 2014). This view has been expressed, indeed, by serial
entrepreneur Phil Windley who stated “The primary reason I like the idea of Kickstarter is that it validates an idea . . . The money we’ll make is likely small potatoes compared to what we’d raise in a typical funding scenario . . . But the big payoff is the information about the potential market we’ll get” (Conner, 2013). Also, a recent survey shows that the most likely reason (with around 70% of responses) that entrepreneurs cited for turning to crowdfunding is “to see if there was demand for the project” (Mollick and Kuppuswamy 2014). In contrast, equity-based crowdfunding might be of limited value in this regard because the complex legal issues involved tend to attract professional and accredited investors such as angel investors or Venture Capitalists (VCs) (Barnett 2014, Payne 2015), and thus, their behavior is unlikely to be representative of general consumers. As our interest lies in crowdfunding as a vehicle to gather information regarding future demand, we focus on reward-based crowdfunding.

When the prior uncertainty about the future prospects of the product is relatively high, running a campaign in order to get an early indication of consumer interest may be extremely valuable for the entrepreneur, especially if she needs additional funding from a VC. This is likely to be the case, for instance, for projects that aim at marketing new consumer products, such as hardware or consumer electronics, which are popular on crowdfunding platforms such as Kickstarter or Indiegogo. Such projects usually require very large amount of capital to support growth and large-scale manufacturing and/or commercialization (Hogg 2014). Given that the amount of capital raised in a typical reward-based crowdfunding campaign is below $1 million (Caldbeck 2013, Shane 2013), marketing of new consumer products necessitates subsequent rounds of funding from professional investors, e.g., VCs (Segarra, 2013). The feedback obtained from consumers in the campaign may help the VC make a better decision regarding the profitability of the project. In fact, due to the high risk of backing startups (Gage 2012), VCs many times do not invest until a company has validated the market, gained traction, and demonstrated it can execute the project (Grant 2013). Thus, they reject 98-99 percent of business plans they see (Rao 2013), while occasionally regretting some missed opportunities (Shontell 2011, Schubarth 2014). In accordance with this view, Barry Schuler, managing director of DFJ Growth (a company that invested in Formlabs, a low cost
A 3D-printing startup that raised $2.95 million on Kickstarter in 2012, referred to a crowdfunding campaign as “an ultimate test market” (Cao 2014). Many other venture capitalists, such as Chris Arsenault from iNovia Capital or Alfred Lin from Sequoia Capital, also have asserted that through reward-based crowdfunding, entrepreneurs as well as VCs can obtain information about the market potential of a new product (Immen 2012, Kolodny 2013).

However, running a crowdfunding campaign also carries some risk to entrepreneurs; the main risk being the ability of the entrepreneur to access VC funding if the campaign fails to meet the campaign goal, i.e., the minimum amount of money required for the campaign to be successful. In fact, failing in crowdfunding has been referred to as a death sentence in the eyes of VCs (Strohmeyer 2013). Because the entrepreneur has the option of approaching professional investors without running a crowdfunding campaign, it is important that she weighs the informational benefits of running a crowdfunding campaign against the adverse consequences of failing in the campaign. This paper investigates the incentives of an entrepreneur to run a crowdfunding campaign in an environment where VC’s supplemental capital is needed to commercialize the entrepreneur’s new product. This campaign generates a signal of future market demand, which can aid the entrepreneur and the VC in their decisions. In case the entrepreneur decides to run a campaign, we examine how the entrepreneur chooses the campaign instruments, which include the goal and the pledge level that entitles campaign backers to receive the product when it becomes available. We also investigate the preference of the VC on running crowdfunding campaigns.

Our model consists of three stages. In the first stage, the entrepreneur decides on whether to approach the VC directly or to run a crowdfunding campaign prior to approaching the VC for funding. If the entrepreneur is in favor of crowdfunding, she sets the pledge level and the goal of the campaign. These two values determine the minimum number of backers required for the campaign to be successful, referred to as the target number. If the total pledges turn out to fall short of the declared goal, the campaign is considered a failure, in which case the entrepreneur does not receive any funds from the campaign following the rule of Kickstarter. As suggested by industry practice, no VC is willing to fund the entrepreneur in this case, thus terminating the project (Strohmeyer...
If the total pledges exceed the declared goal, the campaign is successful and the entrepreneur will receive the funds raised in the campaign. In this case, the entrepreneur then approaches the VC for funding in the second stage. The VC can observe the signal obtained in the campaign regarding the number of backers and the total amount pledged. He also runs independent research to obtain a signal on the prospects of the venture. With the two signals at hand, the VC decides on whether to fund the project. If the VC finds it profitable to fund, the game proceeds to the third stage when negotiations between the parties take place. We use the Generalized Nash Bargaining Solution (GNBS) to predict the outcome of their negotiations.

When the entrepreneur chooses to run a campaign, we find that for a fixed target number of campaign backers, the pledge level she sets declines with the risk backers face that the campaign is successful but the project is never funded by the VC. In this case, backers in the campaign lose their pledges without receiving any benefit in return. To reverse the adverse effect of this risk, the entrepreneur may raise the optimal target number of backers. In particular, the entrepreneur may set a more demanding target number when the prior probability that the VC will obtain a poor signal from his own research is relatively high. When such a higher target number is reached, the signal from the crowdfunding campaign becomes more encouraging, and the likelihood that the project will be funded increases, thus alleviating the concerns of backers.

We also compare the options of crowdfunding and no crowdfunding prior to approaching the VC. We find that the probability of obtaining the VC’s funding is higher under crowdfunding if the prior expectations regarding the future prospects of the project are relatively grim. In such instances, running a campaign to test market raises the odds that the entrepreneur will be able to convince the VC to fund the project. However, given the risk of a failed campaign, we also find that the entrepreneur is in favor of crowdfunding only if the campaign is sufficiently informative in comparison to the signal that the VC obtains from his own research. Finally, our analysis

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1 Our model can be modified to allow for a positive probability of VC funding in case of a failed campaign. Our results hold as long as this probability is smaller than the probability of VC funding in case of a successful campaign.

2 Given that most VCs have access to infrastructure in terms of personnel, technology, and expertise, it is a regular practice for them to conduct independent research to assess the profitability of the project, even after successful crowdfunding. When commenting on how a VC decides to fund startups, Dan Borok, a partner of Millennium Technology Value Partners, stated “Research, research, research. We conduct many months of primary research to identify where value will be created and which companies are best positioned to benefit” (Cohen 2014).
illustrates that the entrepreneur and VC do not always agree on the desirability of running a crowdfunding campaign. While the signal obtained in the campaign ensures that the VC makes more sensible investment decisions, this information is always more valuable to the entrepreneur than it is to the VC. Because funds raised in a successful campaign improve the bargaining position of the entrepreneur relative to the VC, only when the campaign generates a very informative signal relative to that from his own market research will the VC benefit from crowdfunding.

Our findings suggest that the preference for crowdfunding depends on the level of informativeness of the crowdfunding campaign for the given product. For instance, crowdfunding provides valuable information for consumer hardware products, which are indeed very common on crowdfunding platforms. As a matter of fact, after succeeding on Kickstarter or Indiegogo, consumer hardware startups such as Scanadu, Formlabs, Lifx, Romotive, and Canary received VC funding for product development. Similarly, subsequent to raising $2.4 million through Kickstarter, Oculus VR successfully secured $75 million from the venture capital firm, Andreeseen Horowitz (CB Insights 2014). In contrast, reward-based crowdfunding is not particularly informative for consumer medical devices or personal care products that may be too complex to evaluate by individuals active on crowdfunding websites (Grant 2014, Hogg 2014). This unfortunately has been the case for BeActive Brace, a new pressure brace for back-pain that its inventor, the physical therapist Akiva Shmidman, tried to promote through crowdfunding without success. Later he “ditched” crowdfunding after realizing that “his true target audience was not among the backers who frequent Kickstarter or Indiegogo.” As pointed out by Akiva Shmidman, backers active on these platforms tend to be individuals more interested in products that represent the bleeding edge of innovation rather than solving old problems (Samson 2015).

To the best of our knowledge, this is the first paper that examines the role of reward-based crowdfunding campaigns as a vehicle to learn about the potential demand of new products. In contrast to earlier studies that focus on understanding the campaign itself, we study the manner in which an entrepreneur can use the campaign outcome to persuade the VC to fund her project or to avoid unprofitable projects in case the campaign fails. While previous literature has considered
the advantages and disadvantages of acquiring demand information, we examine this question in a setting where crowdfunding is utilized not only for raising capital but also for assessing demand of new products. With an emphasis on the informative role of crowdfunding, our work also differs from the general literature on entrepreneurial financing, which mostly looks at capital constraints and various financing options for technology commercialization (Krishnan 2013). In particular, we show how the role of information affects the choice of campaign instruments when entrepreneurs seek further funding from VCs. We illustrate that the risk of a failed campaign may sometimes lead the entrepreneur to approach the VC directly without crowdfunding. While VCs sometimes benefit from the improved information from crowdfunding campaigns, we characterize conditions under which the preferences of the entrepreneur and VC for running a campaign do not coincide.

The remainder of the paper is organized as follows. In Section 2, we review the relevant literature. We develop the model of crowdfunding and no crowdfunding in § 3 and § 4, respectively. We compare these two options in § 5, and discuss the managerial implications of the analysis as well as future research directions in § 6.

2 Literature Review

With a focus on the role of crowdfunding as a mechanism to gather market information, our paper is related to the extensive literature on the economics of information. Starting with the early work of Stigler (1961), Hirshleifer (1971), and Arrow (1972), the role of information in uncertain environments has been extensively examined in a variety of applications including adverse selection, moral hazard, auctions, and bargaining (Arrow 1984). Some studies investigate the optimal level of information acquisition in the presence of demand uncertainty (Li et al. 1987, Vives 1988), while others investigate oligopolists’ incentives to acquire and/or share private information (Novshek and Sonnenschein 1982, Clarke 1983, Gal-Or 1985). The effect of information acquisition and sharing has also been demonstrated in vertical relationships in supply chains (Lee et al. 1997, Cachon and Fisher 2000, Guo 2009, Guo and Iyer 2010). By showing that it is sometimes better to sidestep the opportunity to obtain demand information via crowdfunding, our work is related to the literature on
the advantages and disadvantages of observing more precise information (Rotemberg and Saloner 1986, Vives 1984, Gal-Or 1987, 1988, Raju and Roy 2000). While prior studies identified the possible disadvantages of gaining access to improved information in competitive environments, we examine this issue in the context of a monopoly entrepreneur running a crowdfunding campaign with the dual objective of raising capital to finance a project and of assessing the potential demand for a product that is yet-to-be-developed. In this respect, our study is related to the work on the informative value of experimentation, where by manipulating their pricing strategy firms can learn about the state of the demand while concurrently generating revenues (Aghion et al. 1991, Mirman et al. 1993). We differ by analyzing how the extent of informativeness of the crowdfunding campaign influences the entrepreneur on whether to proceed or cease her project.

The nascent literature on crowdfunding has investigated the problem mostly from an empirical perspective (Ordanini et al. 2011, Ahlers et al. 2012, Agrawal et al. 2013, Mollick 2013, 2014, Colombo et al. 2015, Mollick and Nanda 2015, Burtch et al. 2013, 2015). Few papers have studied crowdfunding from a theoretical perspective. Belleflamme et al. (2014) compare the profitability of two common forms of crowdfunding, reward-based and equity crowdfunding. Hu et al. (2015) show that under crowdfunding, offering a product line rather than a single product is more likely to be optimal and the quality gap between products is smaller. Similarly, Bender et al. (2015) show that allowing consumers to pledge can lead to more successful surplus extraction when heterogeneity in the consumer population is sufficiently large and when the development cost of the product or the anticipated surplus generated from it is relatively small. None of these studies examine the informative role of crowdfunding and its impact on the subsequent funding decision of the VC.

Our study is also related to the literature on crowd involvement in the innovation process, including Internet-enabled crowd sourcing of ideas, problem solving, and customer voting systems (e.g., Terwiesch and Xu 2008, Boudreau et al. 2011, Marinesi and Girotra 2013, Bayus 2013, Huang et al. 2014). Similar to online customer voting systems, reward-based crowdfunding can be used as a participative mechanism that allows consumers to provide feedback and suggestions, and thus enable firms to gather information about consumers’ preferences. Different from the literature above, the
issue of raising capital to start an entrepreneurial project is central to crowdfunding campaigns and
the entrepreneur has a well-formulated idea for a new product. As a result, consumers commit with
their money rather than simply voting for an innovation. In particular, we study how the campaign
instruments, specifically the campaign goal and the pledge, depend on the informativeness of the
crowdfunding campaign in a setting where further funding from a venture capitalist is necessary.
Moreover, we characterize conditions under which launching a crowdfunding campaign is profitable
for the entrepreneur and venture capitalist, which is new to the literature.

3 The Model: Crowdfunding

Consider an entrepreneur with a design for a new product or service, who is seeking capital to cover
the cost $K$ of developing, producing, and selling a product to mass market. He decides to launch
a crowdfunding campaign, but the funds raised from the crowd are insufficient to cover the entire
cost $K$. Thus, even if the campaign is successful, the entrepreneur still needs to raise remaining
funds from traditional financial intermediaries. There are two groups of potential consumers in the
market. The first group consists of hardcore fans with high valuation $v_H$. They are enthusiastic
about the new product design, and thus, have an incentive to pledge in the campaign to support the
development and production of the product. The second group consists of consumers of the potential
future market. These consumers have a lower valuation $v_L < v_H$, as they tend to value the product
far less than the fans, and will only become active if the product is successfully commercialized.
Because the mass market consists mostly of consumers with the lower valuation $v_L$, if the product
is produced the entrepreneur expects to sell it at price $v_L$. The model consists of three stages.

Stage 1:

The entrepreneur sets the pledge level $r$ and the campaign goal $G$. Anyone who pledges in the
campaign is promised to receive the product for free if it is successfully produced in the future. In
practice, some campaigns have multiple pledge levels, with a higher level entitling the individual to a
more generous reward. In order to keep the analysis tractable we restrict attention to a single pledge
level. Setting multiple levels allows the entrepreneur to more successfully extract surplus from fans
if there is some heterogeneity in the population of fans. However, given our objective to focus on the informative value of crowdfunding campaigns our restriction to a homogeneous population of fans, and therefore, to a single pledge level simplifies the analysis without qualitatively changing our results. In addition, empirical evidence suggests that the majority of fans pledge at the level corresponding to the basic product. For instance, for the game console Ouya, more than 73% of fans pledged at the level that enabled them to receive the basic product for free.

Fans are forward-looking when deciding on whether to pledge in the campaign now or to purchase the product in the future once it is commercialized. Let $N$ denote the random number of fans with realization $n$. Because of our assumption that all fans are identical, they will choose the same action either to back the project or not. For simplicity, we assume a continuous instead of a discrete density for $N$. In particular, we assume that $N$ is uniformly distributed on $[0, N]$. The realization of this random variable may contain useful information regarding the potential future market because a bigger number of backers in the campaign indicate greater enthusiasm for the venture and overall higher demand for the product.\(^3\) Let $N_{\text{min}} = G/r$ be the target number of the campaign, i.e., the minimum number of backers required in order to reach the campaign goal. If $n < N_{\text{min}}$, the total amount raised in the campaign does not meet the goal and the campaign fails. As is the practice on several crowdfunding websites including Kickstarter, we assume that in this case no funds will be collected from backers and the entrepreneur does not receive any money from the campaign. In fact, failing in crowdfunding may be disastrous for the entrepreneur in terms of her ability to raise further funds from the VC (Houssou and Belvisi 2014, Strohmeyer 2013). Therefore, we assume that the project terminates if the campaign fails.\(^4\) Otherwise, if $n \geq N_{\text{min}}$ the campaign goal is met and each backer contributes his pledge $r$. Before transferring the campaign proceeds to the entrepreneur, the crowdfunding website (e.g., Kickstarter) subtracts a fee. Without loss of generality, we normalize this fee to zero.

\(^3\)In this study, we interchangeably use the terms fans and backers to refer to individuals who pledge in the crowdfunding campaign.

\(^4\)In the concluding remarks we discuss the consequences of relaxing this assumption and allowing the entrepreneur to access VC funding following a failed campaign. Note that the probability of getting funded following a failed campaign will always be lower than the probability following a successful campaign. As long as there exists a gap between these two probabilities, the entrepreneur has to weigh the risk of campaign failure against the benefit of improved information. Thus, our qualitative results will continue to hold.
Stage 2:

Following the success of the campaign the entrepreneur approaches a VC to obtain additional funds to finance the remaining cost of the project. The VC observes the number of backers \( n \) in the campaign, and subsequently, conducts an independent market research to evaluate the prospects of the project. This is consistent with the practice of VCs before funding new entrepreneurial ventures (Hill 2012, Zimmerman 2012, Cohen 2014). We assume that this market research generates signal \( X \) of the potential prospects of the venture. This random variable can take one of two possible realizations \( x_L \) and \( x_H \) predicting bad and good prospects, respectively.\(^5\) With probability \( p \), \( X = x_L \), and with probability \( 1 - p \), \( X = x_H \) where \( 0 \leq x_L \leq x_H \). Both the VC and entrepreneur can observe the realization of \( X \). We make this assumption in order to focus on the main objective of the paper, which is the study of the informative value of crowdfunding. Incorporating private information would complicate the analysis without significantly changing the main tradeoffs identified in our model. Without loss of generality we also normalize market research cost to zero reflecting the reality that many venture capitalists, by virtue of funding different projects, have the infrastructure and resources in place to conduct market research investigation at relatively low cost.

Because both the number of campaign backers \( n \) and the independent signal \( x \) may contain valuable information in predicting the future demand for the product, the VC uses the realization of these two random variables in deciding on whether to make the investment in the project. For a given signal, the bigger the spread of its prior distribution the higher the value of the information contained in this signal. A bigger spread indicates significant uncertainty about the state of the world. Observing the actual realization of the signal reduces, therefore, this prior uncertainty to a very large extent, thus increasing its informative value. For the random number of backers in the campaign the spread of the prior distribution is equal to \( \bar{N} \) and for the market research signal it is equal to \( x_H - x_L \). To illustrate, consider the extreme case that that \( x_H = x_L \). In this case, there

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\(^5\)Because fans pledge with their own money in the campaign, the number of backers provides a concrete signal of how the product will be received by them, and hence, is assumed to have a continuous distribution. In contrast, the VC’s research will produce a few scenarios (e.g., good or bad) of future prospect of the product, and therefore is assumed to have two demand states (i.e., high and low). We argue in the concluding remarks that this assumption can be relaxed without changing our qualitative results.
is no spread in the prior distribution of $X$, implying that prior and posterior information remains unchanged given that there is no variability in the possible realizations of the random variable $X$. Therefore, observing the realization of this random variable does not add any useful information. In contrast, if the spread $x_H - x_L$ is very large, observing the actual value significantly improves the information that is available for making decisions. Similarly, when $\overline{N}$ is very big there is significant prior uncertainty about the number of backers. Observing the actual value is of great importance in this case.

We assume that for given realizations of the random variables $n$ and $x$, the best estimate of the expected market size for the product is $\alpha[n h + (1 - h) x]$, where $0 \leq h \leq 1$ (we have normalized the realization of $X$ and the value $h$ so that the same scale parameter applies to both signals). The parameter $h$ measures the extent of informativeness of the crowdfunding campaign in predicting the future state of the demand relative to the extent of informativeness of the external signal $X$ obtained in the market research. The value of the relative informativeness parameter $h$ depends on whether the preferences of backers in the campaign represent the preferences of consumers in the mass market. Because crowdfunding requires fans to put down money for a product that has yet to be produced, when a big number is willing to do so, an early indication of enthusiasm for the product can be inferred. However, if the product is quite complex to evaluate (such as a software that requires special expertise to evaluate) or when fans support the venture for reasons unrelated to actual consumption (such as environmentalist supporting “green” causes) the fan group has preferences that are not necessarily representative of regular consumers, implying that the realization $n$ provides very little information about the future state of the demand. In the extreme case, when $h = 1$ the crowdfunding campaign is perfectly informative, e.g., in case of the game console Ouya or other consumer hardware products. In contrast, when $h = 0$, crowdfunding contains no valuable information about future demand. This may have been the case, for instance, for the above mentioned example of BeActive Brace or other wearable health devices for seniors.

The parameter $\alpha$ is a scale parameter that predicts how observations in the samples used to generate the two signals translate to a prediction about the entire market. To illustrate the
reasonable range of values of the parameter \( \alpha \), consider, for instance, the game console Ouya that had 63,416 backers in its 2012 crowdfunding campaign. For this case, \( h \) is reasonably close to 1. The number of game console users in the United States is about 100 million in 2014 (Statista 2015). Even in the unlikely case that Ouya became as major a player as one of the three giants (Sony, Nintendo and Microsoft), the estimated \( \alpha \) value in this case would not exceed 100,000,000/(4*63,416) \( \approx 394 \). Formlabs, one of the most successful campaigns for 3D printers on Kickstarter, was backed by about 1,000 people in 2012, whereas the total number of shipments of 3D printers reached approximately 217,000 by 2015 (Gartner 2014). Given that the two major players together have 40\% of the market (Crompton 2014), the \( \alpha \) value in this case would be roughly 200,000/(5 * 1,000) = 40, assuming that Formlabs accounts for 20\% of the market. For niche products such as electronic guitars or pad controllers for deejays, this scale parameter may be even smaller.\(^6\)

Many pitfalls may occur in the development process of new products, which prevent entrepreneurs from completing the development. Hence, even after the VC funds the project there is still some risk in bringing the product to the market. We model this possibility by assuming that there is a positive probability of \( 1 - z \) that the entrepreneur will fail to deliver the product. With probability \( z \), the project is successfully developed, in which case the entrepreneur rewards the product to her backers for free, and sells to the mass market at unit price \( v_L \). Including a variable unit production cost in the analysis does not affect our findings qualitatively, and therefore, we normalize it to zero. Let \( R(n, x_i) \equiv v_L \alpha (hn + (1 - h) x_i) \) denote the future revenue given signal \( x_i \), \( i = H, L \). The VC will fund the project if upon the observation of the signals \( n \) and \( x \), the posterior expected profit is nonnegative, namely if

\[
zR(n, x_i) - K \geq 0, i = H, L.
\]

Whenever the posterior expected profits from the project is positive the VC knows that via negotiations (to resume subsequently in Stage 3) he will be able to reach an agreement with the entrepreneur to ensure that each party obtains a positive share of these positive proceeds. Otherwise,\(^6\) Note that we can also define \( a \equiv ah \) and \( b \equiv \alpha (1 - h) \) so that the expected market size can be expressed as \( an + bx_i \). The coefficients \( a \) and \( b \) reflect the informativeness of the two signals in predicting the future state of the demand.

\(^6\)
if the above inequality is reversed the VC decides against funding and the entrepreneur terminates the project. Lack of VC funding of new ventures following successful crowdfunding campaign is quite common. CB Insights reports that only 9.5% of the crowdfunded hardware projects that were able to raise at least $100,000 on Kickstarter and Indiegogo have been later funded by professional investors (CB Insights 2014). We assume that in the absence of funding from the VC, the entrepreneur can still keep $nr$, the funds raised in the crowdfunding campaign. She could have used the campaign funds already to develop a patent or to prepare a demo of the product. In this case, even if the entrepreneur wanted to return the funds she would not be able to do so. Mollick (2014) reports on some incidence of fraud in crowdfunding campaigns, where entrepreneurs keep campaign funds even though they never develop the promised products. Crowdfunding websites such as Kickstarter warn entrepreneurs against such behavior. In our formulation, the entrepreneur’s inability to deliver on her promises may not necessarily be the result of fraudulent behavior. It may simply be the result of her lack of competence and/or her inability to raise sufficient funds to complete the project. This happened, for instance, in the case of Quest that was sued by some backers after failing to deliver their promised product Hanfree that had been successfully crowdfunded on Kickstarter (Markowitz 2013). Similarly, despite being one of the most successful campaigns on Indiegogo, Kreyos Smartwatch collapsed without being able to fulfill backers’ legitimate requests partly because of managerial incompetence and partly because of fraud (Alois 2014). At any rate, the entrepreneur always derives some benefit from the campaign funds even when the project fails due to lack of external funds. Because backers cannot observe how their pledges are used by the entrepreneur, we assume that the entrepreneur can retain the funds raised in a successful campaign (whenever the goal of the campaign is met) even if she cannot secure sufficient external funds subsequently.

**Stage 3:**

If the VC approves funding for the project, the entrepreneur first decides to contribute an amount $s$, $0 \leq s \leq nr$, to cover part of the development cost, whereas the VC comes up with the remaining $K - s$. The VC then negotiates with the entrepreneur about his equity share,
Specifically, about the manner in which they will split the future profits if the product is successfully developed. This profit could also represent the valuation of the startup. We use the Generalized Nash Bargaining Solution (GNBS) to characterize the outcome of the negotiation. Specifically, let $\delta$ and $1 - \delta$ denote the entrepreneur’s and VC’s bargaining power, respectively, where $0 \leq \delta \leq 1$. Similarly, let $\lambda$ and $1 - \lambda$ designate the shares of the total profit from selling to the mass market that will accrue to the entrepreneur and VC, respectively. Under GNBS, each party’s expected payoff depends both on its bargaining power and on its outside option. In our environment, the entrepreneur’s outside option is $nr$, because the entrepreneur can keep the campaign funds even if she is unable to secure additional funds from the VC. The outside option of the VC is his opportunity cost when investing in the entrepreneur. This opportunity cost is determined by the return the VC could have earned when investing in other ventures. Because such return is completely unrelated to the characteristics of the crowdfunding campaign, we can normalize it to zero. In Lemma 1 we derive the expected payoffs of the entrepreneur and VC that result from their negotiation. Interestingly, although the share of future profit $\lambda$ that accrues to the entrepreneur increases with her contribution $s$, the expected payoff of each party is independent of the amount the entrepreneur puts in upfront. In fact, the way they split the expected profit net of development cost is determined solely by their relative bargaining power as well as their outside options. The entrepreneur’s decision on $s$ is irrelevant for all values $s$ within the range $[0, nr]$.

**Lemma 1:** After observing the campaign outcome $n$ and the market signal $x_i$, the VC approves funding for the project if $zR(n, x_i) - K \geq 0$. Under the Generalized Nash Bargaining Solution (GNBS),

(i) The share of profits from selling to the mass market that will accrue to the entrepreneur is:

$$\lambda^* = \delta - \frac{\delta K - s}{zR(n, x_i)}.$$  \hspace{1cm} (1)

(ii) As a result, the expected profit of each party, based on the campaign outcome and market signal,
is given by:

\[ W_E(n, x_i) = \delta (zR(n, x_i) - K) + nr, \]  
\[ W_{VC}(n, x_i) = (1 - \delta) (zR(n, x_i) - K). \]  

From part (ii) of Lemma 1, the GNBS predicts that the expected payoff of each party comprises of the sum of the party’s outside option and a portion of the total expected surplus generated upon agreement, where portions are determined by the bargaining power of each party. In our case, the total expected surplus that is available to the parties upon agreement is equal to \( zR(n, x_i) - K \), and the entrepreneur and VC split this surplus according to their bargaining power, \( \delta \) and \( 1 - \delta \), respectively. Note that while the development costs have to be incurred with certainty in order for the project to proceed, the availability of revenues from the sale of the product is uncertain and realizes only with probability \( z \). This is the reason that the probability measure \( z \) multiplies only the revenue and not the cost of the project. In addition to its share of the total surplus, each party receives also its outside option (\( nr \) and 0, for the entrepreneur and VC, respectively). In part (i) we derive the shares of future expected profits from the mass market that should accrue to each party in order to implement the GNBS outcome. Note that the entrepreneur’s share from the mass market \( \lambda \) may fall short of her bargaining power \( \delta \) when her upfront contribution \( s \) is below \( \delta K \). Given that the funds raised in the crowdfunding campaign comprise a very small percentage of the cost needed for development and commercialization, it is very likely indeed that the entrepreneur is unable to use campaign funds to fully cover her share of cost dictated by the GNBS. In this case, the gap \( \delta - \lambda \) increases with \( K \) and declines with \( s, z \) and \( R(n, x_i) \). If instead \( \delta K < s < nr \), then her share \( \lambda \) actually exceeds her power \( \delta \) and the behavior of \( \delta - \lambda \) with these parameters will be reversed. When the number of backers in the campaign is relatively small so that even the maximum possible contribution, \( nr \), is below \( \delta K \), the entrepreneur is forced to accept a smaller share of future expected profits. It is interesting, though, that irrespective of the level of her contribution upfront to cover the development cost, the adjustment of the share \( \lambda \) ensures that the expected payoff of each party remains the same as shown in part (ii).

Lemma 1 also illustrates how the funds raised in the crowdfunding campaign increases the
outside option for the entrepreneur and thus, improves her expected payoff. It is possible that a bigger value of $n$ may also increase the value of $\delta$. However, including this possibility in our model is unlikely to change our results qualitatively. For simplicity, we assume that the bargaining power of the entrepreneur and VC remains the same irrespective of the realization of $n$. We discuss this issue in concluding remarks.

Before starting the analysis, we make some further assumptions regarding the distributions of the signals $N$ and $X$ to ensure that each signal on its own has informational value for the VC’s decision making. For the signal $N$ we assume that there is a value of $\hat{n} \in (0, N)$ for which $z\alpha_L \hat{n} - K = 0$, implying that if the signal $N$ were the only one available to the VC he would make the investment if $n \geq \hat{n}$ because $z\alpha_L n - K > 0$ and would not make the investment if $n < \hat{n}$ because $z\alpha_L n - K < 0$. Note, in particular, that this assumption implies that the investment would definitely be profitable for the highest possible number of backers because $z\alpha v_L \overline{N} - K \geq 0$. Similarly, we assume that if $X$ were the only information available to the VC, it would also have some value. Specifically, we assume that the project would be deemed unprofitable upon the observation of $x_L$ and profitable upon the observation of $x_H$, or that $z\alpha v_L x_L - K \leq 0$, but $z\alpha v_L x_H - K \geq 0$. These assumptions imply, in particular, that $x_L \leq \overline{N}$.

The VC observes both signals and uses them in deciding on whether to finance the project. For a given level of relative informativeness of the crowdfunding campaign $h$, we define by $N_L$ the minimum number of campaign backers needed for the VC to decide in favor of investment when the external signal indicates poor prospects for the project (i.e., when $X = x_L$). And similarly, let $N_H$ designate the minimum number of backers needed in order to support the VC’s investment when the external signal indicates good prospects for the project (i.e., when $X = x_H$). It is easy to show that

$$N_L = \frac{K - (1 - h)z\alpha v_L x_L}{h z \alpha v_L}$$

If the expected profits of the VC assumed the same sign (either always positive or always negative) for all values of $n$, the number of backers in the campaign would have no informational value, as the decision of the VC would remain the same whether or not the realization of $N$ is observed. 

If the sign of expected profits remained the same, observing the realization of $x$ would add no valuable information.
and

\[ N_H = \frac{K - (1 - h)z\alpha v_Lx_H}{h\alpha v_L}. \]  

(5)

Because \( z\alpha v_Lx_L - K \leq 0 \) and \( z\alpha v_Lx_H - K \geq 0 \) it follows that \( N_L \geq x_L \) and \( N_H \leq x_H \). Moreover, because \( x_L \leq x_H \), it follows that \( N_L \geq N_H \). Note that when the external signal indicates very unfavorable prospects for the project, i.e., when \( x_L \) assumes a very small value, \( N_L \) may exceed the highest possible number of campaign backers, namely \( N_L > \overline{N} \). In this case, the VC will never invest in the project when \( x_L \) realizes irrespective of the number of backers in the campaign. In contrast, when the external signal indicates very favorable prospects for the project, i.e., when \( x_H \) assumes a very big value, \( N_H < 0 \). That is, the VC will invest in the project whenever the external signal is \( x_H \) irrespective of the number of backers. When \( N_L < \overline{N} \), the entrepreneur may decide to invest even when the external signal is bad as long as the number of campaign backers is sufficiently large, namely when \( n \geq N_L \). When \( N_H > 0 \), the VC may decide against investment even when the external signal is good if the number of campaign backers is sufficiently small, namely when \( n < N_H \). Obviously \( N_H < \overline{N} \), i.e., \( K \leq z\alpha v_L [h\overline{N} + (1 - h)x_H] \). Otherwise the project will never get funded by the VC.

In Stage 1, the entrepreneur sets the pledge level \( r \) and the campaign goal \( G \). For the campaign to be successful, the number of backers needs to be at least \( N_{\text{min}} = G/r \). Thus, the entrepreneur’s choice of \( r \) and \( G \) is equivalent to setting \( r \) and \( N_{\text{min}} \). In Lemma 2 we derive the range for the optimal \( N_{\text{min}} \).

**Lemma 2:** \( \max (N_H, 0) \leq N_{\text{min}}^* \leq \min (N_L, \overline{N}) \).

To understand the lower bound of \( N_{\text{min}}^* \), note that if \( N_{\text{min}} \) were below \( \max (N_H, 0) \) it would be possible for the campaign to be successful and for the VC never to fund the project even when observing a good signal in his independent market research (i.e., when \( N_{\text{min}} < n < \max (N_H, 0) \)). However, such a possibility would discourage fans from pledging in the campaign given the increased risk of losing their pledge without receiving any benefit. In addition, it would reduce the likelihood of receiving funds from the VC. To understand the upper bound on \( N_{\text{min}}^* \), note that if \( N_{\text{min}} \) were bigger than \( N_L \) it would be possible for the campaign to fail even if the VC would definitely fund
the project regardless of the signal obtained in his market research (when the \( N_L < n < N_{\text{min}} \)).

The characterization of the equilibrium depends on whether \( N_L \) exceeds or falls short of \( \bar{N} \). We will refer to the former case as an environment where “Observing \( x_L \) kills the project” and the latter as an environment where “Observing \( x_L \) is not fatal for the project.”

3.1 Case 1: \( N_L \leq \bar{N} \) (Observing \( x_L \) is not fatal for the project)

In this case, if the campaign goal is reached and the campaign outcome is sufficiently good, i.e., \( n \geq N_L \), the VC funds the project in spite of observing a bad outcome in his own market research. Fans decide on whether to pledge in the campaign or purchase the product if it becomes available in the future. Because of their enthusiasm for the project we assume that fans derive extra utility from sponsoring the new venture in comparison to simply consuming the product when it becomes available. Specifically, we assume that each fan, if pledging, derives the utility \( v_H \) from consumption. He derives the lower utility \( \gamma v_H \), \( 0 \leq \gamma \leq 1 \), if he chooses not to pledge. The extra utility of campaign backers may represent their pride to be part of the team that identified the great potential of the project and helped it become a reality. The bigger the value of \( \gamma \) is the smaller this extra benefit derived by backers of the campaign. In particular, when \( \gamma = 1 \), there is no difference in the consumption utility derived by fans whether they back the project in the campaign or not. We assume that even if fans do not pledge, they still find it optimal to purchase the product if it becomes available, namely \( \gamma v_H - v_L > 0 \).

Upon the observation of the pledge level \( r \) and \( N_{\text{min}} \) (and thus, the goal \( G \)) selected by the entrepreneur, fans choose to participate in the campaign if the following inequality holds:

\[
-r\left( \frac{N_L - N_{\text{min}}}{N} \right) + \left( z v_H - r \right) \left( \frac{(1 - p)(\bar{N} - N_{\text{min}})}{N} \right) + p \left( \frac{\bar{N} - N_L}{N} \right) \geq z(\gamma v_H - v_L) \left( \frac{(1 - p)(\bar{N} - N_{\text{min}})}{N} \right) + p \left( \frac{\bar{N} - N_L}{N} \right).
\]

The left hand side of the inequality is the expected utility of a fan who pledges in the campaign. The first term of the fan’s expected utility corresponds to the risk of losing his pledge without receiving any benefit for it. This happens when the campaign is successful because \( n \geq N_{\text{min}} \) but the project is not funded by the VC because the independent research yields a bad outcome (i.e.,
X = x_L) and the number of backers in the campaign is insufficient to convince the VC to fund the project (i.e., n < N_L). The second term corresponds to the fan’s utility when the VC funds the project. This happens when the funds raised in the campaign reach the goal (i.e., n ≥ N_{min}) and the market research yields either a good or a bad outcome, but the number of backers in the campaign is sufficiently high (e.g., n ≥ N_L if X = x_L). Under such circumstances the net utility of the backer is \( zv_H - r \), his consumption benefit \( v_H \) which materializes with probability \( z \) when the product is produced net of his pledge \( r \) that is paid in the campaign.

The right hand side corresponds to a fan’s expected utility when he simply waits for the product to become available in the future. He will consume the product only when the VC chooses to invest in the project, and in this case, derives the net expected surplus \( z(\gamma v_H - v_L) \) because his consumption benefit is discounted by \( \gamma \) and he pays the market price \( v_L \) for it. Both of these happen, however, only if the product is actually produced (with probability \( z \)).

From the above inequality, fans will pledge in the campaign only if the threshold \( N_{min} \) satisfies the condition below:

\[
N_{min} \geq \frac{[z(\gamma - 1)v_H - zv_L + r](N - pN_L) + rpN_L}{(1 - p) [z(\gamma - 1)v_H - zv_L + r] + rp}.
\] (6)

The entrepreneur’s problem is to maximize her expected profit under crowdfunding \( \pi_E^C \), where the superscript “C” denotes the crowdfunding option and the subscript “E” indicates the profit of the entrepreneur.

\[
(P1) \quad Max_{\{r, N_{min}\}} \quad \pi_E^C = \frac{1}{N} \int_{N_{min}}^N nrdn + \frac{p}{N} \int_{N_{min}}^N \delta[z\alpha v_L(hn + (1 - h)x_L) - K]dn
\]

\[+ \frac{(1 - p)}{N} \int_{N_{min}}^N \delta[z\alpha v_L(hn + (1 - h)x_H) - K]dn\]

s.t. \( max(N_H, 0) \leq N_{min} \leq N_L \)

\[N_{min} \geq \frac{[z(\gamma - 1)v_H - zv_L + r](N - pN_L) + rpN_L}{(1 - p) [z(\gamma - 1)v_H - zv_L + r] + rp}.
\]

The first term of \( \pi_E^C \) corresponds to the funds raised in the campaign, which can be retained by the entrepreneur as long as the number of backers \( n \) exceeds \( N_{min} \). The second and the third term correspond to her expected profit derived from the sale of the product to the mass market when
and \( x_H \) realizes, respectively. The entrepreneur chooses \( r \) and \( N_{\min} \) to maximize this objective, subject to the constraints that \( N_{\min} \) is restricted to the region specified in Lemma 2 and that fans find it optimal to pledge in the campaign.

In setting the level of \( N_{\min} \) two counteracting forces are at play. Setting the level closer to the upper bound \( N_L \) reduces the likelihood that fans will lose their pledge without receiving any benefits (when the campaign is successful but subsequently is not funded by the VC). The decline in this risk makes it less costly for the entrepreneur to convince fans to pledge (allows her to raise the pledge level.) However, this higher level of \( N_{\min} \) reduces also the likelihood that the goal of the campaign is met. Similarly, setting \( N_{\min} \) closer to the lower bound \( \max (N_H, 0) \) increases the likelihood of a successful campaign, but increases the probability that fans will receive no benefit from their pledge, thus depressing their pledge level. The detailed derivation of Case 1 and all other derivations and proofs can be found in the Appendix.

### 3.2 Case 2: \( N_L > \overline{N} \) (Observing \( x_L \) kills the project)

In this case, the signal \( x_L \) is so bad that observing it will kill the project. However, when \( x_H \) is observed, the project will be funded by the VC as long as the campaign is successful. According to Lemma 2, the optimal level of \( N_{\min} \) lies in the region \( \left[ \max (N_H, 0), \min (N_L, \overline{N}) \right] \). As a result, whenever the campaign goal is met (i.e., \( n > N_{\min} \)), it is also true that the number of backers is sufficient (i.e., \( n > \max (N_H, 0) \)) to convince the VC in favor of funding when the good signal \( x_H \) is observed. Fans choose to pledge in the campaign instead of purchasing the product if it becomes available in the market if the following inequality holds:

\[
-rp \frac{\overline{N} - N_{\min}}{\overline{N}} + (1 - p)(zv_H - r) \frac{\overline{N} - N_{\min}}{\overline{N}} \geq (1 - p)z(\gamma v_H - v_L) \frac{\overline{N} - N_{\min}}{\overline{N}} \\
(1 - p)z [v_H(1 - \gamma) + v_L] \geq r.
\]

The entrepreneur’s problem can be written as:

\[
(P2) \quad \text{Max}_{r, N_{\min}} \quad \pi^C = \frac{1}{N} \int_{N_{\min}}^{\overline{N}} nr \, dn + \frac{(1 - p)}{\overline{N}} \int_{N_{\min}}^{\overline{N}} \delta[z\alpha v_L(hn + (1 - h)x_H) - K] \, dn \\
\text{s.t.} \quad \max (N_H, 0) \leq N_{\min} \leq \overline{N} \\
r \leq (1 - p)z[v_H(1 - \gamma) + v_L].
\]
The objective $\pi_C^g$ consists of the funds raised in the campaign and the expected profits from sale of the product to the mass market, both contingent on the goal of the campaign being met (i.e., $n > N_{\text{min}}$).

**Optimal solution**

The solution to the entrepreneur’s problem in Case 1 critically depends on the probability $p$ of observing the bad signal $x_L$. Before characterizing the solution in Proposition 1, it will be helpful to define the lower and upper threshold levels for this probability as follows.

$$p_L = \begin{cases} \frac{2N_H}{2N_H + N - N_L} \delta_{\text{strategy}} & \text{if } N_H \geq 0 \\ \frac{\frac{2}{N_H + N - N_L} \delta_{\text{strategy}}}{1} & \text{if } N_H < 0 \end{cases}, \quad \text{and}$$

$$p_U = \frac{(1 - \gamma)v_H + v_L}{(1 - \gamma)v_H + v_L} \left( \frac{N}{N_L} - N_L \right) + \delta h v_L \left( N_L - N_H \right).$$

In Case 1, the lower threshold $p_L$ corresponds to the probability $p$ at which the entrepreneur shifts from setting the target of the campaign at its lowest possible value of $\max(N_H, 0)$ to a level strictly above $\max(N_H, 0)$. The upper threshold $p_U$ corresponds to the $p$ value at which the entrepreneur shifts from a strictly interior value to the upper bound $N_L$. It is easy to verify that $0 \leq p_L < p_U \leq 1$ when $N_L < N$. Note that when $h = 1$, $N_L = N_H = \frac{K}{2 \sigma v}L$ and $p_L = p_U = \frac{2K}{2 \sigma v L N + K} < 1$.

**Proposition 1:**

(i) When observing $x_L$ is not necessarily fatal for the project (Case 1), the optimal minimum number of backers for the entrepreneur is:

$$N_{\text{min}}^* = \begin{cases} \max(N_H, 0) & \text{if } 0 \leq p \leq p_L \\ N_{\text{min}}^{\text{inter}} & \text{if } p_L \leq p \leq p_U \quad \text{where} \\ N_{\text{min}} & \text{if } p_U \leq p \leq 1 \end{cases}$$

$$N_{\text{min}}^{\text{inter}} = \frac{2\gamma p \left[ (1 - \gamma)v_H + v_L \right] (N - N_L) - (1 - p)\delta_{\text{strategy}}}{(1 - \gamma)v_H + v_L + \delta h v_L \left( N_L - N_H \right)}.$$  

The optimal pledge $r^*$ is equal to:

$$r^* = z \left[ (1 - \gamma)v_H + v_L \right] \left[ 1 - p + p \frac{N - N_L}{N - N_{\text{min}}} \right].$$

The optimal goal is given by $G^* = r^* N_{\text{min}}^*$. The probability of the project to be funded by the VC is:

$$\Pr^C = \begin{cases} p \left( 1 - \frac{N_H}{N} \right) + (1 - p) \left( 1 - \frac{\max(N_H, 0)}{N} \right) & \text{if } 0 \leq p \leq p_L \\ p \left( 1 - \frac{N_H}{N} \right) + (1 - p) \left( 1 - \frac{N_{\text{min}}^{\text{inter}}}{N} \right) & \text{if } p_L \leq p \leq p_U \\ 1 - \frac{N_L}{N} & \text{if } p_U \leq p \leq 1 \end{cases}.$$
(ii) When observing $x_L$ kills the project (Case 2), the optimal minimum number of backers is $N_{\text{min}}^* = \max(N_H, 0)$. The optimal pledge is $r^* = z[(1 - \gamma)v_H + v_L][1 - p].$ The optimal goal is given by $G^* = r^*N_{\text{min}}^*$. The probability of the project to be funded by the VC is $\Pr^C = (1 - p) \left(1 - \frac{\max(N_H, 0)}{N}\right)$.

Proposition 1 demonstrates that for a fixed target number of campaign backers, the pledge level $r^*$ declines with the risk backers face that the campaign is successful but the project is not completed. Specifically, when $N_{\text{min}}^*$ is fixed, the pledge level declines with the probability $z$ of technical failure, the probability $p$ that the VC’s market research yields a bad outcome, and (in the case that observing $x_L$ is not fatal) the bigger the gap of $N_L - N_{\text{min}}$. The expressions derived for the pledge level are consistent with the reality that pledges in crowdfunding campaigns are typically lower than the future selling price of the product. Note, however, that the pledge level increases with the fan valuation $v_H$. This indicates that in addition to raising capital the crowdfunding campaign may serve as a price discrimination device between high and low valuation consumers. In fact, when $v_H$ is much bigger than $v_L$, the pledge level may actually exceed the future selling price of the product in spite of the risk backers face when pledging in the campaign.

With regard to the campaign goal as implied by the value of $N_{\text{min}}$, the optimal value depends on whether observing $x_L$ is fatal for the project. If it is fatal (Case 2), the VC funds the project only upon the observation of $x_H$, and because $N_{\text{min}} \geq \max(N_H, 0)$, backers in the campaign do not face any risk related to lack of funding following a successful campaign (the only remaining risk relates to technical failure.) As one type of risk is eliminated, the entrepreneur can choose the lowest level for $N_{\text{min}}$ to make it easier to meet the goal and ensure the success of the campaign.

When observing $x_L$ is not fatal (Case 1), the optimal value of $N_{\text{min}}$ depends upon the value of $p$. For relatively low values of $p$ (i.e., $p < p_L$) the entrepreneur chooses the lower bound $\max(N_H, 0)$, for relatively high values of $p$ (i.e., $p > p_U$) the entrepreneur chooses the upper bound $N_L$, and for intermediate values of $p$ ($p_L < p < p_U$), an interior solution $N_{\text{int}}^*$ arises as the optimum. In this case, $N_{\text{int}}^*$ must satisfy the first order condition $\frac{\partial \pi_E^C}{\partial N_{\text{min}}^*} = 0$, i.e.,

$$-(1 - p)\delta z \alpha v_L h (N_{\text{min}}^* - N_H) - N_{\text{min}}^* r^* + \left(\frac{N + N_{\text{min}}^*}{2}\right) z [(1 - \gamma)v_H + v_L] \left[p \frac{N - N_L}{N - N_{\text{min}}^*}\right] = 0.$$  

(9)
The first two terms measure the marginal loss incurred by the entrepreneur if the campaign were to fail because of an increase in $N_{\min}$. When $\max(N_{H}, 0) < n = N_{\min} < N_{L}$, the project is definitely funded when the VC observes the good signal $x_{H}$ and never funded when he observes $x_{L}$. When the entrepreneur raises slightly the value of $N_{\min}$, the first term reflects the loss of future expected revenues that the project could have potentially generated in this case if the good signal were to realize. The second term is the proceeds from the campaign that the entrepreneur would lose because of a higher $N_{\min}$. The last term measures the added benefit from a higher pledge that the entrepreneur could obtain by raising $N_{\min}$. In particular, the marginal increase in the pledge is $z [(1 - \gamma)v_{H} + v_{L}] \left( \frac{\mathcal{N} - N_{L}}{\mathcal{N} - N_{\min}} \right)$, whereas $\frac{N^{*} + N_{\min}}{2}$ is the expected number of backers conditional on a successful campaign. By setting a higher threshold for the campaign success, the entrepreneur reduces the risk that backers face of losing their contribution. Due to the reduced risk, the entrepreneur can set a higher pledge level.

Proposition 2 summarizes the comparative statics of the interior solution $N^{\text{int}}_{\min}$ in Case 1 with respect to some parameters of the model based on Equation (9). Note that, when the optimal $N_{\min}$ is reached at the boundary ($N_{H}$ or $N_{L}$), the comparative statics is trivial and thus is omitted.

**Proposition 2:** In Case 1, the optimal target number for $p_{L} \leq p \leq p_{U}$ is $N^{*}_{\min} = N^{\text{int}}_{\min}$, which decreases with $\delta$, and increases with $p$, $\overline{N}$, and $(1 - \gamma)v_{H}$. In addition, for a fixed value of the mean of the external signal $\frac{x_{H} + x_{L}}{2}$, $N^{\text{int}}_{\min}$ decreases as the spread $x_{H} - x_{L}$ increases.

We utilize the envelope theorem to understand the comparative statics results.\(^9\) Consider, for instance, a change in the parameter $p$. Such a change affects the first marginal loss term and the last marginal benefit term of Equation (9) in the same direction. When $p$ increases, the marginal loss from a failed campaign is smaller because the campaign is less likely to be funded even if it were to succeed. Moreover, a higher $p$ increases also the risk facing backers, and therefore, reducing this risk in order to hike their pledge is more important. As a result, when the bad outcome in the market research is more likely, the entrepreneur unambiguously sets a higher target number $N_{\min}$.

\(^9\)When a parameter $w$ changes the first order condition should still be satisfied. Totally differentiating the first order condition with respect to $w$ yields $\frac{\partial \pi_{E}^{*}}{\partial N_{\min}} \frac{\partial N_{\min}}{\partial w} + \frac{\partial \pi_{E}^{*}}{\partial N_{\min}} \frac{\partial N_{\min}}{\partial w} = 0$. Because at the interior equilibrium $\frac{\partial ^{2} \pi_{E}^{*}}{\partial N_{\min}^{2}} < 0$, $\text{sign} \left( \frac{\partial \pi_{E}^{*}}{\partial N_{\min}} \bigg|_{N_{\min}=N_{\min}} \right) = \text{sign} \left( \frac{\partial ^{2} \pi_{E}^{*}}{\partial N_{\min}^{2}} \bigg|_{N_{\min}=N_{\min}} \right)$. 

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The comparative statics result with respect to \( p \) is consistent with the experience of the startup that developed the game console Ouya. It set a campaign goal of $950,000, one of the highest goals ever on Kickstarter, which required a substantial number of backers to succeed. The presence in the industry of giants such as Microsoft, Sony, and Nintendo creates a rather inhospitable environment for startups (high value of \( p \)). Calling for such a large number of backers serves to signal high prospects to VCs and to reduce the risk facing backers of losing their pledges. Eventually, Ouya was able to raise about $8.6 million in the campaign, which later allowed the startup to receive additional $15 million from VCs (Rigney 2013). The result that \( N_{\text{min}} \) increases with \( \overline{N} \) is consistent with anecdotal evidence from Kickstarter when comparing campaign goals for niche versus mass-market products in the same product category. For instance, the startup that developed QuNeo 3D, a pad controller for electronic musicians (for which \( \overline{N} \) is likely to be relatively small) chose a goal of $15,000, thus requiring a much lower number of backers to succeed as compared with Pono Music, the digital media player (for which \( \overline{N} \) is likely to be rather big) for which the entrepreneur-musician Neil Young chose a goal of $700,000.\(^{10}\)

Given our emphasis on the informational role of crowdfunding campaigns, it may be especially valuable to understand the last comparative statics result reported in the Proposition, namely the effect of changes in the spread of the prior distribution of the external signal \( X \) on the optimal value of \( N_{\text{min}} \). Observing the first order condition for \( N_{\text{min}} \) it is easy to verify that \( \frac{\partial^2 \pi_C}{\partial N_{\text{min}} \partial x_L} > 0 \) and \( \frac{\partial^2 \pi_C}{\partial N_{\text{min}} \partial x_H} < 0 \). Hence, the optimal value of \( N_{\text{min}} \) increases with \( x_L \) but decreases with \( x_H \). As a result, a mean preserving increase in the spread of the prior distribution of the external signal \( X \) leads to a smaller value of \( N_{\text{min}} \) selected by the entrepreneur. Recall that when the spread of the prior distribution of a given signal increases its informative value is increased. In our case, in his funding decision the VC is likely to rely more heavily on the outcome of his market research and reduce the weight he places on the signal conveyed by a poor campaign outcome. With backers of the campaign facing a lower risk of losing their contributions, the entrepreneur can afford, therefore,

\(^{10}\)In this case, the lower goal set for QuNeo 3D as compared with Pono Music also reflected the lower target number, given that the pledge level to have access to the basic product was similar for the two products, besides being the most popular pledge level for both products.
to reduce the value of $N_{\text{min}}$.

In contrast to the unambiguous comparative statics results with respect to the parameters of the model that we report in Proposition 2, in Proposition 3 we demonstrate that when the parameter $h$ changes the optimal value of $N_{\text{min}}$ may increase or decrease.

**Proposition 3:** The optimal $N_{\text{min}}^*$ is an increasing, a decreasing, or a single peak function of the parameter $h$ on $0 \leq h \leq 1$. In the latter case, there exists a value $\hat{h}$ so that $N_{\text{min}}^*$ is strictly increasing for $0 \leq h \leq \hat{h}$ and strictly decreasing for $\hat{h} \leq h \leq 1$.

To understand Proposition 3, we first investigate the impact of $h$ on the optimal value of $N_{\text{min}}$ outside of the region of $p$ values that support an interior solution in Case 1. Recall that when $p \leq p_L$ the optimal solution is $N_H$ (if positive) and when $p \geq p_U$ it is $N_L$ (if less than $N$), where $N_H$ increases and $N_L$ decreases with $h$. In the former case, the good news portrayed by the high likelihood of a good outcome in the market research (when $p$ is very small $x_H$ is very likely) is tempered by a big value of $h$ that indicates that the extent of informativeness of this external signal is relatively small. As a result, the signal of good news is not as reliable and the entrepreneur sets a higher $N_{\text{min}}$ to alleviate the increased risk facing backers. In contrast, when $p$ is very big the bad news portrayed by a high likelihood of a bad outcome in the market research is not as grim when $h$ is bigger, which indicates that the external signal is less reliable. In this case, the entrepreneur reduces $N_{\text{min}}$ as the risk facing backers in the campaign is less significant. The interpretation under Case 2 is similar as the optimal solution is $N_H$ (if positive).

The comparative statics reported in Proposition 3 reflect the difficulty of predicting how changes in $h$ affect the interior solution $N_{\text{min}}^{\text{int}}$. Because a bigger value of $h$ reduces the weight that the VC places on his market research (the information contained in either the bad or the good outcome is discounted) it is unclear whether a bigger value of $h$ reduces or increases the risk facing backers. An inspection of Equation (9) indicates that, indeed, every term of this first order condition is affected by a change in $h$. When the optimal value of $N_{\text{min}}$ is a single peak function of $h$, the Proposition states that while the effect on the marginal benefit term dominates for small values of $h$ (like in the corner solution $N_{\text{min}} = N_H$ when $p$ is very small) the effect on the marginal loss term dominates.
when $h$ is relatively big (like in the corner solution $N_{\min} = N_L$ when $p$ is very big).

4 The Model: No Crowdfunding

In this section, we consider the case that the entrepreneur approaches the VC directly without conducting the crowdfunding campaign. Given that the number of fans is not observable in the absence of a campaign, the best estimate of the number of backers that potentially could have contributed in the campaign is equal to the prior expected value of the random variable $N$ which is equal to $\bar{N}/2$. There are now only two stages to the game. In Stage 1, the VC decides on whether to fund the project after conducting the market research and the external signal $X$ realizes. If the VC decides against funding the project terminates. In Stage 2 negotiations between the entrepreneur and VC take place if the VC decides in favor of supporting the project.

Under no crowdfunding, the entrepreneur’s outside option is zero, whereas the total surplus to be split by both parties includes the potential sales to fans who would have pledged in the crowdfunding campaign. Thus, the entrepreneur’s decision of whether to use crowdfunding affects both her outside option and the total surplus under negotiation. The rules of the negotiations are the same as those described in the model with crowdfunding. We continue to assume that the entrepreneur’s and VC’s bargaining power are $\delta$ and $1 - \delta$, respectively. Because Lemma 1 also applies here, $\delta$ and $1 - \delta$ are also the shares of the expected total surplus of the new venture that accrue to the parties. It is conceivable that the bargaining power of a startup under no crowdfunding may be different than the power of a startup that negotiates with the VC following a successful campaign. However, given our focus on understanding the informational role of crowdfunding we assume that the startup’s bargaining power is not affected by her decision on whether to run a campaign or not. In this manner, we do not introduce additional factors in favor of one of the two alternatives.

The expected profits of the entrepreneur and VC depend on the realization of the external signal as follows:
i) if \( X = x_H \), the entrepreneur’s expected profit under no crowdfunding is

\[
\pi^{NC}_E|_{X=x_H} = \frac{1}{N} \int_0^N \delta[z\alpha v_L(hn+(1-h)x_H)+zv_Ln-K]dn = \delta[z\alpha v_L(h\frac{N}{2}+(1-h)x_H)+zv_L \frac{N}{2}-K].
\]

The superscript “NC” stands for the no crowdfunding option. Note that \( \pi^{NC}_E|_{X=x_H} \geq 0 \) when \( \frac{N}{2} \geq \frac{K-z\alpha v_L(1-h)x_H}{zv_L(\alpha h+1)} = \left( \frac{\alpha h}{\alpha h+1} \right) N_H. \)

ii) If \( X = x_L \), we have

\[
\pi^{NC}_E|_{X=x_L} = \frac{1}{N} \int_0^N \delta[z\alpha v_L(hn+(1-h)x_L)+zv_Ln-K]dn = \delta[z\alpha v_L(h\frac{N}{2}+(1-h)x_L)+zv_L \frac{N}{2}-K].
\]

Note that \( \pi^{NC}_E|_{X=x_L} \geq 0 \) when \( \frac{N}{2} \geq \frac{K-z\alpha v_L(1-h)x_L}{zv_L(\alpha h+1)} = \left( \frac{\alpha h}{\alpha h+1} \right) N_L. \)

Therefore, three possible cases may arise:

a) if \( \frac{N}{2} > \left( \frac{\alpha h}{\alpha h+1} \right) N_L \), the total expected profit from the project is:

\[
\pi^{NC}_E + \pi^{NC}_V = z\alpha v_L(h\frac{N}{2}+(1-h)((1-p)x_H+px_L)) + vz_L \frac{N}{2} - K.
\]

Based on Lemma 1, the total profit is split between the entrepreneur and VC according to their bargaining power \( \delta \) and \( 1-\delta \), respectively. In this range of parameter values, the VC will always fund the project under no crowdfunding.

b) if \( \left( \frac{\alpha h}{\alpha h+1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h+1} \right) N_L \), the total expected profit is:

\[
\pi^{NC}_E + \pi^{NC}_V = (1-p)[z\alpha v_L(h\frac{N}{2}+(1-h)x_H) + vz_L \frac{N}{2} - K].
\]

Similarly, it is split between the entrepreneur and VC according to their bargaining power. In this range of parameter values, with probability \( 1-p \), the good signal \( x_H \) realizes and the VC will fund the project. With probability \( p \), the bad signal \( x_L \) realizes, and the VC will not fund the project.

c) if \( \frac{N}{2} < \left( \frac{\alpha h}{\alpha h+1} \right) N_H \), the expected profits of the entrepreneur and the VC are zero, as the VC will not be interested in funding the project at all.

Summarizing the three cases, we have the proposition below.

**Proposition 4:** When the entrepreneur does not conduct a crowdfunding campaign the probability that the project is funded by the VC is:

\[
\Pr^{NC} = \begin{cases} 
1 & \text{if } \frac{N}{2} > \left( \frac{\alpha h}{\alpha h+1} \right) N_L \\
1-p & \text{if } \left( \frac{\alpha h}{\alpha h+1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h+1} \right) N_L \\
0 & \text{if } \frac{N}{2} < \left( \frac{\alpha h}{\alpha h+1} \right) N_H
\end{cases}
\]
Proposition 4 suggests that in the absence of a crowdfunding campaign the entrepreneur will always receive funding from the VC irrespective of the external signal $X$, if the prior expected size of the fan group is sufficiently large (i.e., when $N > \left(\frac{ah}{ah+1}\right)N_L$.) If the expected size of the fan group is very small (i.e., when $N < \left(\frac{ah}{ah+1}\right)N_H$) the entrepreneur will never receive funding. In the intermediate range $\left(\frac{ah}{ah+1}\right)N_L \leq \frac{N}{2} \leq \left(\frac{ah}{ah+1}\right)N_H$, the realization of the external signal $X$ determines whether or not the entrepreneur receives funding. In the comparison between the crowdfunding and no crowdfunding options we will focus on the case that the probability of receiving funding in the absence of crowdfunding is strictly less than one. It is very unlikely, that the prospects of a new venture are so definitely favorable that there is no need for the VC to seek additional information to investigate the profitability of his investment. The case $N > \left(\frac{ah}{ah+1}\right)N_L$ corresponds to such an extreme and unrealistic case. In this case, even when the bad outcome materializes investment is profitable for the VC.

5 Comparison of Crowdfunding and No Crowdfunding

In this section, we compare the probability of launching the project and the profit that accrue to the parties under the crowdfunding and no crowdfunding options. As explained earlier, in this comparison we restrict attention to the reasonable case $N \leq \frac{ah}{ah+1}N_L$.

Proposition 5 (Comparison of the probability of funding): Crowdfunding leads to higher probability of funding than no crowdfunding when $N < \frac{ah}{ah+1}N_H$, or if $p$ is sufficiently high when

$$\max\left\{\frac{ah}{ah+1}N_H, \frac{Nh}{2}\right\} \leq \frac{N}{2} \leq \frac{ah}{ah+1}N_L.$$

A priori, it is unclear which of the two options increases the odds of obtaining funding from the VC. On one hand, running the product design through the fans helps terminate projects that are not promising, thus lowering the probability of VC funding. On the other hand, the availability of campaign funds and a high number of backers in a crowdfunding campaign may help convince the VC to fund the project. According to Proposition 5, the increased odds of VC funding when the entrepreneur runs a campaign are more likely when the prior distributions indicate that the project is not very profitable. This happens when the expected number of fans $N/2$ is small or when the
probability of observing a bad external signal in the independent market research conducted by the VC is relatively high. In both of these cases, the absence of additional information from the campaign is likely to kill the project, whereas demonstrating some success in the crowdfunding campaign may resuscitate the odds of funding. This result is consistent, for instance, with the story of Pebble Watch’s founder Eric Migicovsky, who was initially rejected by VC investors. They considered it too risky to invest in a hardware startup and worried about the potential of an untested product in a mature market (Immen 2012, Wing Kosner 2012). Using our modeling approach, they assigned a high prior probability \( p \) of a bad outcome. Nevertheless, after he was able to “kickstart” around $10 millions from almost 69,000 people, he received around $15 millions from a VC firm (Burns 2013). Chris Arsenault, a managing partner of the early stage venture company iNovia Capital, which was one of the companies that had rejected Migicovsky’s idea, admitted that Pebble Watch was a missed opportunity and that through Kickstarter Migicovsky validated the large potential of the product (Immen 2012). Our result is in line with general statistics about consumer hardware startups, which could face a high prior probability of poor prospects due to the high risk implied by unproven products and large manufacturing costs (Cao 2014). It has been reported that the percentage of hardware startups receiving VC funding after successful crowdfunding (i.e., 9.5%) is higher than the typical funding rate of VCs (i.e., 1%-2%) (CB Insights 2014, Caldbeck 2014).

In comparing the profitability of the two options it may be worthwhile to understand the advantages and disadvantages of crowdfunding for the entrepreneur and VC. The advantage that crowdfunding offers to both is that it produces a market signal of the potential success of the product and the managerial capabilities of the entrepreneur. This helps eliminate projects that are doomed for failure. There are two additional potential advantages of running a campaign that accrue only to the entrepreneur. The first is that conducting the campaign may serve as a price discrimination device to extract extra surplus from fans of the product. This is especially true when fans derive significantly more utility when backing the campaign. Note, however, that the pledge in the campaign may fall short of the price the product can command in the future market because backers in the campaign face the dual risk of lack of future VC funding and technical failure.
The second potential advantage of crowdfunding to the entrepreneur is that a successful campaign generates contributions upfront that improve her outside option. Moreover, these contributions can be retained even if the VC decides against funding. Also, the entrepreneur is entitled to the entire contributions of the fans in the campaign, whereas she receives only portion $\delta$ of the expected profits from selling the product to fans in the regular market. These potential advantages to the entrepreneur are the reason that crowdfunding may sometimes be disadvantageous for the VC. Indeed, running the campaign implies that a portion of the potential population of consumers is eliminated from future sales in the market. If the group of fans is relatively big this loss to the VC can be substantial.

In Proposition 6 we compare the profitability of crowdfunding and no crowdfunding from the perspective of both the entrepreneur and the VC.

**Proposition 6 (Comparison of profits):**

i) If the prior expected value of the size of the fan group is relatively small, specifically when $N_2 < \left(\frac{ah}{nh+1}\right)N_H$, both the entrepreneur and VC prefer crowdfunding because the project would never be funded otherwise.

ii) For a bigger expected size of the fan group, specifically when $\left(\frac{ah}{nh+1}\right)N_H \leq N_2 \leq \left(\frac{ah}{nh+1}\right)N_L$, the VC prefers crowdfunding over a smaller region of parameter values than the entrepreneur does. Specifically, when $ah < 1$, crowdfunding is preferred by the entrepreneur when $N_2$ is sufficiently big, and the VC never prefers the crowdfunding option. When $ah \geq 1$ crowdfunding is always preferred by the entrepreneur, while the VC’s preference is ambiguous.

iii) In the extreme case that $\delta = 1$ and $\gamma = 1$, the entrepreneur prefers crowdfunding if and only if $ah > 1$.

While crowdfunding may offer significant advantages to the entrepreneur, as explained above, it introduces also a significant risk to the entrepreneur. If the campaign fails, the entrepreneur is unlikely to obtain funds to continue the project. Failure in crowdfunding campaigns has been documented as a “death sentence” in terms entrepreneurs’ ability to access of VC funding. This risk is worth assuming for the entrepreneur if the extent of informativeness of the campaign is
relatively high, namely when the parameter $h$ is big. This is the reason that in Proposition 6 the preference of the entrepreneur in favor of crowdfunding crucially depends upon the value of the parameter $h$. When $h \geq 1/\alpha$ the entrepreneur unambiguously prefers crowdfunding. However, when $h$ is relatively small crowdfunding is preferred only if $N$ is relatively big. This is because a big $N$ implies both a higher outside option for the entrepreneur in the negotiation and greater uncertainty regarding the number of fans. The conditions for preferring crowdfunding by the entrepreneur are tied to the informational value of observing the actual number of fans in the campaign, with higher informational value making crowdfunding more profitable for the entrepreneur.

The fact that the VC is less likely to prefer crowdfunding than the entrepreneur relates to the fact that crowdfunding campaigns reduce the size of the future market for the product, because the VC does not receive any portion of the contributions from the fans of the project that is raised in the campaign. As a result, only if the informational value of the campaign is relatively high, namely when $\alpha h \geq 1$, the VC may find crowdfunding more profitable, but even in this case less often than the entrepreneur does. For different values of $N$ and $\alpha h$, Figure 1 provides a representative example of regions over which the entrepreneur and VC prefer crowdfunding to no crowdfunding in Case 2, when observing $x_L$ is fatal. The upper and lower bounds define the sensible region for Case 2. Specifically, the lower bound depicts values that satisfy the equation $N = N_H$. For values below this bound, the VC never funds the project under crowdfunding. The upper curve $N = \min \left( N_L, N_L \frac{2\alpha h}{\alpha h + 1} \right)$ ensures that funding is not guaranteed under no crowdfunding and that observing $x_i$ kills the project (Case 2) under crowdfunding. As can be seen from the plot, when $\alpha h$ is relatively small, neither the entrepreneur nor VC prefer crowdfunding for relatively small values of $N$, whereas the entrepreneur prefers crowdfunding but VC does not for relatively big values of $N$. When $\alpha h$ assumes higher values, both the entrepreneur and VC prefer crowdfunding if $N$ is not too big. When $\alpha h$ is relatively large, i.e., to the right of the plot, both entrepreneur and VC prefer crowdfunding, but this region shrinks as $\alpha h$ increases.$^{11}$

$^{11}$In this representative example, we have $K = 50,000,000; v_H = 100; v_L = 50; x_H = 49,000; x_L = 48,500; z = 0.5; \delta = 0.65; \gamma = 0.9; p = 0.5$. Note that we set $x_H$ and $x_L$ close to each other to show that running a crowdfunding campaign can be detrimental to the entrepreneur even in a setting where crowdfunding is highly informative as compared with the signal obtained by the VC through the market research (recall that when $x_H$ and $x_L$ become
Figure 1. Regions of preference when observing $x_L$ is fatal for the project (Case 2).

In order to focus on the informational value of crowdfunding campaigns, part (iii) of the proposition investigates the special case that $\delta = 1$ and $\gamma = 1$. In this case any conflict of interests between entrepreneur and VC regarding the future sharing of revenues has been eliminated as the entire revenue accrues to the entrepreneur both in the campaign and in the future market. As well, when $\gamma = 1$, the advantage of using the campaign to extract extra surplus from fans is eliminated. Hence, the entire benefit from running the campaign is the information it provides regarding the future prospects of the project. We find that in this case, the condition $\alpha h \geq 1$ becomes the sufficient and necessary condition for crowdfunding to dominate no crowdfunding. Hence, even in this case, the entrepreneur finds crowdfunding profitable only if its informational value exceeds a certain minimal threshold. Only when $\alpha h \geq 1$ it is worth for the entrepreneur to assume the risk of running a campaign that might fail and consequently ruin the opportunity of getting funded by the VC.

Note that in evaluating the odds of obtaining funding from the VC, $\alpha h$ can serve as a proxy for the incremental value of one additional backer observed in a crowdfunding campaign. This close, knowing the realization of $X$ is not that important).
factor is used by the VC when translating the level of interest in the campaign into a prediction concerning future demand. In the absence of crowdfunding, the VC cannot observe the actual number of backers and assesses the level of interest using the prior expected value of the number of fans. For the Uniform distribution this expected value per backer is equal to \((\alpha h + 1)/2\). Only when \(\alpha h > (\alpha h + 1)/2\), it can be worth for the entrepreneur to assume the risk of a failed campaign, because running the campaign improves the odds of VC funding. This inequality translates into the condition \(\alpha h > 1\) reported in Proposition 6. If we assumed a different, non-uniform prior distribution for the number of backers, we would probably obtain a different condition. However, this condition would still require that \(\alpha h\) is sufficiently big.

Proposition 6 may help explain why we observe many campaigns on Kickstarter and similar product-based crowdfunding websites that are related to hardware and consumer electronics products such as game consoles and Internet-of-Things devices. Consumers are largely able to evaluate the properties of such products, thus implying a high level of informativeness of the signal provided by the crowd with regard to the potential size of the market (Postscapes 2014). As a matter of fact, many have argued that crowdfunding has become the first stop for hardware entrepreneurs to test their product concept on the market (Postscapes 2014, Alois 2015, Lewin 2015). On the other hand, product categories that require significant consumer education and training might not be the best fit for crowdfunding (Key 2013, Hogg 2014). Similarly, we observe that complex software or consumer chemical products, such as cosmetics, are rare on such platforms, arguably because it is difficult for consumers to assess the quality of these products. In addition, consumers active on the crowdfunding platform may not be representative of the targeted segment for certain products, implying reduced informative value of the crowdfunding campaign. This may have been the case for Lively, a startup producing a device to allow fragile seniors to alert their family in case of emergency. The startup realized that their choice of launching a crowdfunding campaign via Kickstarter was a mistake given that their potential customers, i.e., seniors, were not used to accessing crowdfunding platforms. As a result, any campaign for this type of products would be of limited informative value in unveiling the market potential (Konrad 2013).
In the next Proposition we evaluate the profitability of conducting crowdfunding campaigns when the VC’s decision depends primarily on the realization of the external signal and not on the number of backers in the campaign. This happens when $x_H$ assumes a very large value so that $N_H < 0$ and when $x_L$ assumes a very small value so that $N_L > \N$. In this case, the project is always funded when $x_H$ is observed and the project is never funded if $x_L$ is observed. Hence observing the outcome of the campaign is of no informational value, as the decision of the VC depends only on the realization of the external signal.

**Proposition 7:** If $x_H$ is very big so that $N_H < 0$ and $x_L$ is very small so that $N_L > \N$, the entrepreneur prefers crowdfunding to no crowdfunding but the VC has the opposite preference.

The reason the entrepreneur prefers crowdfunding even though the crowdfunding campaign is of no informational value is that the entrepreneur sets the goal of the campaign at the lowest possible level (i.e., $N_{\text{min}} = 0$) in this case. This ensures that the goal is always met irrespective of the number of backers in the campaign. As a result, the entrepreneur can always keep the campaign contributions even when the project is subsequently not funded by the VC. Because the VC does not gain any valuable information in the campaign he definitely prefers no crowdfunding in this case.

Finally, Proposition 8 compares the preference of the entrepreneur in favor of crowdfunding between the two cases that we termed “Observing $x_L$ is not fatal for the project” (Case 1) and “Observing $x_L$ kills the project” (Case 2).

**Proposition 8:** The entrepreneur is less likely to prefer crowdfunding in the case that observing $x_L$ kills the project ($N_L > \N$) than in the case that observing $x_L$ is not fatal for the project ($N_L \leq \N$).

There are two reasons that the preference in favor of crowdfunding is weakened when observing $x_L$ kills the project. First, in this case the informational value of the external signal is enhanced relative to the information conveyed by the number of backers in the campaign, so that running a campaign is not that useful. Second, the fact that $x_L$ kills the project implies that $\N$ is relatively small, thus predicting that crowdfunding can generate, on average, only a modest amount of funds.
6 Discussion and Conclusion

Our study demonstrates that reward-based crowdfunding can provide valuable information for decision making purposes in an environment that VC funding is needed to commercialize the entrepreneur’s product. In particular, entrepreneurs should consider the fact that reward-based crowdfunding campaigns allow them to learn more about the potential success of their products and, in case of positive signals from the campaign, to use this information to convince skeptical VCs to provide additional financial resources. Moreover, our findings suggest that by using crowdfunding entrepreneurs can improve their expected payoff from negotiation because capital raised in successful campaigns improves the entrepreneur’s outside option. However, we also caution entrepreneurs about the consequences of failing in crowdfunding campaigns, which may significantly reduce, if not entirely eliminate, her chance to ever raise capital. We show, in particular, that running a campaign before approaching a VC for funding is not always optimal for the entrepreneur. Only if the signal obtained in the campaign is sufficiently informative in comparison with the signals that the VC can obtain on his own, using crowdfunding can be optimal for the entrepreneur. We discuss characteristics of products that are unlikely to yield highly valuable information from crowdfunding campaigns, specifically, when features of the product are difficult to evaluate by consumers (e.g., consumer medical devices or personal care products) or when the preferences of backers active on the crowdfunding platform are not representative of the preferences of consumers in the targeted market for the product. Under such circumstances, entrepreneurs should approach VCs directly for funding without running a campaign in order to avoid the risk of confronting a failed campaign.

We also offer entrepreneurs advice on the manner in which the instruments of the crowdfunding campaign should be selected, in case running such a campaign is optimal. We show that the campaign target number and the pledge level should be set in consideration of the risk that even following a successful campaign VCs may refuse to fund the project. When the risk is especially high we recommend that the entrepreneur raises the target number in order to convince backers that reaching a more demanding target is a good indication of future success. As the concerns of backers for failure are alleviated, the entrepreneur can afford to set a higher pledge level.
We also evaluate the benefits of running reward-based crowdfunding campaigns from the perspective of VCs. We point out that the information obtained in the campaign can guide the VC in making sensible investment decisions and in eliminating from consideration projects that show little potential for success. However, the entrepreneur’s decision to run a campaign may introduce some disadvantages to the VC. First, the improved bargaining position of the entrepreneur following a successful campaign necessarily implies a loss to the VC. Moreover, backers in the campaign could potentially be future consumers of the product, whereas revenues pledged in the campaign accrue exclusively to the entrepreneur and not to the VC. Because of these two disadvantages, we demonstrate that the preference of the VC in favor of crowdfunding is not as strong as that of the entrepreneur. Specifically, the VC benefits from crowdfunding over a smaller region than that of the entrepreneur. In particular, the informativeness of the signal obtained in the campaign has to be sufficiently high for the VC to benefit.

Given our objective to focus on the informative role of reward-based crowdfunding in an environment where further VC funding is necessary, we make several simplifying assumptions in our model. Some of these assumptions can be relaxed without affecting the qualitative results. For instance, the assumption that the number of backers in the campaign is uniformly distributed can be easily relaxed. If we changed the specification of the density function to allow for a bigger (smaller) number of backers to be more likely, the prior expectations regarding the prospects of the product would improve (deteriorate), respectively, in comparison with the uniform specification. As a result, the region of the parameters that support running a crowdfunding campaign before approaching the VC may change. Nevertheless, the existence of the trade-offs that we identify for both entrepreneurs and VCs would remain. Similarly, we can easily change the two-state distribution function for the external signal observed in the market study conducted by the VC. Assuming a continuous distribution would generate more cumbersome derivations without affecting the main intuition. For the sake of tractability, we also assume that the signal obtained in the campaign is independently distributed of the signal obtained in the VC’s external market study. If we assumed correlation between the two signals, instead, the incremental value observing one more signal would
decline. We conjecture that in this case the profitability of running a crowdfunding campaign would decline in comparison with an environment where the signals are independently distributed. Relaxing our assumption that the unit production cost is normalized to zero is also unlikely to change the trade-offs we identify for both entrepreneurs and VCs.

As we pointed out already, relaxing the assumption that a failed campaign dooms the project is unlikely to change the qualitative results, as long as the likelihood of VC funding is higher following a successful rather than a failed campaign. The characterization of the equilibrium would then depend on the gap between the two probabilities of funding. However, given the reduced risk for the entrepreneur in this case, we conjecture that the entrepreneur would then have higher incentive to run a campaign before approaching the VC. Similarly, relaxing the assumption that the startup’s bargaining power $\delta$ is not affected by her decision on whether to run a campaign or approach the VC directly does not change the qualitative results. Indeed, we could assume that under crowdfunding, the bargaining power of the entrepreneur improves in case of a successful campaign and deteriorates in case of failed campaign in comparison with the option of no crowdfunding. In this case, we conjecture that the region of the entrepreneur’s preference in favor of crowdfunding would expand or contract depending on whether the benefit of the enhanced bargaining power following success dominates the disadvantage of the weakened bargaining power following failure.

Finally, our analysis is based upon the rule used on Kickstarter that allows entrepreneurs to keep the amount pledged only if funds raised in the campaign exceed the declared goal. Platforms such as Indiegogo allow the entrepreneur to keep a portion of the amount pledged even when the campaign goal is not met. This different rule reduces the negative consequence of a failed campaign, and is likely to increase her preference for running a campaign.

Relaxing other assumptions of our model may yield substantially new forces that our current formulation does not capture. For instance, in order to focus on the informative value of crowdfunding, we assume that the entrepreneur and VC observe the same information regarding the uncertainty. Hence, our model assumes imperfect but complete information, using the terminology introduced in the literature of information economics. If we allow, instead, the parties to have
access to private information regarding the uncertainty, new incentives may arise. For instance, if entrepreneurs had access to private information about the prospects of the project that could not be credibly communicated to the VC, running a campaign would become a signal of this private information. Such signaling considerations would increase the odds that crowdfunding campaigns were selected by entrepreneurs observing positive signals of the demand in order to separate themselves from entrepreneurs facing negative signals. Similarly, if the VC could privately observe the results of his own market research, he might have incentives to withhold some of this information from the entrepreneur in order to improve his bargaining position. In our formulation we also assume that backers in the campaign are identical in terms of the information they have about the product. If we assumed, instead, that some backers are better informed than others, it would become interesting to investigate the dynamics of placing pledges in the campaign. Our conjecture is that better informed backers would submit pledges early in order to convince more poorly informed backers to join the campaign as well, by sending them a signal that they believe in the prospects of the product. We leave these issues for future research.
7 Appendix

Proof of Lemma 1: If \( zR(n, x_i) - K \geq 0 \), then the entrepreneur and VC, with bargaining power \( \delta \) and \( 1 - \delta \) respectively, negotiate on the share \( \lambda \) and \( 1 - \lambda \) to split the future profit \( R(n, x_i) \). The entrepreneur contributes an amount \( s \) to cover part of the development cost, with \( s \leq nr \). The VC contributes the remaining \( K - s \). Thus, the entrepreneur’s expected payoff is \( \lambda zR(n, x_i) + nr - s \) if they reach the agreement. In case no agreement is reached, her payoff is her outside option \( nr \).

The VC’s agreement payoff is \((1 - \lambda) zR(n, x_H) - (K - s)\) and his disagreement payoff is zero.

The GNBS maximizes the following in \( \lambda \):

\[
\left[ \lambda zR(n, x_i) + nr - s - nr \right]^\delta \left[ (1 - \lambda) zR(n, x_i) - (K - s) \right]^{1-\delta},
\]

which yields \( \lambda^* = \delta - \frac{\delta K - s}{zR(n, x_i)} \). Substituting back into the agreement payoffs of the entrepreneur and VC yields:

\[
W_E(n, x_i) = \delta (zR(n, x_i) - K) + nr,
\]

\[
W_{VC}(n, x_i) = (1 - \delta) (zR(n, x_i) - K).
\]

This completes the proof.

Proof of Lemma 2: The proof follows directly from the discussion after Lemma 2.

Proof of Proposition 1: (i) When observing \( x_L \) is not necessarily fatal for the project (Case 1), by (P1) the entrepreneur’s profit \( \pi_E^C \) decreases with \( N_{\min} \). We first assume \( N_{\min} \) achieves the lower bound in constraint (6), and then check if the corresponding solution satisfies \( \max(N_H, 0) \leq N_{\min} \leq N_L \). Evaluating (6) as equality yields:

\[
r (\bar{N} - N_{\min}) = \left[ (1 - p) z [ (1 - \gamma) v_H + v_L ] (\bar{N} - N_{\min}) - z p [ (\gamma - 1) v_H - v_L ] (\bar{N} - N_L) \right].
\]

Substituting it into the profit function yields:

\[
\pi_E^C = \frac{z(N^2 - N_{\min}^2)}{2N} \left[ (1 - p) [(1 - \gamma) v_H + v_L + \delta v_L h] + p [(1 - \gamma) v_H + v_L] \frac{\bar{N} - N_L}{\bar{N} - N_{\min}} \right]
\]

\[
+ \frac{p}{N} \int_{N_{\min}}^{\bar{N}} \delta [z z \alpha v_L (h n + (1 - h) x_L) - K] d\alpha + \frac{(1 - p)}{N} [\delta z \alpha v_L (1 - h) x_H - \delta K] (\bar{N} - N_{\min}).
\]

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Taking the derivative with respect to \( N_{\min} \) and setting it to zero yields the interior solution

\[
N_{\min}^{\text{int}} = \frac{1}{2} \left[ \frac{(1 - \gamma) v_H + v_L}{(1 - p)} \right] \left( N - N_L \right) - (1 - p) \delta \left[ \alpha v_L (1 - h) x_H - K \right]
\]

For this solution to satisfy the constraint \( \max(N_H, 0) \leq N_{\min}^{\text{int}} \leq N_L \), we have:

\[
N_{\min}^{\text{int}} \geq \max(N_H, 0) \Rightarrow p \geq p_L = \begin{cases} \frac{2N_H}{2N_H + N - N_L} \delta \left[ \alpha v_L (1 - h) x_H - K \right] & \text{if } N_H \geq 0 \\ \frac{1}{2} \left[ (1 - \gamma) v_H + v_L \right] \left( N - N_L \right) & \text{if } N_H < 0 \end{cases}
\]

\[
N_{\min}^{\text{int}} \leq N_L \Rightarrow p \leq p_U = \frac{((1 - \gamma) v_H + v_L) N_L + \delta \alpha v_L (N_L - N_H)}{((1 - \gamma) v_H + v_L) \left( \frac{N + N_L}{2} \right) + \delta \alpha v_L (N_L - N_H)}.
\]

It is easy to verify \( N = N_L \Rightarrow p_L = p_U = 1 \) and \( 0 \leq p_L < p_U \leq 1 \) when \( N_L \leq N \). Therefore, \( \max(N_H, 0) \leq N_{\min}^{\text{int}} \leq N_L \leq N \iff p_L \leq p \leq p_U \) so that

\[
N_{\min}^{*} = \begin{cases} \max(N_H, 0) & \text{if } 0 \leq p < p_L \\ N_{\min}^{\text{int}} & \text{if } p_L < p < p_U \\ N_L & \text{if } p_U < p \leq 1 
\end{cases}
\]

Because the constraint (6) is binding at the optimum, we have

\[
r^{*} = z \left[ (1 - \gamma) v_H + v_L \right] \left[ 1 - p + \frac{N - N_L}{N - N_{\min}^{*}} \right].
\]

The highest pledge \( r^{*} = z \left[ (1 - \gamma) v_H + v_L \right] \) is reached when \( p_U < p \leq 1 \). The optimal goal is \( G^{*} = r^{*} N_{\min}^{*} \). It is straightforward to derive the probability of launching the project.

(ii) If observing \( x_L \) kills the project (Case 2), then \( N_L \geq N \). By (P2), \( \pi_{E}^{C} \) decreases with \( N_{\min} \) and increases with \( r \). Thus, the optimal solution is reached at boundary with \( N_{\min}^{*} = \max(N_H, 0) \), \( r^{*} = z \left[ (1 - \gamma) v_H + v_L \right] \left[ 1 - p \right] \), \( G^{*} = r^{*} N_{\min}^{*} \). The VC will fund the project only when \( x_H \) realizes and \( n \geq N_{\min}^{*} \) so that the probability of launching the project is \( (1 - p) \left( 1 - \frac{\max(N_H, 0)}{N} \right) \).

**Proof of Proposition 2:** By the first order derivatives, it is straightforward to verify that \( N_{\min}^{\text{int}} \) increases with \( p \) and \( N \). To show \( \frac{\partial N_{\min}^{\text{int}}}{\partial p} \leq 0 \) we need

\[
N_H (1 - p) \leq \frac{1}{2} p (N - N_L),
\]

which holds when \( N_H < 0 \). When \( N_H > 0 \), this condition is

\[
\frac{2N_H}{2N_H + N - N_L} \leq p.
\]
This is equivalent to the condition $p_L \leq p$ when $N_H > 0$. Therefore, $N_{\text{int}}_{\min}$ decreases with $\delta$ over the valid region.

As $N_{\text{int}}_{\min}$ is essentially a function of $(1 - \gamma) v_H$, we define $w = (1 - \gamma) v_H$ and show that $N_{\text{int}}_{\min}$ increases with $w$.

$$\frac{\partial N_{\text{int}}_{\min}}{\partial w} = \left[ \delta z \alpha v_L h \right] \frac{1}{2} \frac{1}{(1 - p) z} \geq 0,$$

which always holds when $N_H < 0$. When $N_H > 0$, this condition is equivalent to $p \geq p_L$, which holds for $N_H \geq 0$.

By taking derivatives with respect to $x_H$ and $x_L$, respectively, we know that $N_{\text{int}}_{\min}$ increases with $x_L$ and decreases with $x_H$. Therefore, $N_{\text{int}}_{\min}$ decreases with the spread $x_H - x_L$ if we increase $x_H - x_L$ while keeping $\frac{x_H + x_L}{2}$ fixed.

**Proof of Proposition 3:** It is straightforward to verify that the boundary solution $\max(N_H, 0)$ ($N_L$) weakly increases (decreases) with $h$. For the interior solution, taking the first order derivative with respect to $h$ yields:

$$\frac{\partial N_{\text{int}}_{\min}}{\partial h} = \frac{1}{2} \frac{p}{(1 - p) z} (1 - \gamma) v_H + v_L] | N_L - x_L | + \frac{\delta \alpha v_L (x_H - N_{\text{int}}_{\min})}{(1 - \gamma) v_H + v_L + \delta \alpha v_L h}.$$

Setting it equal to zero yields a quadratic equation in $h$, which has one positive root only:

$$h^* = \frac{p}{2} \frac{(1 - \gamma) v_H + v_L} {\sqrt{K - z \alpha v_L x_L}} - \frac{\delta \alpha v_L p \sqrt{K - z \alpha v_L x_L + \alpha v_L \sqrt{\delta p H}}}{(1 - \gamma) v_H + v_L + \delta \alpha v_L h}.$$

where $H = z \left( \frac{N}{p} - 2(1 - p) x_H - px_L \right) \left( (1 - \gamma) v_H + v_L \right) - \delta \left( K(2 - p) - z \alpha v_L (2(1 - p) x_H + px_L) \right)$.

The second order derivative at $h^*$ is negative and thus, $h^*$ is a maximizer. Therefore, $N_{\text{int}}_{\min}$ first increases then decreases with $h$. However, $h^*$ might fall outside the range for $N_{\text{int}}_{\min}$ to be optimal.

**Proof of Proposition 4:** The proof follows directly from the discussion before Proposition 4.

**Proof of Proposition 5:** When $\frac{N}{2} < \frac{ah}{ah+t} N_H$, the probability of getting funded is 0 under no crowdfunding, which is dominated by crowdfunding.

When $\frac{ah}{ah+t} N_H \leq \frac{N}{2} \leq \frac{ah}{ah+t} N_L$, the probability of launching the project under no crowdfunding is $\text{Pr}^{N_C} = 1 - p$.

(I) If $N \geq N_L$, Case 1 arises under crowdfunding, which is compatible with $\frac{ah}{ah+t} N_H \leq \frac{N}{2} \leq \frac{ah}{ah+t} N_L$ only if $ah \geq 1$:  

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1) If $p_U < p \leq 1$, the probability of getting funded under crowdfunding $Pr^C = 1 - \frac{N}{N}$. Note that $p_U \geq \frac{N}{N} \Rightarrow \frac{(1-\gamma) \nu H + \nu L}{2} (N - N_L) \geq -\delta h \nu L (N_L - N_H) (N - N_L)$, which always holds.

We have, therefore, $1 - \frac{N}{N} > 1 - p = Pr^{NC}$, i.e., crowdfunding leads to higher probability.

2) If $0 < p < p_U$, crowdfunding leads to higher probability of getting funded when

$$\begin{cases} p \geq \frac{N_H}{N-N_L} \left( \frac{1-\gamma \nu H + \nu L}{2} + N_L \right), & \text{if } p_L < p < p_U \\ p \geq \frac{N_H}{N-N_L+N_H}, & \text{if } p \leq p_L \end{cases}$$

which always hold when $N_H \leq 0$, and may or may not hold when $N_H \geq 0$.

(II) If $N < N_L$, Case 2 arises under crowdfunding, under which the probability of getting funded $Pr^C < 1 - p$. $N < N_L$ is compatible with $\frac{a}{\alpha + 1} N_H \leq \frac{N}{2} \leq \frac{a}{\alpha + 1} N_L$ only if $N_L \geq 2 \left( \frac{a}{\alpha + 1} \right) N_H$, in which case $Pr^{NC} = 1 - p > Pr^C$.

To summarize, when $\frac{a}{\alpha + 1} N_H \leq \frac{N}{2} \leq \frac{a}{\alpha + 1} N_L$ crowdfunding leads to higher probability of funding only if $p$ is sufficiently high.

**Proof of Proposition 6:** (i) When $\frac{N}{2} < \left( \frac{a}{\alpha + 1} \right) N_H$, the comparison is trivial.

(ii) When $\left( \frac{a}{\alpha + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{a}{\alpha + 1} \right) N_L$, there are two cases. We first present the simpler case, which is Case 2, and then move to Case 1.

**Case 2.** $N_L > N$. In this case $N_{\min}^* = \max(N_H, 0)$ by Proposition 1.

**Entrepreneurs’ Profit Comparison**

$N_L > N$ is compatible with $\left( \frac{a}{\alpha + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{a}{\alpha + 1} \right) N_L$ only if $N_L \geq 2 \left( \frac{a}{\alpha + 1} \right) N_H$. In this case, the entrepreneur’s profit under crowdfunding and no crowdfunding are, respectively,

$$\begin{align*}
\pi^C_E &= (1-p) \left[ z \frac{\nu H (1-\gamma) + \nu L}{2} (N - (N_{\min}^*)^2) + \frac{\delta \alpha h}{2N} h (N - N_{\min}^*) (N + N_{\min} - 2N_H) \right], \\
\pi^{NC}_E &= \delta \alpha v_L h (1-p) \left[ \frac{N}{2} \left( \frac{a h + 1}{a h} \right) - N_H \right]
\end{align*}$$

so that

$$\pi^C_E \geq \pi^{NC}_E \Leftrightarrow N \geq \max(N_H, 0) \sqrt{\frac{\nu H (1-\gamma) + \nu L - \delta \alpha v_L h}{\nu H (1-\gamma) + \nu L - \delta v_L}}.$$

If $N_H \leq 0$, this condition always holds. Otherwise, if $N_H > 0$, given that $N > N_H$, the above condition is always satisfied when $a h \geq 1$. When $a h < 1$, crowdfunding leads to higher profit than no crowdfunding if $N$ is sufficiently high. In the latter case it is indeed possible for $N \geq N_H \sqrt{\frac{\nu H (1-\gamma) + \nu L - \delta \alpha v_L h}{\nu H (1-\gamma) + \nu L - \delta v_L}}$ to overlap with the range $\left( \frac{a}{\alpha + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{a}{\alpha + 1} \right) N_L$. 

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VC’s Profit Comparison

Under \( N_L \geq \overline{N} \), the VC’s profit under crowdfunding and no crowdfunding are, respectively,

\[
\pi^C_{VC} = (1 - \delta) (1 - p) \frac{z \alpha v_L h}{2 \overline{N}} (N - N^*_m)(N + N^*_m - 2N_H),
\]

\[
\pi^{NC}_{VC} = (1 - \delta) z \alpha v_L h (1 - p) \left[ \frac{N}{2} \left( \frac{\alpha h + 1}{\alpha h} \right) - N_H \right]
\]

so that

\[
\pi^C_{VC} \geq \pi^{NC}_{VC} \iff N \leq \max(N_H, 0) \sqrt{\alpha h}.
\]

If \( N_H \leq 0 \), this condition never holds, so that the VC always makes lower profit under crowdfunding. Otherwise, if \( N_H > 0 \), then if \( \alpha h < 1 \), the condition never holds because \( N \geq N_H \). If \( \alpha h > 1 \) and \( N \leq N_H \sqrt{\alpha h} \), the VC’s profit is higher under crowdfunding. Note that in this case it is possible for \( N \leq N_H \sqrt{\alpha h} \) to overlap with the range \( \left( \frac{\alpha h}{\alpha h + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h + 1} \right) N_L \).

Case 1. \( N_L \leq \overline{N} \).

Entrepreneurs’s Profit Comparison

\( N_L \leq \overline{N} \) is compatible with \( \left( \frac{\alpha h}{\alpha h + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h + 1} \right) N_L \) only if \( \alpha h \geq 1 \). In this case, the entrepreneur’s profits under crowdfunding and no crowdfunding are, respectively,

\[
\pi^C_E = \frac{r}{2 \overline{N}} (N^2 - (N^*_m)^2) + \frac{(1 - p)\delta}{\overline{N}} \left[ \int_{N^*_m}^{N^*} [z \alpha v_L (hn + (1 - h)x_H) - K] dn \right. \\
+ \left. \frac{p\delta}{\overline{N}} \int_{N_L}^{N^*} [z \alpha v_L (hn + (1 - h)x_L) - K] dn \right],
\]

\[
\pi^{NC}_E = \delta z \alpha v_L h (1 - p) \left( \frac{N}{2} \left( \frac{\alpha h + 1}{\alpha h} \right) - N_H \right),
\]

where by Proposition 1

\[
N^*_m = \begin{cases} 
\max(N_H, 0) & \text{if } 0 \leq p < p_L \\
N^*_{min}^{int} & \text{if } p_L < p < p_U \\
N_L & \text{if } p_U \leq p \leq 1 
\end{cases}
\]

We next show that since \( \alpha h \geq 1 \) must hold for this case to arise, crowdfunding always leads to higher profit than no crowdfunding for the entrepreneur.

It suffices to show 1) \( \pi^C_E (N^*_m = \max(N_H, 0)) \geq \pi^{NC}_E \) always, and 2) \( \pi^C_E (N^*_m = N_L) \geq \pi^{NC}_E \) on \( p_U < p \leq 1 \). This is because \( \pi^C_E (N^*_m = \max(N_H, 0)) \geq \pi^{NC}_E \) implies that \( \pi^C_E (N^*_m = N^*_{min}^{int}) \geq \pi^{NC}_E \) because the interior solution \( N^*_{min}^{int} \) outperforms the boundary solution \( \max(N_H, 0) \).
1) When \( N_{\text{min}}^* = \max(N_H, 0) \), \( \pi_E^C \) is increasing in \( x_L \), whereas \( \pi_E^{NC} \) does not depend on \( x_L \). It suffices to show \( \pi_E^C \geq \pi_E^{NC} \) at the minimum value of \( x_L \), where \( N_L = \mathbb{N} \). However, this simply reduces to the comparison under Case 2, where we have shown \( \pi_E^C \geq \pi_E^{NC} \) as long as \( ah \geq 1 \).

2) Consider \( N_{\text{min}}^* = N_L \), which is valid on \( p_U < p \leq 1 \). The entrepreneur’s profits under crowdfunding and no crowdfunding are, respectively,

\[
\pi_E^C(N_{\text{min}}^* = N_L) = \frac{(N + N_L)(N - N_L)}{2N} z [(1 - \gamma)v_H + v_L + \delta \alpha v_L h] + \frac{\delta z \alpha v_L (1 - h)}{N}[(1 - p)v_H + px_L](N - N_L) - \frac{\delta}{N}K(N - N_L),
\]

\[
\pi_E^{NC} = \delta z \alpha v_L h (1 - p) \left[ \frac{N}{2} \left( \frac{\alpha h + 1}{\alpha h} \right) - N_H \right].
\]

It is easy to show \( \frac{\partial^2 [\pi_E^C(N_{\text{min}}^* = N_L) - \pi_E^{NC}]}{\partial p^2} = 0 \), which implies that \( \pi_E^C(N_{\text{min}}^* = N_L) - \pi_E^{NC} \) is monotone in \( p \) on \( p_U \leq p \leq 1 \). Thus, it suffices to show \( \pi_E^C(N_{\text{min}}^* = N_L) \geq \pi_E^{NC} \) at both \( p = p_U \) and \( p = 1 \).

At \( p = p_U \), \( N_{\text{min}}^{int} = N_L \). Note that \( \pi_E^C(N_{\text{min}} = N_{\text{min}}^{int}) \geq \pi_E^C(N_{\text{min}} = \max(N_H, 0)) \) because \( N_{\text{min}}^{int} \) is the interior solution, and we have proved \( \pi_E^C(N_{\text{min}} = \max(N_H, 0)) \geq \pi_E^{NC} \) on \( p \in [0, 1] \). Therefore, we have \( \pi_E^C(N_{\text{min}} = N_L) \geq \pi_E^C(N_{\text{min}} = \max(N_H, 0)) \geq \pi_E^{NC} \) at \( p = p_U \). At \( p = 1 \), \( \pi_E^{NC} = 0 \leq \pi_E^C(N_{\text{min}}^* = N_L) \). Thus, the entrepreneur’s profit is higher when Case 1 arises under crowdfunding.

**VC’s Profit Comparison**

\( N_L \leq \mathbb{N} \) is compatible with \( \left( \frac{\alpha h}{\alpha h + \tau} \right) N_H \leq \mathbb{N} \leq \left( \frac{\alpha h + 1}{\alpha h + \tau} \right) N_L \) only if \( \alpha h \geq 1 \). In this case, the VC’s profits under crowdfunding and no crowdfunding are, respectively,

\[
\pi_{VC}^C = \frac{(1 - \delta)}{N} \left[ (1 - p) \int_{N_{\text{min}}^*}^{N} [z \alpha v_L h n + z \alpha v_L (1 - h) x_H - K] dn \right] + p \int_{N_L}^{N} [z \alpha v_L (h n + (1 - h) x_L) - K] dn,
\]

\[
\pi_{VC}^{NC} = (1 - \delta) z \alpha v_L h (1 - p) \left[ \frac{N}{2} \left( \frac{\alpha h + 1}{\alpha h} \right) - N_H \right].
\]

Depending on the value of \( N_{\text{min}}^* \), there are three cases.

(I) \( p \leq p_L \)

When \( p \leq p_L \), \( N_{\text{min}}^* = \max(N_H, 0) \). We first examine the case of \( N_H \geq 0 \). In this case the VC’s profit under Case 1 of crowdfunding is:

\[
\pi_{VC}^C(N_{\text{min}}^* = N_H) = (1 - \delta) z \alpha v_L h (1 - p)(N - N_H)^2 + (1 - \delta) \frac{pz \alpha v_L h}{2N}(N - N_L)^2.
\]
\[ \pi_{VC}^C (N_{\min}^* = N_H) \geq \pi_{VC}^N \] can be simplified to:

\[
\left[p - \frac{1-p}{\alpha h} \right] N^2 - 2pNN_L + p(N_L)^2 + (1-p) (N_H)^2 \geq 0. \tag{11}
\]

(I.a) When \(1 - p - pah = 0\), the VC makes higher profit under crowdfunding if

\[ N \leq \frac{\alpha h (N_H)^2 + (N_L)^2}{2N_L}. \]

(I.b) When \(1 - p - pah > 0\), evaluating (11) at equality yields two roots. The smaller root is negative, so that the VC makes higher profit under crowdfunding if

\[ N \leq \frac{-p + \sqrt{p^2 + \left[ \frac{1-p}{\alpha h} - p \right] \left[ p + (1-p) \frac{(N_H/N_L)^2}{pah+p-1} \right]}}{1-p-pah}. \tag{12} \]

(I.c) When \(1 - p - pah < 0\), again by (11) we know that the VC makes higher profit under crowdfunding if

\[ N \geq \frac{p + \sqrt{p^2 + \left[ \frac{1-p}{\alpha h} - p \right] \left[ p + (1-p) \frac{(N_H/N_L)^2}{pah+p-1} \right]}}{pah+p-1}. \tag{13} \]

If \(p^2 + \left[ \frac{1-p}{\alpha h} - p \right] \left[ p + (1-p) \frac{(N_H/N_L)^2}{pah+p-1} \right] < 0\), then VC always makes higher profit under crowdfunding. Otherwise, the VC prefers crowdfunding if \(N\) satisfies (12) and (13).

Note that when \(p = p_L = \frac{2N_H}{2N_H+N_N-L}\), we have \(N = N_L + \frac{2N_H(1-p)}{p}\), which is always above the root \(\alpha h N \frac{p^2 + \left[ \frac{1-p}{\alpha h} - p \right] \left[ p + (1-p) \frac{(N_H/N_L)^2}{pah+p-1} \right]}{pah+p-1}\) (the proof of this result is available upon request) so that (12) is not valid. When \(p < p_L\), it is indeed possible for (12) and (13) to overlap with

\[ \left( \frac{\alpha h}{\alpha h+1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h+1} \right) N_L. \]

To summarize, under the solution \(N_{\min}^* = N_H\), if \(1 - p - pah \geq 0\), then the VC receives higher profit under crowdfunding if \(N\) is below a certain threshold. If \(1 - p - pah < 0\), then the VC receives higher profit under crowdfunding if \(N\) is either relatively high or relatively low.

When \(N_H < 0\), the solution \(N_{\min}^* = 0\). We have verified that in this case the smaller root is always below \(N_L\). As a result, when \(1 - p - pah < 0\), crowdfunding leads to higher profit for the VC if \(N\) is sufficiently high, whereas under \(1 - p - pah \geq 0\), the VC always prefers no crowdfunding.
(II) $p \geq p_U$

When $p \geq p_U$, $N_{\text{min}}^* = N_L$. Then VC’s profit under crowdfunding is:

$$\pi_{\text{VC}}^C (N_{\text{min}}^* = N_L) = \frac{(1 - \delta) [N - N_L]}{N} \left[ z \alpha v_L h \left( \frac{N + N_L}{2} \right) + (1 - h) \left[ (1 - p)x_H + px_L \right] \right] - K$$

$$= \frac{(1 - \delta) z \alpha v_L h (N - N_L)}{N} \left[ \frac{N + N_L}{2} - (pN_L + (1 - p)N_H) \right].$$

We can simplify $\pi_{\text{VC}}^C (N_{\text{min}}^* = N_L) \geq \pi_{\text{VC}}^C$ to:

$$\frac{N^2}{p - \frac{1 - p}{\alpha h}} - 2pN_LN + (2p - 1)(N_L)^2 + 2(1 - p)N_HN_L \geq 0. \quad (14)$$

It is straightforward to verify that $p - \frac{1 - p}{\alpha h} \geq 0$ for $p \geq p_U$ given that $\alpha h \geq 1$ and $\frac{2\alpha h}{1 + \alpha h} N_L \geq N$. Evaluating (14) at equality yields two roots; the smaller root is below $N_L$ and is discarded. Thus, the VC prefers crowdfunding if

$$p \geq \frac{\sqrt{p^2 - \left( p - \frac{1 - p}{\alpha h} \right) \left[ 2p - 1 + 2(1 - p)N_H/N_L \right]} - p\alpha h + p - 1}{p\alpha h + p - 1}.$$

$p^2 - \left( p - \frac{1 - p}{\alpha h} \right) \left[ 2p - 1 + 2(1 - p)N_H/N_L \right]$ could be negative, in which case the VC prefers crowdfunding for all $p \geq p_U$.

(III) $p_L \leq p \leq p_U$

In this case $N_{\text{min}}^* = N_{\text{min}}^{int}$. The inequality $\pi_{\text{VC}}^C (N_{\text{min}}^* = N_{\text{min}}^{int}) \geq \pi_{\text{VC}}^C$ can be simplified to:

$$\frac{p}{1 - p} \left( N - N_L \right)^2 - \frac{N^2}{\alpha h} \geq \left( N_{\text{min}}^{int} - N_H \right)^2 - N_H^2.$$

By noting

$$N_{\text{min}}^{int} - N_H = \left[ \frac{p(N - N_L)}{2(1 - p)} - N_H \right] \frac{[(1 - \gamma)v_H + v_L]}{[(1 - \gamma)v_H + v_L + \delta \alpha v_L h]},$$

we can rewrite the inequality as

$$\frac{p}{1 - p} \left( N - N_L \right)^2 - \frac{N^2}{\alpha h} \geq \left[ \left( \frac{p(N - N_L)}{2(1 - p)} \right)^2 + (N_H)^2 - \frac{p(N - N_L)N_H}{(1 - p)} \right] A - N_H^2,$$

where

$$A = \left( \frac{[(1 - \gamma)v_H + v_L]}{[(1 - \gamma)v_H + v_L + \delta \alpha v_L h]} \right)^2 < 1.$$
Rearranging the terms yields

$$\left[ \frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} \right] N^2 + NB + C \geq 0$$

(15)


Evaluating (15) at equality yields two roots:

$$N_{1,2} = \frac{-B \pm \sqrt{B^2 - 4 \left[ \frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} \right] C}}{2 \left[ \frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} \right]}.$$  

(16)

When $\frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} = 0$, the VC makes higher profit under crowdfunding if $NB + C \geq 0$.

When $\frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} < 0$, the VC makes higher profit under crowdfunding if $N$ falls within the two roots in (16) (it is possible for the range between two roots to overlap with $\left( \frac{\alpha h}{\alpha h + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h + 1} \right) N_L$. In case there is no overlap, then the VC never makes higher profit under crowdfunding).

When $\frac{4p - (4 + A)p^2}{4(1 - p)} - \frac{(1 - p)}{\alpha h} > 0$, the VC makes higher profit under crowdfunding if $N$ is either above the bigger root or below the smaller root in (16) and also satisfies $\left( \frac{\alpha h}{\alpha h + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h + 1} \right) N_L$, which can happen.

Summarizing cases 1 and 2, we conclude that when $\left( \frac{\alpha h}{\alpha h + 1} \right) N_H \leq \frac{N}{2} \leq \left( \frac{\alpha h}{\alpha h + 1} \right) N_L$, the VC never prefers crowdfunding when $\alpha h < 1$, whereas his preference is ambiguous when $\alpha h \geq 1$. The entrepreneur prefers crowdfunding for big $N$ when $\alpha h < 1$, and she always prefers crowdfunding when $\alpha h \geq 1$.

(iii) The case that $\delta = 1$ and $\gamma = 1$ can be easily verified.

Proof of Propositions 7 and 8

The proof of these two results follows directly from the proof of Proposition 6.
8 References


Krishnan, V. 2013. Operations Management opportunities in technology commercialization and


