Reward-based crowdfunding campaigns: informational value and access to venture capital

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Abstract

Consider an entrepreneur who designs a reward-based crowdfunding campaign when the campaign provides a signal about the future demand for the product and subsequent Venture Capital (VC) is needed. Her design entails choosing both the goal that has to be reached for the campaign to be successful, and the pledge level that entitles campaign backers to the product if it becomes available. While failure to reach the goal sends a negative signal likely to eliminate the entrepreneur's access to VC funding, succeeding does not guarantee subsequent VC funding either because the signal obtained in the campaign is not necessarily accurate. The prospect of lack of VC funding following a successful campaign creates concerns for backers, as they lose their pledges without receiving anything in return in this case. We find that both the informativeness of the campaign and considerations related to gaining access to VC funding affect the choice of campaign instruments, as well as the decision of whether to run a campaign. When the extent of informativeness of the campaign is very low so that the number of campaign backers has no impact on the VC's decision, the entrepreneur prefers to launch a campaign. She is also in favor of running a campaign when informativeness is relatively high. When informativeness is relatively low but the VC does take into account the number of backers in his decision, circumstances may arise under which the entrepreneur prefers approaching the VC directly without running a campaign. Finally, we show that the VC is less likely to prefer crowdfunding than the entrepreneur.

Keywords: reward-based crowdfunding, information acquisition, venture capital, new product development.

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 the funder a reward, which often takes the form of the completed product if it is successfully produced (Grant 2013, 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 $34.4 billion raised across the globe in 2015 and expected to top $60 billion in 2016 (Hogue 2015). Kickstarter, a leading platform for reward-based crowdfunding worldwide, has launched more than 307,000 crowdfunding campaigns, with 36% successfully funded by more than 11 million individuals.

In recent years, there has been a trend of using reward-based crowdfunding for developing consumer technology products. On Kickstarter, games, technology and product design are the top three categories in terms of total dollars raised. These projects typically require large amount of capital to support development 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 in these categories necessitates subsequent rounds of funding from professional investors, e.g., Venture Capitalists (VCs) (Segarra, 2013). However, a successful campaign does not guarantee the support of VCs. According to CB Insights, only 9.5% of crowdfunded hardware campaigns receiving at least $100,000 campaign funds have secured subsequent funding from VCs. Thus, apart from the inherent uncertainty in new product development, the prospect of lack of VC funding in spite of a successful campaign makes technology related projects highly risky. In fact, campaigns of technology projects have the lowest success rate of 19.95% on Kickstarter, compared to dancing or theater projects that enjoy success rates of more than 60%. The latter type of projects typically do not require funding from professional investors.

Consumers who pledge in reward-based crowdfunding campaigns, whom we refer to as *backers*,

are typically interested in experimenting with early prototypes and possibly gaining early access to new products. Because backers put down money for a product that has yet to be produced, and because they tend to be drawn from the population of potential consumers, the number of backers and the overall capital raised in the campaign 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). 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). The community of professional investors shares similar views. In fact, due to the high risk of backing startups, VCs many times do not invest until a company has validated the market, gained traction, and demonstrated it can execute the project (Grant 2013). Barry Schuler, managing director of DFJ Growth (a company that invested in Formlabs, a low cost 3D-printing startup that raised $2.95 million on Kickstarter in 2012), referred to a crowdfunding campaign as "an ultimate test market" (Cao 2014). In this regard, equity-based crowdfunding might be of limited value because the complex legal issues involved tend to attract professional and accredited investors such as angel investors or VCs (Barnett 2014, Payne 2015) whose behavior is unlikely to be representative of general consumers.

While reward-based crowdfunding may provide information on the market potential of the product, running it carries some risk to entrepreneurs. As suggested by industry practice, VCs typically interpret a failed campaign as a grim signal of the potential success of the product and the managerial capabilities of the entrepreneur. As a result, the entrepreneur is most likely to lose access to VC funding after a failed campaign, thus leading to the termination of her project (Strohmeyer 2013, Houssou and Belvisi 2014). This provides the entrepreneur an incentive to set the campaign goal at a low level, because a campaign is deemed successful only when the amount raised in the campaign exceeds this goal. However, choosing a low goal increases the likelihood

that the campaign is successful but the project is not subsequently funded by the VC, because VCs typically run their own market research before making funding decisions. Thus, a lower goal increases the risk backers face of losing their pledge without receiving any benefit in return, which may discourage them from pledging. This dilemma facing the entrepreneur showcases the interesting research questions that can arise in an environment where crowdfunding campaigns serve as a source of information about future demand and where VC funding is essential for commercializing a new product. Specifically, how should the entrepreneur choose the *campaign goal* and the *pledge level* that entitles backers to receive the product if it becomes available? Does the entrepreneur always prefer to run a crowdfunding campaign prior to approaching VC for funding? What is the VC's preference regarding the entrepreneur's choice of running a campaign?

To address these questions we develop a three-stage game. In the first stage, the entrepreneur sets the goal and the pledge level. These two instruments determine the *target number*, i.e., the minimum number of backers required for the campaign to be successful. Once the entrepreneur runs the campaign, the number of backers and the total amount of pledges realize. Following the rule of Kickstarter, if total pledges fall short of the declared goal, the campaign is considered a failure and the entrepreneur does not receive any of the backers' funds. As discussed above, the failed campaign implies also that the VC does not fund the project, thus terminating it.[1] If total pledges exceed the declared goal, the campaign is successful and the entrepreneur receives the funds raised in the campaign. The second stage of the game materializes only when the campaign is successful, in which case the entrepreneur approaches the VC for funding. The VC observes the outcome of the campaign and conducts an independent market research to assess the prospects of the venture.[2] Using the information obtained from these two sources, the VC decides whether to fund the project. If he decides in favor of funding, the game proceeds to the third stage when both parties negotiate on how to split the future revenue if the product is successfully commercialized.

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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, as explained in greater details in the model section.

[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).

We use the Generalized Nash Bargaining Solution (GNBS) to predict the negotiation outcome. As we consider only reward-based crowdfunding campaigns, the term "reward-based" is often omitted in the rest of the paper.

Our study illustrates that both the extent of informativeness of the campaign and considerations related to gaining access to VC funding play important roles in setting the campaign instruments. When the campaign is not informative of future demand so that the VC ignores it in his funding decision, the target number and the goal should be set very low to ensure campaign success. The pledge level is the lowest in this case. When the campaign becomes more informative, the entrepreneur chooses to raise the target number and the goal because a more demanding goal, once it is reached, demonstrates better prospects for the product, thus supporting higher pledge levels. When the level of campaign informativeness is high, the VC's decision relies mostly on the campaign outcome, so backers are less concerned about losing their pledges and the entrepreneur might choose to lower the target number and the goal in order to improve the odds of campaign success.

We find that crowdfunding offers the entrepreneur three potential benefits to offset against the risk of campaign failure. In addition to serving as a source of information regarding future demand, crowdfunding can be used as a vehicle to practice price discrimination between backers and consumers. In addition, the entrepreneur improves her outside option in the negotiation with the VC because she can keep the entire contributions of backers, in case the negotiation fails. In contrast, she receives only portion of the expected profits from selling the product to backers in the future market under no crowdfunding. We show that for relatively small projects, running a campaign before approaching the VC for funding is definitely the right choice for the entrepreneur. In this case, the risk associated with campaign failure is limited because obtaining funding for small project is not challenging. The entrepreneur can strategically set a low goal in this case to raise the odds of a successful campaign. In contrast, for projects that require large development costs the entrepreneur's preference in favor of running a crowdfunding campaign depends on the relative informativeness of the campaign in comparison to the informativeness of the VC's own

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market research. Surprisingly, the entrepreneur prefers to run the campaign not only when the extent of campaign informativeness is high, but also when it is very low. In the latter case, the VC relies only on his own market research in making his funding decision. Therefore, the entrepreneur can eliminate the risk of campaign failure by setting a very low target number (thus a very low goal). The strict preference in favor of running a campaign originates, in this case, exclusively from benefits unrelated to the informativeness of the campaign. When relative informativeness is high, the entrepreneur is forced to raise the target number, resulting in a higher likelihood of campaign failure. However, high informativeness combined with the other two benefits that crowdfunding offers outweigh the increased risk of campaign failure. For relatively low informativeness but when the number of backers realized in the campaign has an effect on the VC's decision, circumstances may arise under which the benefits of running the campaign are insufficient to offset against the risk of campaign failure, and the entrepreneur prefers to approach the VC directly without running a campaign.

Because the only benefit from crowdfunding that accrues to the VC relates to the informativeness of the campaign, we find that the VC prefers crowdfunding over a smaller region of parameter values than the entrepreneur does. Indeed, running the campaign implies that a portion of the potential population of consumers is removed from future sales in the market. If the group of backers is relatively big this loss to the VC can be substantial.

Our findings are consistent with some observations in the industry. Crowdfunding appears to provide valuable information for consumer hardware products that tend to be quite common on crowdfunding platforms. For example, 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 does not seem to be particularly informative for consumer medical devices or personal care products that may be too complex to evaluate by individuals active on crowdfunding websites (Grant 2013, 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). For products that are unlikely to yield valuable information via crowdfunding campaigns, our results indicate that entrepreneurs might either approach VCs directly without running a campaign, or if running a campaign, set a low goal to ensure campaign success.

Crowdfunding platforms have revolutionized the manner in which entrepreneurs choose to finance new projects. In our investigation we explore the behavior of three types of reward-baesd crowdfunding platform users. Backers who pledge funds on the crowdfunding platform, entrepreneurs who design the campaign with the dual objectives of learning about future demand and raising funds to finance the project, and venture capitalists who use the outcome of the campaign to make investment decisions. We offer advice to entrepreneurs on the manner in which they should design the crowdfunding campaign and whether they should choose this new method of financing at all. Our study illustrates how considerations related to gaining access to venture capital and to acquiring demand information affect the entrepreneur's decisions. We also identify the reasons that the VC is less likely to prefer crowdfunding than the entrepreneur. Our findings help deepen the understanding of the economic framework of reward-based crowdfunding, which sheds light on the opportunities as well as challenges associated with crowdfunding platforms.

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

2 Literature Review

The nascent literature on crowdfunding has investigated the problem mostly from an empirical perspective (Ordanini et al. 2011, Agrawal et al. 2013, Mollick 2013, 2014, Ahlers et al. 2015; 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. 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. We contribute to this literature by examining the design of a reward-based crowdfunding campaign when the campaign generates demand information and subsequent VC funding is essential for commercializing the product. We also examine whether it is always beneficial to launch a crowdfunding campaign, an issue that has not been examined in the literature.

Our study is also related to the literature on crowd involvement in the innovation process, including Internet-enabled financing, 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, Chen et al. 2015, Liu et al. 2015). Similar to consumer voting systems, reward-based crowdfunding can be used as a participative mechanism that enables 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 already a well-formulated idea for a new product. As a result, consumers commit with their money rather than simply voting for an innovation.

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 uncer-

tain environments has been studied 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). 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, Raju and Roy 2000). In particular, 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 campaign instrument design, as well as the entrepreneur's decision of whether to launch a crowdfunding campaign.

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 the 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 professional investors. 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 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 who 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 size of each group is unknown before the crowdfunding campaign. Let N denote the random number of fans with realization n. For simplicity, we assume a continuous instead of a discrete density for N. In particular, we assume that N is uniformly distributed on $[0, \overline{N}]$. After the campaign this random variable realizes. It can be used to infer the size of the mass market because a bigger number of backers in the campaign indicates greater enthusiasm and overall higher demand for the product.[3] The model consists of three stages.

Stage 1:

The entrepreneur sets the goal G that specifies the minimum amount of funds necessary for the campaign to be considered successful and the pledge level r that entitles backers to receive the product for free if it becomes available.[4] 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 when VC funding is needed, our restriction to a homogeneous population of fans, and therefore, to a single pledge level simplifies the analysis without qualitatively changing our results. Empirical evidence also 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 r in the campaign now or to purchase the product in the future if it is commercialized. Because of our assumption that all fans are identical, they choose the same action either to back the project or not. Let $N_{\min} = G/r$ be the target number of the campaign, i.e., the minimum number of backers required in order to reach the campaign goal. If $n < N_{\min}$, 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,

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[3] In this study, we interchangeably use the terms fans and backers to refer to individuals who pledge in the crowdfunding campaign.

[4] Assuming that backers receive, instead, a discount on the future purchase price of the product will not change the tradeoffs we identify in this paper.

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 addition, 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.[5] Otherwise, if $n \geq N_{\min}$ 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.

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.[6] 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. Incorporating private information would complicate the analysis without significantly changing the main trade-offs identified in our model. For the sake of tractability, we assume that N and X are independently distributed. Assuming correlation between the two signals is unlikely to change our results qualitatively. We discuss in concluding

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[5] In the concluding remarks we discuss the consequences of relaxing this assumption and allowing the entrepreneur to access VC funding following a failed campaign. It is reasonable to expect that the probability of being funded by the VC after failing in the campaign is lower than that in case of campaign success. We can extend our model by introducing a positive (but less than 1) probability ξ of receiving VC funding after a failure. In this case, it can be easily proved that Lemma 2 still holds. The only difference is that with a positive (and strictly less than 1) probability ξ, the project will not be terminated for realizations in the range $[N_H, N_{\min}]$. However, this possibility reduces (but does not eliminate) the risk associated with campaign failure. As long as there exists a gap between the probability of being funded following campaign success and failure, the entrepreneur has to weigh the risk of campaign failure against the benefit of improved information. As a result, our findings will continue to hold.

[6] 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.

remarks the implication of introducing correlation between these two random variables. 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 $\overline{N}$ 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 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 size of the mass market for the product is $\alpha[hn + (1-h)x_i]$, 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 future demand relative to the extent of informativeness of the external signal X. The value of the relative informativeness 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. 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. However, if the product is too 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), h will be close to 0, implying that the realization n provides little information about the future demand.

In our model α is a scale parameter that predicts how observations used to generate the two signals translate to a prediction about the market size. To illustrate the reasonable range of values of α, 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 α value 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 α 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.[7]

Many pitfalls may occur in the development process of new products. 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 probability $1 - z$ that the entrepreneur will fail to deliver the product. With probability z, the project is successfully developed, in which case the

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[7]Note that we can also define $a \equiv \alpha h$ 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.

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 $R(n, x_i) \doteq v_L \alpha \left(hn + (1-h) x_i \right)$ 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 total profit is nonnegative,[8] namely if

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

Whenever this inequality holds the VC knows that via negotiations (to resume subsequently in Stage 3) he will be able to reach an agreement with the entrepreneur so that each party obtains a positive share of these positive proceeds. Otherwise, if the above inequality is reversed the VC decides against funding and the entrepreneur terminates the project. Lack of VC funding following successful crowdfunding campaign is 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. 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

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[8]The profit $zR(n, x_i) - K$ could also represent the valuation of the startup.

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 campaign funds even if she cannot secure sufficient external funds subsequently.

Stage 3:

If the VC approves funding for the project, the entrepreneur negotiates with the VC her profit share. We use the Generalized Nash Bargaining Solution (GNBS) to characterize the outcome of the negotiation. Let δ and $1 - \delta$ denote the entrepreneur's and VC's bargaining power, respectively, where $0 \leq \delta \leq 1$. Under GNBS, each party's expected payoff depends on its bargaining power as well as 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, which 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. Lemma 1 gives the expected payoffs of the entrepreneur and VC that result from their negotiation.

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), the expected profit of each party is given by:*

$$W_E(n, x_i) \;=\; \delta \left[zR(n, x_i) - K \right] + nr, \tag{1}$$

$$W_{VC}(n, x_i) \;=\; (1 - \delta) \left[zR(n, x_i) - K \right]. \tag{2}$$

The GNBS predicts that the expected payoff of each party comprises of the sum of the party's outside option (nr and 0, for the entrepreneur and VC, respectively) and a portion of the total expected surplus generated upon agreement ($zR(n, x_i) - K$), where portions are determined by their bargaining power, δ 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

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the probability measure z multiplies only the revenue but not the cost of the project. Lemma 1 illustrates also how funds raised in the crowdfunding campaign increase the outside option for the entrepreneur, and therefore, her expected payoff.

It is noteworthy that the expected profit reported in Lemma 1 remains the same irrespective of the amount of funds the entrepreneur contributes upfront for the development. To illustrate, if the entrepreneur contributed an amount s, $0 \leq s \leq nr$, to cover part of the development cost, the VC would contribute the remaining $K - s$. As illustrated in the Appendix, the GNBS requires that the share of future profits that accrue to the entrepreneur as $\lambda = \delta - (\delta K - s)/(z R(n, x_i))$. The negotiated share of future profits, λ, is adjusted above (if $\delta K - s < 0$) or below (if $\delta K - s > 0$) the bargaining power δ to ensure that the parties split the total net expected surplus of the project according to their relative bargaining powers, δ and $1 - \delta$. Note also that in Lemma 1 we implicitly assume that the bargaining power of the entrepreneur is determined independent of the amount of funds raised in the campaign. As we report in the concluding section this assumption can be relaxed to allow for δ to be an increasing function of the funds raised, nr.

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. Specifically, when $h = 1$ so that the VC relies exclusively on the crowdfunding campaign for demand information, the investment is definitely profitable for the highest possible number of backers, i.e., $z \alpha v_L \overline{N} - K \geq 0$. This implies that the VC's expected profit is negative for low realizations of N but positive if a large number of backers pledge in the campaign. When $h = 0$, instead, so that the VC uses only the realization of X to predict future demand, we assume that the project will be deemed unprofitable upon the observation of x_L and profitable upon the observation of x_H, i.e., $z \alpha v_L x_L - K \leq 0$ and $z \alpha v_L x_H - K \geq 0$.

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 campaign h, we define by N_L the minimum number of backers needed for the VC to decide in favor of investment when the external signal indicates poor prospects for the project (i.e., when $X = x_L$). Similarly, let N_H designate the minimum number

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of backers needed in order to support the VC's investment when the external signal is good (i.e., when $X = x_H$). It is easy to show that

$$N_L = x_L + \frac{K - z\alpha v_L x_L}{hz\alpha v_L}, \text{ and} \tag{3}$$

$$N_H = x_H - \frac{z\alpha v_L x_H - K}{hz\alpha v_L}. \tag{4}$$

Because $z\alpha v_L x_L - K \leq 0$ and $z\alpha v_L x_H - K \geq 0$ 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 $N_H < \overline{N}$ because $K \leq z\alpha v_L \left[h\overline{N} + (1-h)x_H \right]$.

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 $N_{\min} = G/r$. Thus, the entrepreneur's choice of r and G is equivalent to setting r and $N_{\min}$. We will formulate the entrepreneur's decision, therefore, as a choice of r and $N_{\min}$. We first show that the optimal value of $N_{\min}$ lies within a region.

Lemma 2: *The optimal target number is never below* $\max(N_H, 0)$ *or above* $\min(N_L, \overline{N})$, *i.e.,* $\max(N_H, 0) \leq N^*_{\min} \leq \min(N_L, \overline{N})$.

If $N_{\min}$ is bigger than N_L, it would be possible to have $N_L < n < N_{\min}$. In this case, the entrepreneur has every incentive to lower the target number to increase the chance of winning the campaign, without hurting her chance of getting funded by the VC. On the other hand, if $N_{\min}$ is below $\max(N_H, 0)$, it is possible that the campaign is successful but the VC does not fund the

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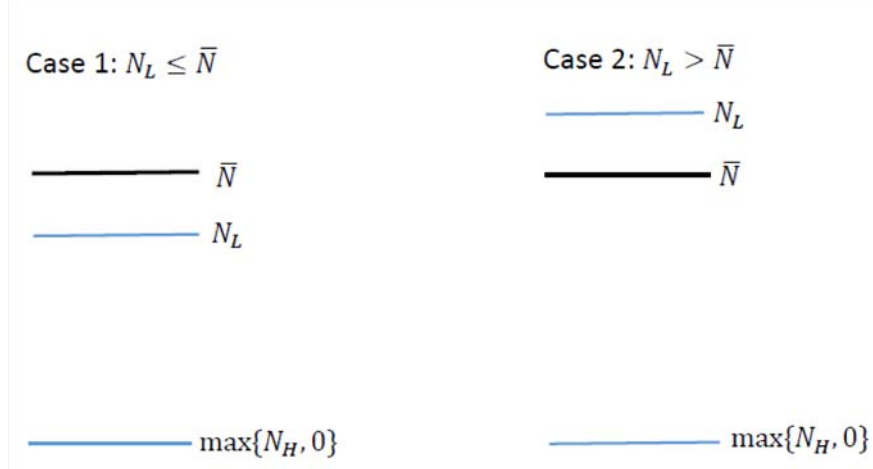**Case 1:** $N_L \leq \bar{N}$ **Case 2:** $N_L > \bar{N}$

Figure 1: Two possible cases under crowdfunding

project irrespective of the outcome of his independent research (i.e., when $N_{\min} < n < \max(N_H, 0)$). This would discourage backers from pledging in the campaign given the increased risk of losing their pledge due to lack of VC funding. Lemma 2 suggests that it is optimal to eliminate such possibility by setting $N_{\min}$ at or above $\max(N_H, 0)$.

This result indicates that the entrepreneur cannot simply lower the target number to zero to ensure the success of her campaign. From the expression (4) of N_H, if the relative informativeness of the campaign is sufficiently high (i.e., when $h > 1 - \frac{K}{z\alpha v_L x_H}$), then $N_H > 0$, implying that the entrepreneur's optimal target number is strictly positive. In fact, the more informative the campaign is, the bigger N_H is, implying a more demanding lower bound for $N_{\min}$.

The characterization of the equilibrium depends on whether N_L exceeds or falls short of $\bar{N}$, as depicted in Figure 1. 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 now 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 γv_H, $0 \leq \gamma \leq 1$, if he chooses not to pledge. The extra utility of 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 γ 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 pledge or not. We assume that even if fans do not pledge, they will still purchase the product if it becomes available, namely $\gamma v_H - v_L > 0$.

Upon observation of the pledge level r and $N_{\min}$ (and thus, the goal G) selected by the entrepreneur, fans choose to participate in the campaign if the following inequality holds:[9]

$$-rp\frac{N_L - N_{\min}}{\overline{N}} + (zv_H - r)\left[\frac{(1-p)\left(\overline{N} - N_{\min}\right)}{\overline{N}} + \frac{p\left(\overline{N} - N_L\right)}{\overline{N}}\right]$$

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

From Lemma 2, it is optimal to set $N_{\min}$ between $\max\left(N_H, 0\right)$ and N_L because $N_L \leq \overline{N}$. The left hand side of the inequality is the expected utility of a fan who pledges in the campaign. The first term corresponds to the risk of losing his pledge without receiving any benefit in return. This happens when the campaign is successful ($n \geq N_{\min}$) 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., $n \geq N_{\min}$) 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., $n \geq N_L$ 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.

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[9]Consistent with the equilibrium concept, the inequality implicitly assumes that when an individual fan makes her choice she does not perceive herself big enough to be able to affect the behavior of all other fans. In particular, she expects other fans to continue to contribute.

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 if the VC invests 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 γ 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:

$$N_{\min} \geq \frac{[z(\gamma - 1)v_H - zv_L + r]\left(\overline{N} - pN_L\right) + rpN_L}{(1 - p)[z(\gamma - 1)v_H - zv_L + r] + rp}. \tag{5}$$

The entrepreneur's problem is to maximize her expected profit under crowdfunding π_E^C, where the superscript "C" denotes the crowdfunding option and the subscript "E" indicates the profit of the entrepreneur.

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

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

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

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

The first term of π_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 x_L and x_H realizes, respectively. The entrepreneur chooses r and $N_{\min}$ to maximize this objective, knowing that the optimal $N_{\min}$ lies in the region specified in Lemma 2 and that fans find it optimal to pledge in the campaign.

Note that setting $N_{\min}$ closer to N_L reduces the likelihood that fans lose their pledge due to lack of VC funding. 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. Conversely, setting $N_{\min}$ closer to $\max(N_H, 0)$

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increases the likelihood of a successful campaign, which implies a higher probability that fans will receive no benefit from their pledge, thus depressing their pledge level. Detailed derivation of Case 1 and all other 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 because the optimal target level $N_{\min}^* \geq \max(N_H, 0)$ by Lemma 2. Fans choose to pledge in the campaign instead of purchasing the product if it becomes available if the following inequality holds:

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

That is, $(1-p)z\left[v_H(1-\gamma) + v_L\right] \geq r$. The entrepreneur's problem can be written as:

$$(P2) \quad Max_{\{r, N_{\min}\}} \quad \pi_E^C = \frac{1}{\overline{N}}\int_{N_{\min}}^{\overline{N}} nrdn + \frac{(1-p)}{\overline{N}}\int_{N_{\min}}^{\overline{N}} \delta[z\alpha v_L(hn + (1-h)x_H) - K]dn$$

$$s.t. \quad \max(N_H, 0) \leq N_{\min} \leq \overline{N}$$

$$r \leq (1-p)z\left[v_H(1-\gamma) + v_L\right].$$

The objective π_E^C 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 campaign success.

3.3 Optimal target number and pledge level

The optimal campaign instruments in Case 1 critically depends on the probability p of observing the bad signal x_L. Before characterizing the solution, it will be helpful to define the lower and upper threshold levels for this probability:

$$p_L = \begin{cases} \frac{2N_H}{2N_H + \overline{N} - N_L} & \text{if } N_H \geq 0 \\ \frac{\delta[z\alpha v_L(1-h)x_H - K]}{\frac{1}{2}z[(1-\gamma)v_H + v_L](\overline{N} - N_L) + \delta[z\alpha v_L(1-h)x_H - K]} & \text{if } N_H < 0 \end{cases}, \text{ and} \tag{6}$$

$$p_U = \frac{((1-\gamma)v_H + v_L)N_L + \delta h\alpha v_L(N_L - N_H)}{((1-\gamma)v_H + v_L)\frac{(\overline{N} + N_L)}{2} + \delta h\alpha v_L(N_L - N_H)}. \tag{7}$$

In Case 1, the lower threshold p_L corresponds to the probability p at which the entrepreneur shifts from setting the target number at its lowest possible value of $\max(N_H, 0)$ to a level strictly above

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$\max(N_H, 0)$. 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 $0 \le p_L < p_U \le 1$ when $N_L < \overline{N}$. Note that when $h = 1$, $N_L = N_H = \frac{K}{z\alpha v_L}$ and $p_L = p_U = \frac{2K}{z\alpha v_L \overline{N} + K} < 1$.

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:*

$$N^*_{\min} = \begin{cases} \max(N_H, 0) & \text{if } 0 \le p \le p_L \\ N^{int}_{\min} & \text{if } p_L \le p \le p_U \\ N_L & \text{if } p_U \le p \le 1 \end{cases} \quad where$$

$$N^{int}_{\min} = \frac{\frac{p}{2(1-p)} \left[(1-\gamma)v_H + v_L\right]\left(\overline{N} - N_L\right) + \delta h\alpha v_L N_H}{(1-\gamma)v_H + v_L + \delta h\alpha v_L}. \tag{8}$$

The optimal pledge r^* is equal to:

$$r^* = z\left[(1-\gamma)v_H + v_L\right]\left[1 - p + p\frac{\overline{N} - N_L}{\overline{N} - N^*_{\min}}\right]. \tag{9}$$

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

$$\Pr^C = \begin{cases} p\left(1 - \frac{N_L}{\overline{N}}\right) + (1-p)\left(1 - \frac{\max(N_H, 0)}{\overline{N}}\right) & \text{if } 0 \le p \le p_L \\ p\left(1 - \frac{N_L}{\overline{N}}\right) + (1-p)\left(1 - \frac{N^{int}_{\min}}{\overline{N}}\right) & \text{if } p_L \le p \le p_U \\ 1 - \frac{N_L}{\overline{N}} & \text{if } p_U \le p \le 1 \end{cases}.$$

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

According to Lemma 2, the optimal target number falls within the range $\left[\max\left(N_H, 0\right), \min\left(N_L, \overline{N}\right)\right]$. While setting a high target number makes it difficult to succeed in the campaign, setting a low target number raises the risk that backers lose their pledges due to lack of VC funding. This risk depresses the pledge level, and therefore, the entrepreneur's profits and bargaining position. When the probability of a bad outcome in the VC's market research is intermediate and observing this bad outcome is not necessarily fatal (Case 1), these two counteracting forces may push the optimal target number inside the range of $\left[\max\left(N_H, 0\right), \min\left(N_L, \overline{N}\right)\right]$, thus yielding the interior solution $N^{int}_{\min}$. If instead this probability is high, the optimal target number is set at the upper bound N_L.

In this case, the VC will fund the project whenever the campaign is successful, which eliminates the concerns of backers and allows for the highest pledge level.

The optimal target number is set at the lowest level $\max(N_H, 0)$ either when observing x_L is fatal (Case 2) or if the probability p of a bad outcome in the VC's market research is very low ($p \leq p_L$) when observing x_L is not necessarily fatal (Case 1). In the former case, the entrepreneur cannot alleviate the concerns of backers because irrespective of the target number she chooses VC funding is denied when x_L is observed. The entrepreneur therefore sets the target at its lowest level to maximize her chance of winning the campaign while ensuring VC funding when x_H realizes. This results in the highest risk for backers, and correspondingly the lowest pledge level. In the latter case observing x_L is not necessarily fatal and the VC is very unlikely to observe x_L. Therefore, backers are not particularly concerned about lack of VC funding and the entrepreneur can afford to set the target number at the lowest level $\max(N_H, 0)$.

The expressions derived for the pledge level r^* are consistent with the reality that pledges in crowdfunding campaigns typically fall short of the price the product can command in the future market, because backers face the dual risk of lack of VC funding and technical failure. Note, however, that the pledge increases with the fan valuation v_H. This indicates that in addition to raising capital the crowdfunding campaign may price discriminate between fans and general consumers. In fact, when v_H is much bigger than v_L, the pledge level may exceed the future selling price in spite of the risk backers face. The parameter γ captures the extent to which the campaign can serve as a price discrimination device. When backers derive significantly higher benefit from participating in the campaign, namely when γ is smaller, the entrepreneur can extract via crowdfunding more surplus from backers in comparison to regular consumers. In contrast, when $\gamma = 1$ backers derive the same consumption benefit regardless of whether or not they pledge in the campaign. In this case, crowdfunding loses its function as a price discrimination device.

The behavior of the optimal target number

In our study the crowdfunding campaign serves the purpose of acquiring market information. It may be interesting, therefore, to investigate how the choice of campaign instruments depends

on the relative informativeness parameter h. We focus on how informativeness affects the target number, which determines the pledge level. We first examine how an increase in h affects N_L, N_H and $N_{\min}^{int}$.

Lemma 3: *(i) N_H (N_L) strictly increases (decreases) with h. Moreover, $\overline{N} > N_L = N_H > 0$ at $h = 1$, and $N_L > N_H$ on $0 < h < 1$.*

(ii) $N_{\min}^{int}$ is either increasing with h everywhere or strictly decreasing after reaching a peak at a positive value of h.

Part (i) of Lemma 3 reports that when the VC observes the good outcome x_H, a bigger value of h implies that the good news should be revised downward because the external signal has less informative value. As a result, the crowdfunding campaign should generate a stronger signal necessary to obtain VC funding, namely N_H is bigger. In contrast, when the bad outcome x_L is observed, a bigger value of h implies that the bad news should be revised upward. As it becomes easier to convince the VC to support the project, N_L declines.

For $N_{\min}^{int}$, note that both the numerator and denominator in (8) increase with h. The first term of the numerator captures the incentive of the entrepreneur to raise the pledge level by increasing the target number, in order to alleviate the backers' concerns of losing their contributions due to lack of VC funding. From Equation (9), the extent of increase in r^* that is implied by an increase in the target number is more significant the higher the probability that a bad outcome will arise (the higher p is), the more likely the VC is to fund the project in this case (the bigger $\overline{N} - N_L$ is), and the higher the willingness to pay of backers (the bigger $(1 - \gamma)v_H + v_L$ is). These factors all determine the magnitude of the first term in the numerator of (8). The second term of the numerator in (8) captures the incentive of the entrepreneur to keep the target number close to N_H in order to raise the likelihood of a successful campaign.

The weights assigned to these two counteracting incentives depend upon their relative importance to the entrepreneur. The higher the expected future profit of the project, which is captured by the expression $\delta h \alpha v_L$ in (8), the more eager the entrepreneur is to succeed in the campaign. She is more likely, therefore, to set a target number closer to $\max(N_H, 0)$. The higher the willingness-

to-pay of backers, which is captured by the expression $[(1 - \gamma)v_H + v_L]$ in (8), the more likely the entrepreneur is to raise the target number away from N_H in order to encourage higher pledges. From part (i) we know that as h increases to 1, the gap between N_L and N_H shrinks to 0. From (3), (4) and Lemma 2, the target number is between N_H and N_L for relatively big values of h. Backers know, therefore, that the entrepreneur has very little room to maneuver the target number, and the VC is very likely to fund the project following a successful campaign in this case. As the risk facing backers is reduced the entrepreneur may focus on the objective of attaining a successful campaign by lowering the target number when h is relatively big.
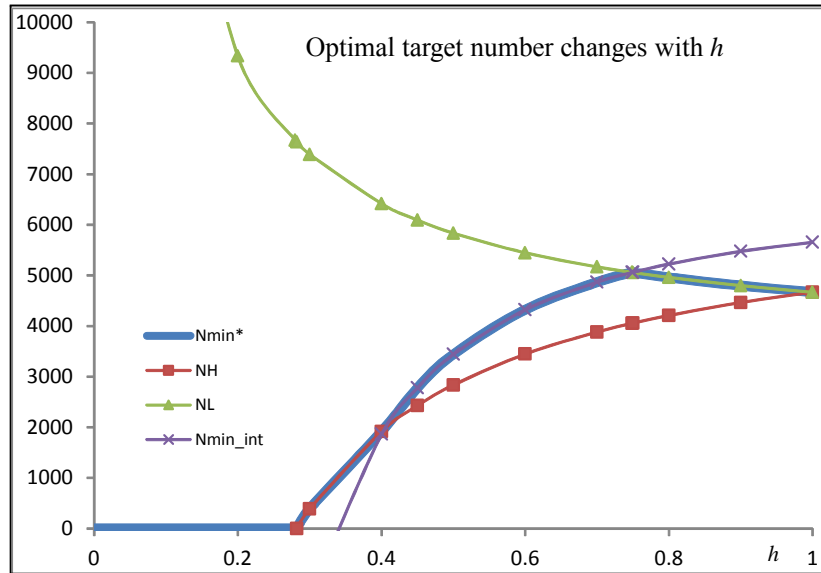

Figure 2: Target number as a function of h

Figure 2 plots an example where $N_{\min}^{int}$ strictly increases with h on [0,1]. Consistent with Lemma 3, N_H (N_L) in the plot strictly increases (decreases) with h. The optimal target number $N_{\min}^*$ assumes the boundary solution $\max(N_H, 0)$ for low values of h. As h increases, $N_{\min}^{int}$ arises as optimal and finally $N_{\min}^* = N_L$ when h approaches 1. The optimal target number depends on how the interior solution $N_{\min}^{int}$ crosses $\max(N_H, 0)$ and N_L, and therefore, different cases can arise. Nevertheless, we show in the next proposition that across all different cases, the optimal target number is either non-decreasing in h or a single peak function of h.

Proposition 2: *The optimal target number $N_{\min}^*$ is either a non-decreasing function of h over*

the entire interval $[0, 1]$, *or is a single peak function of* h *with peak* $h^* \in [0, 1]$. *In the latter case,* $N^*_{\min}$ *is non-decreasing in* h *when* $h < h^*$ *and strictly decreasing in* h *when* $h > h^*$.

For very small values of h it follows from Equation (3) that N_L assumes a very big number, and in particular, $N_L > \overline{N}$. Case 2 of Proposition 1 applies and $N^*_{\min} = \max(N_H, 0)$ that is non-decreasing in h. For bigger values of h the value of N_L becomes smaller than $\overline{N}$ and Case 1 arises. The optimal target number $N^*_{\min}$ might assume the values of N_L, N_H, or $N^{int}_{\min}$, and $N^*_{\min}$ could be a single peak function of h.

It is interesting to examine the two extreme cases when the campaign provides no useful information (i.e., $h = 0$) and perfect information (i.e., $h = 1$). When $h = 0$, $N_L \to \infty$ and $N_H < 0$. In this case, the VC does not consider the number of backers when making his funding decision. As a result, the entrepreneur sets the goal at zero with $N^*_{\min} = \max(N_H, 0) = 0$ and $G^* = 0$. Because the campaign is always successful and backers lose their pledge with certainty when the VC observes x_L, backers face the highest risk of losing their contribution due to lack of VC funding. Correspondingly, the pledge is set at the lowest possible level of $r^* = z\left[(1-\gamma)v_H + v_L\right][1 - p]$. When $h = 1$, $N_H = N_L = K/(z\alpha v_L)$, and therefore, $N^*_{\min} = K/(z\alpha v_L)$. In this case, the VC funds the project whenever the campaign is successful, so that backers are no longer concerned about losing their pledge due to lack of VC funding. As a result, the pledge is at the highest possible level $r^* = z\left[(1-\gamma)v_H + v_L\right]$.

Propositions 1 and 2 together lead to the characterization of the optimal pledge and goal reported in Corollary 1.

Corollary 1: *The optimal pledge* r^* *and the goal* G^* *are non-decreasing in* h *whenever the optimal target number* $N^*_{\min}$ *is non-decreasing in* h. *When* $N^*_{\min}$ *assumes the boundary solution* N_L, *the optimal pledge level reaches its maximum and remains constant, whereas the optimal goal decreases with* h.

The remaining parameters of the model also play a role in affecting the optimal target number. For instance, when the development cost K is high, naturally it becomes difficult for the entrepreneur to convince the VC to fund. Indeed, both N_H and N_L are strictly increasing func-

tions of K. However, this is not necessarily the case for the interior solution $N_{\min}^{int}$. The spread $(x_H - x_L)$ determines how informative the VC's external signal is, with a bigger spread indicating a more informative signal. As a result, when this spread increases the relative informative value of the campaign diminishes, and the entrepreneur can afford to reduce the target number to improve the chance of campaign success. In the next Proposition we investigate this conjecture as well as the role of other parameters in determining the target number. We restrict the investigation to the interior solution $N_{\min}^{int}$ because the results for the boundary solutions $\max(N_H, 0)$ or N_L are trivial.

Proposition 3: $N_{\min}^{int}$ decreases with the development cost K if the campaign informativeness is below a certain threshold, i.e., $h < \frac{p[(1-\gamma)v_H + v_L]}{2(1-p)\delta\alpha v_L}$. Otherwise, it increases with K. For a fixed value of the mean of the external signal, $(x_H + x_L)/2$, $N_{\min}^{int}$ decreases as the spread $x_H - x_L$ increases. As well, $N_{\min}^{int}$ decreases with δ, and increases with p, $\overline{N}$, and $(1-\gamma)v_H$.

From (8), a bigger value of K may have an ambiguous effect on $N_{\min}^{int}$ because while the first term of the numerator of (8) decreases with K, the second term increases with K. Specifically, because of the increase in N_L the ability of the entrepreneur to raise the pledge of backers by raising the target number is more limited given that it is less likely that the VC will support the project upon the observation of x_L. This leads to the decline in the first term, thus suggesting that the entrepreneur might have an incentive to reduce the target in order to improve the odds of a successful campaign. On the other hand, because of the increase in N_H the entrepreneur has to generate a stronger signal in the campaign when the VC observes a good signal x_H, thus forcing her to raise the optimal target number so that the second term increases. This is especially true when the campaign is very informative (i.e., h is relatively big). It follows that the change in the second term dominates if the campaign is sufficiently informative. Hence, $N_{\min}^{int}$ can be a decreasing function of K when h assumes a relatively small value.

Upon inspection of (8) it is easy to verify that $N_{\min}^{int}$ is decreasing with x_H and increasing with x_L. 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 $N_{\min}^{int}$. Recall that when this spread increases, its informative value is higher. That is, the VC relies more heavily on his own market research in making his

funding decisions, and the entrepreneur chooses, therefore, to reduce the target number.

Note also that the first term of the numerator in (8) increases with p and $\overline{N}$, implying that the entrepreneur has a stronger incentive to raise the target number in order to alleviate the backers' concerns. The effect of δ and $(1 - \gamma)v_H$ seems ambiguous as a change in them affects both the numerator and denominator of (8) in the same direction. However, Proposition 3 states that when $(1 - \gamma)v_H$ decreases or δ increases, $N_{\min}^{int}$ unambiguously declines because the entrepreneur is less concerned about the amount raised in the campaign given that $(1 - \gamma)v_H$ is smaller. She is more eager for the campaign to be successful, so that she can gain access to the higher future profit that is implied by the bigger value of δ.

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).

4   Comparison with No Crowdfunding

In the absence of a campaign, the number of fans is no longer observable, and the best estimate of this number is the prior expected value of the random variable N, which is equal to $\overline{N}/2$. The game has two stages. In Stage 1, the VC decides on whether to fund the project after conducting his market research and the external signal X realizes. If the VC decides against funding, the project terminates. If the VC decides in favor of supporting the project, negotiations between the entrepreneur and VC take place in Stage 2.

Under no crowdfunding, the entrepreneur's outside option is zero, whereas the total surplus to be split between the parties includes the potential sales to fans who would otherwise have

pledged in the campaign. The rules of the negotiations remain as described in the model with crowdfunding. We continue to assume that the entrepreneur's and VC's bargaining power is δ and $1 - \delta$, respectively. Because Lemma 1 applies here, δ and $1 - \delta$ are also the shares of the expected total surplus of the new venture that accrue to the parties.[10] The detailed analysis can be found in the appendix.

In the absence of a crowdfunding campaign, the VC will never fund the project if the expected size of the fan group is very small (i.e., when $\overline{N} < \left(\frac{2\alpha h}{\alpha h + 1} \right) N_H$). In the intermediate range $\left(\frac{2\alpha h}{\alpha h + 1} \right) N_H \leq \overline{N} \leq \left(\frac{2\alpha h}{\alpha h + 1} \right) N_L$, 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. Finally, if the expected size of the fan group is very large (i.e., when $\overline{N} > \left(\frac{2\alpha h}{\alpha h + 1} \right) N_L$), the entrepreneur always receives funding from the VC irrespective of the external signal X. However, it is highly unlikely that the prospects of a new venture are so favorable that the VC will fund the project for sure. Therefore, we restrict our analysis to the reasonable case that $\overline{N} \leq \left(\frac{2\alpha h}{\alpha h + 1} \right) N_L$.

Running a crowdfunding campaign does not always increase 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 big number of backers may help convince the VC to fund the project. 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 is probably the case for consumer hardware startups, for which some success in the crowdfunding campaign may help obtain VC funding. For instance, Pebble Watch's founder Eric Migicovsky was initially rejected by VC investors, who considered it too risky to invest and worried about the potential of an untested product (Immen 2012, Kosner 2012). Nevertheless, after he was able to "kickstart" around $10 millions from 69,000 people, he received around $15 millions from a VC firm (Burns 2013). Indeed, the percentage of hardware startups receiving VC funding after successful crowdfunding (i.e., 9.5%)

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[10]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. We assume that the startup's bargaining power is not affected by her decision on whether to run a campaign so that we do not introduce additional factors in favor of one of the two alternatives.

is reported to be higher than the typical funding rate of VCs (i.e., 1%-2%) (Caldbeck 2014).

In comparing the profitability of the two options it may be worthwhile to understand the advantages and disadvantages of crowdfunding. The main advantage that accrues to both the entrepreneur and the VC is that crowdfunding produces a signal of the future demand for the product and the managerial capabilities of the entrepreneur. This signal helps eliminate projects that are doomed for failure. The main disadvantage for the entrepreneur is that failure to reach the campaign goal terminates the project. However, the entrepreneur benefits from two additional advantages that accrue exclusively to her but not to the VC. The first is that a successful campaign generates funds upfront. This improves the entrepreneur's outside option given that the entrepreneur can retain campaign contributions even if the VC decides against funding. Moreover, the entrepreneur is entitled to the entire contributions of the fans in the campaign, whereas she receives only the portion δ of the expected profits from selling the product in the future market. The second advantage is that conducting the campaign may serve as a price discrimination device to extract extra surplus from fans, especially when fans derive more utility from backing the campaign, namely when γ is relatively small.

The values of δ and γ determine the magnitude of the two additional advantages from crowdfunding that accrue exclusively to the entrepreneur. The closer these values are to 1, the less significant these extra advantages become. In particular, when $\gamma = 1$ fans derive the same consumption benefits regardless of whether they contribute in the campaign or simply wait for the product to be commercialized without pledging. Because the campaign pledge in this case is equivalent to the price expected for the product in the future market, the entrepreneur has no opportunity to practice price discrimination. When $\delta = 1$, the entrepreneur receives the entire revenue from selling the product in the future market. Therefore, she is indifferent between receiving the pledge from fans upfront or selling to fans in the future market.

In analyzing the entrepreneur's preference for crowdfunding, we start by removing the two additional advantages discussed above by setting $\gamma = 1$ and $\delta = 1$. While this case may not sound realistic, analyzing it allows us to focus exclusively on the informative role of crowdfunding and

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obtain the entrepreneur's preference when the only potential advantage relates to the signal of future market demand. Also, the results in this special case help shed light on the general case that we will present later.

Before proceeding we first define two threshold levels of the relative informativeness parameter h from (3) and (4). The threshold level $h_1 = 1 - \frac{K}{z\alpha v_L x_H}$ that yields $N_H = 0$ and the threshold level $h_2 = \frac{K - z\alpha v_L x_L}{z\alpha v_L [\overline{N} - x_L]}$ that yields $N_L = \overline{N}$. As a result,

$$h \leq h_1 \Leftrightarrow N_H \leq 0, \text{ and } h \leq h_2 \Leftrightarrow N_L \geq \overline{N}. \tag{10}$$

When $h \leq \min\{h_1, h_2\}$, both $N_H \leq 0$ and $N_L \geq \overline{N}$ indicating that irrespective of the outcome of the campaign (as long as it is successful) the VC always funds the project if his own market research yields a positive signal x_H and never funds the project if his market research yields a negative signal x_L. Proposition 1 demonstrates that in this case the entrepreneur finds it optimal to set the lowest goal possible (i.e., $N^*_{\min} = 0$) in order to eliminate any risk associated with campaign failure. In the next Lemma we show that when the only advantage of crowdfunding originates from acquiring demand information, the entrepreneur is indifferent between running a campaign and approaching the VC directly for funding for very small values of h.

Lemma 4: *In the special case that $\delta = 1$ and $\gamma = 1$:*

(i) The entrepreneur is indifferent between running a crowdfunding campaign and approaching the VC directly without crowdfunding when the outcome of the campaign does not affect the funding decision of the VC (as long as it is successful). Specifically, when $h \leq \min\{h_1, h_2\}$.

(ii) The entrepreneur may prefer no crowdfunding when the development cost is high (i.e., $K > (\alpha - 1)zv_L x_H$) and the relative informativeness h assumes values in the range $[h_1, 1/\alpha]$.

(iii) In all other instances, running a crowdfunding campaign dominates no crowdfunding for the entrepreneur.

When $\delta = 1$, any conflict of interests between the entrepreneur and the VC regarding the future sharing of revenues has been eliminated, as the entire revenue accrues to the entrepreneur in the future market. As well, when $\gamma = 1$, the advantage of using the campaign to extract extra surplus from fans is eliminated. In this case, the entrepreneur receives the same expected amount

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of money from the fans via their pledges when running a campaign or when selling to them in the future market without the campaign. Hence, the only potential benefit of crowdfunding left for the entrepreneur is the signal of future demand that it generates. Lemma 4 suggests, therefore, that when the campaign is not informative at all, namely when $h \leq \min\{h_1, h_2\}$, the entrepreneur is indifferent between the option of running and not running a campaign. In this case, the relative informativeness of the campaign is so low that the VC ignores the realization of the signal N when making his funding decision, and therefore, the entrepreneur sets the target number (and the goal) at the lowest possible level to ensure that the campaign is always successful. The entrepreneur faces no risk of campaign failure, nor does she receive any benefit from crowdfunding, so that she is indifferent between running a campaign or approaching the VC directly.

When $h > \min\{h_1, h_2\}$, the outcome of the campaign affects the funding decision of the VC. For instance, a high number of backers in the campaign can help convince the VC to fund the project even if his own market research yields a poor signal x_L. In this case, the entrepreneur has the incentive to raise the target number to convince backers to pledge, an act that also raises the odds of campaign failure. Thus, the entrepreneur faces a trade-off between the benefit of obtaining demand information and the risk of campaign failure. Lemma 4 asserts that this risk can potentially outweigh the informative value of crowdfunding only when the development cost is relatively high ($K > (\alpha - 1)zv_Lx_H$) and the relative informativeness is small but the VC still considers the number of backers in his decision ($h_1 < h < 1/\alpha$). This implies that the entrepreneur always favors crowdfunding when the development cost is relatively low ($K \leq (\alpha - 1)zv_Lx_H$).

We now present the entrepreneur's preference in the general case of $\delta + \gamma < 2$. In this case, at least one of the parameters, δ or γ, is smaller than 1.

Proposition 4 (The entrepreneur's preference): *When $\delta + \gamma < 2$:*

(i) The entrepreneur strictly prefers crowdfunding when the outcome of the campaign (if successful) does not affect the funding decision of the VC, namely when $h \leq \min\{h_1, h_2\}$.

(ii) The entrepreneur may prefer no crowdfunding when the development cost is high (i.e., $K > K_1$ where $K_1 > (\alpha - 1)zv_Lx_H$) and the relative informativeness parameter h assumes values in the

range $h \in [h_a, h_b]$, where $h_1 < h_a < h < h_b < 1/\alpha$. The region that supports the decision of no crowdfunding is biggest when $\delta = 1$ and $\gamma = 1$. It shrinks as δ and γ decrease, and may disappear completely when δ and γ are very small or when $K < K_1$.

(iii) In all other instances, running a crowdfunding campaign dominates no crowdfunding for the entrepreneur.

In contrast with Lemma 4, when at least γ or δ is smaller than 1, the entrepreneur *strictly* prefers crowdfunding for very small values of h, namely when $h \leq \min\{h_1, h_2\}$. As explained following Lemma 4, in this case the relative informativeness of the campaign is so low that the VC does not take into account the number of backers and the entrepreneur can eliminate any risk of campaign failure by setting the target number at 0. Without any risk of campaign failure, the entrepreneur can only benefit from crowdfunding which avails price discrimination and extracts the entire contributions from fans (rather than splitting revenue with the VC under no crowdfunding). Note that in this case the entrepreneur's preference is driven by her incentive to raise funds from fans, and it has nothing to do with the informativeness of the campaign.

For $h > \min\{h_1, h_2\}$, the VC factors the realization of the signal N in making his funding decision. The risk of campaign failure is re-introduced because the entrepreneur will raise the target number in order to convince fans to pledge. For $h \in [h_a, h_b]$ and sufficiently high development cost $K > K_1$, part (ii) of Proposition 4 argues that the benefit of crowdfunding may be insufficient to overcome the risk of campaign failure and it could become optimal for the entrepreneur to approach the VC directly without running the campaign. However, in comparison to the case that $\gamma = 1$ and $\delta = 1$, the size of the region that supports such a decision shrinks because when $\gamma < 1$ and $\delta < 1$ the entrepreneur regains two additional benefits of crowdfunding (i.e., price discrimination and obtaining the entire contribution of fans). Moreover, the size of this region shrinks as γ and δ become smaller, namely the more significant the two additional sources of benefit are. In fact, the region supporting no crowdfunding as the optimal choice may disappear altogether, when the development cost K is relatively low or when γ and δ are small. For larger values of h, the relative informativeness of the campaign is so high that, when combined with the other two benefits,

crowdfunding strictly dominates in spite of the risk of campaign failure.

Proposition 4 may help explain why we observe many campaigns on Kickstarter and similar 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 2013). 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 (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 target 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 later realized 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 this case, the entrepreneur might want to skip the campaign altogether, or if she chooses to launch one, set a campaign goal that can be achieved easily to facilitate access to venture capital.

Overall, Proposition 4 confirms and strengthens the insights derived from the special case reported in Lemma 4. The proposition demonstrates that the decision on whether to run a crowdfunding campaign prior to approaching the VC is not a trivial one. While crowdfunding is definitely preferred for relatively small projects (small K), it may not always be the best choice for technology-based products that typically require significant amount of capital for development. In this case, only when the campaign is either uninformative or highly informative that crowdfunding is preferred. When the campaign is somewhat informative, the entrepreneur needs to carefully weigh the

potential benefits of running the campaign against the risk of campaign failure.

Next we examine the VC's preference.

Proposition 5 (The VC's preference): *The VC prefers crowdfunding over a smaller region of parameter values than the entrepreneur does. In particular, the VC never prefers crowdfunding for small values of h ($h < 1/\alpha$) and for bigger values of h his preference is ambiguous.*

The fact that the VC is less likely to prefer crowdfunding than the entrepreneur is due to the two additional benefits that accrue exclusively to the entrepreneur. As we have discussed, besides the informational value, crowdfunding allows the entrepreneur to appropriate the entire contributions of fans, an outcome that has two adverse consequences on the VC's profit. First, crowdfunding reduces the size of the future market, given that the VC does not receive any portion of the contributions of the fans raised in the campaign. In contrast, if the entrepreneur does not launch the campaign, fans become part of the consumer population and the revenue generated from them are split between the VC and the entrepreneur. If the group of fans is relatively big this loss to the VC can be substantial. Second, the fact that the VC is not entitled to any portion of the contributions raised in the campaign implies also that he cannot benefit from the role of the campaign as a price discrimination device.

Recall that when $h < \min\{h_1, h_2\}$, $N_H < 0$ and $N_L > \overline{N}$ so that the VC's decision depends solely on the realization of the external signal and not on the number of backers in the campaign. Because there is no informational benefit from the crowdfunding campaign in this case, the VC strictly prefers no crowdfunding, whereas the entrepreneur strictly prefers crowdfunding due to the two additional sources of benefits that are unrelated to the informative role of the campaign. More generally, the VC is never in favor of the entrepreneur's decision to run a crowdfunding campaign when its relative informativeness is small ($h < 1/\alpha$). For bigger values of h, the VC may or may not prefer crowdfunding.

5 Discussion and Conclusion

Running a reward-based crowdfunding campaign may be extremely valuable, especially for projects that aim at developing new technology-based consumer products, which typically face high market uncertainty and require supplemental capital from professional investors. Indeed, crowdfunding can provide information about the market potential of the product and thus, in case of positive signals from the campaign, to convince skeptical VCs to invest in the project. The entrepreneur can also utilize the campaign as a price discrimination device and as a vehicle to obtain the full contribution from backers, even if the VC decides against subsequent funding. Despite these advantages, campaign failure may significantly reduce, if not entirely eliminate, the entrepreneur's access to VC capital. Our study examines how the informational role of the campaign and the access to VC funding influence the campaign design, as well as the preference of the entrepreneur and the VC for running a crowdfunding campaign.

Specifically, we offer entrepreneurs insights on how to set the campaign instruments, namely the goal and the pledge, which together determine the target number of backers required for a successful campaign. When the campaign is not very informative, the goal should be set very low to ensure campaign success. The pledge level is the lowest in this case. When the campaign becomes more informative so that the VC starts to consider the number of backers in his funding decision, the entrepreneur should raise the target number to alleviate the concerns of backers about lack of VC funding following a successful campaign. This allows for a higher pledge level and campaign goal. When the level of campaign informativeness is high, the VC's decision relies mostly on the campaign outcome, so backers are less concerned. In this case, the entrepreneur's ability to influence the pledge level by strategically increasing the target number becomes more limited and she might lower the target number and the goal to reduce the risk of campaign failure.

Our study reveals that the entrepreneur's preference for crowdfunding is not straightforward. We find that running a campaign before approaching the VC is definitely optimal for the entrepreneur for relatively small projects as obtaining lower levels of funding is less challenging. However, for new technology-based products that require large investment, entrepreneurs should

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launch the campaign if it is either highly informative or not informative at all. In the latter case, the VC does not take into account the number of backers in his funding decision. There is no need, therefore, to set a demanding goal that would hurt the likelihood of campaign success. For relatively low levels of informativeness but when the VC considers the number of backers in his funding decision, our study suggests that entrepreneurs should forgo the opportunity of running a crowdfunding campaign before approaching the VC. This is because the informative value of the campaign (together with the additional benefits that crowdfunding offers) is not high enough to offset the risk of campaign failure. We sometimes observe products that are unlikely to yield valuable information from crowdfunding campaigns because features of the product are difficult to evaluate by consumers (e.g., consumer medical devices) or because the preferences of backers active on the crowdfunding platform do not reflect the preferences of consumers in the target market (e.g., senior health care wearable). Our guideline is that under such circumstances, entrepreneurs should choose to either approach VCs directly without running a campaign, or if they choose to run a campaign, set a very low target number to ensure the success of the campaign.

The information obtained in the campaign can guide the VC in making sensible investment decisions. However, the entrepreneur's decision to run a crowdfunding campaign may introduce disadvantages to the VC. Because contributions from fans accrue only to the entrepreneur, the campaign reduces the size of the future market. As a result, the VC is less likely to prefer crowdfunding than the entrepreneur does.

Given our focus on the role of information and access to VC funding on the design of crowdfunding campaigns, we make several assumptions in our model. We can easily change the two-state distribution 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 of observing one more signal through the campaign would decline. Due to reduced informative value of the campaign,

we conjecture that in this case the entrepreneur would have higher incentive to lower the target number to raise the odds of campaign success. Similarly, the profitability of utilizing crowdfunding before approaching the VC would decline in comparison with an environment where the signals are independently distributed.

As we pointed out already, relaxing the assumption that a failed campaign dooms the project will not 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 a stronger incentive to raise the level of the campaign instruments and run a campaign before approaching the VC. Similarly, relaxing the assumption that the startup's bargaining power is not affected by her decision on whether to run a campaign or to 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 a 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 the campaign goal is met. Platforms such as Indiegogo also 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 induce the entrepreneur to raise the level of the campaign instruments and prefer crowdfunding.

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 informational role of crowd-funding, 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

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 campaigns were selected by entrepreneurs observing positive signals 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 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, by sending them a signal that they believe in the prospects of the product. We leave these issues for future research.

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Online Supplement for "Reward-based crowdfunding campaigns: informational value and access to venture capital"

Proof of Lemma 1: If $zR(n, x_i) - K \geq 0$, then the entrepreneur and VC, with bargaining power δ and $1 - \delta$ respectively, negotiate how to split the future profit $R(n, x_i)$. λ and $1 - \lambda$ are the shares of the total profit from selling to the mass market that will accrue to the entrepreneur and VC, respectively, if the product is successfully developed. The entrepreneur contributes nr to cover part of the development cost. The VC contributes the remaining $K - nr$. Thus, the entrepreneur's expected payoff is $\lambda z R(n, x_i) + nr - nr = \lambda z R(n, x_i)$ if they reach an agreement. In case no agreement is reached, her payoff is her outside option nr. The VC's agreement payoff is $(1 - \lambda) z R(n, x_H) - (K - nr)$ and his disagreement payoff is zero.

The GNBS maximizes the following in λ:

$$[\lambda z R(n, x_i) - nr]^{\delta} [(1 - \lambda) z R(n, x_i) - (K - nr)]^{1-\delta},$$

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

$$W_E(n, x_i) = \delta (z R(n, x_i) - K) + nr,$$

$$W_{VC}(n, x_i) = (1 - \delta) (z R(n, x_i) - K).$$

These payoffs indicate that the entrepreneur and VC split the total cost K based on their bargaining power δ and $1-\delta$, respectively. Given that the funds raised in the crowdfunding campaign comprise a very small percentage of the cost needed for development and commercialization, it is indeed possible that $nr < \delta K$, i.e., the entrepreneur is unable to use campaign funds to fully cover her share of cost dictated by the GNBS. In this case, the entrepreneur will be forced to accept a smaller share of future expected profits. In fact, the negotiated share of future profits, λ^*, is adjusted above (if $\delta K - nr < 0$) or below (if $\delta K - nr > 0$) the bargaining power δ of entrepreneur to ensure that each party splits the total expected revenue $z R(n, x_i)$ and the total development cost K based on their bargaining power δ and $1-\delta$, respectively, although at the time the investment is made, they split the total development cost by contributing nr and $K - nr$, respectively.

It is noteworthy that the expected profit reported in Lemma 1 remains the same irrespective of the amount of funds the entrepreneur contributes upfront for the development. To illustrate, if the entrepreneur contributed an amount s, $0 \leq s \leq nr$, to cover part of the development cost, the VC would contribute the remaining $K - s$. The GNBS requires that the share of future profits that accrue to the entrepreneur would be

$$\lambda(s) = \delta - \frac{\delta K - s}{z R(n, x_i)}. \tag{11}$$

When the entrepreneur's initial contribution $s > \delta K$, by (11) her share of profits from the mass market $\lambda(s) > \delta$. On the other hand, her share from the mass market $\lambda(s)$ may fall short of her bargaining power δ when her upfront contribution s is below δK. In this case, the VC has to contribute $K - s > (1 - \delta) K$, and correspondingly receives a larger share $1 - \lambda(s)$ of future expected profits. Substituting (11) back into the agreement payoffs of the entrepreneur and VC yields the same expected payoff as in Lemma 1. Thus, although the share of future profit $\lambda(s)$ that accrues to the entrepreneur increases with her contribution s, the expected payoff of each party is independent of the manner in which they cover the development cost K upfront. The adjustment of the share $\lambda(s)$ ensures that the parties split the expected profit net of development cost solely based upon their relative bargaining powers, δ and $1 - \delta$. ∎

Proof of Lemma 2: We only provide the proof that $N_{\min}^* \geq N_H$ when $N_H \geq 0$ under Case 1. Proof of the other cases is either similar or trivial.

If $N_{\min} < N_H$, the fan's preference in favor of contributing in the campaign is valid if the following inequality holds:

$$-rp \frac{N_L - N_{\min}}{\overline{N}} - (1 - p)r \frac{N_H - N_{\min}}{\overline{N}} + p(zv_H - r) \frac{\overline{N} - N_L}{\overline{N}} + (1 - p)(zv_H - r) \frac{\overline{N} - N_H}{\overline{N}}$$
$$\geq (1 - p)z(\gamma v_H - v_L) \frac{\overline{N} - N_H}{\overline{N}} + pz(\gamma v_H - v_L) \frac{\overline{N} - N_L}{\overline{N}}.$$

After simplification we obtain:

$$N_{\min} \geq \overline{N} - \frac{\left(\overline{N} - (1 - p) N_H - p N_L\right) z \left[(1 - \gamma) v_H + v_L\right]}{r}. \tag{12}$$

The entrepreneur's problem, with $N_{\min} < N_H$, can be written as

$$Max_{\{n,r\}} \; \pi_E^C = \frac{1}{\overline{N}} \int_{N_{\min}}^{\overline{N}} nr dn + \frac{(1-p)}{\overline{N}} \int_{N_H}^{\overline{N}} \delta[z\alpha v_L(hn + (1-h)x_H) - K]dn$$

$$+ \frac{p}{\overline{N}} \int_{N_L}^{\overline{N}} \delta[z\alpha v_L(hn + (1-h)x_L) - K]dn$$

$$s.t. \quad 0 \leq N_{\min} \leq N_H,$$

$$N_{\min} \geq \overline{N} - \frac{\left(\overline{N} - (1-p)N_H - pN_L\right) z \left[(1-\gamma)v_H + v_L\right]}{r}.$$

The second and third terms in the profit function π_E^C do not depend on decision variables. For the first term, the partial derivative with respect to $N_{\min}$ is negative, so the constraint (12) is binding with $N_{\min} = \overline{N} - \frac{\left(\overline{N} - (1-p)N_H - pN_L\right)z[(1-\gamma)v_H + v_L]}{r}$. We rewrite this expression as $r = \frac{\left(\overline{N} - (1-p)N_H - pN_L\right)z[(1-\gamma)v_H + v_L]}{\overline{N} - N_{\min}}$ and substitute it into the first term to obtain, after simplification,

$$\frac{1}{\overline{N}} \int_{N_{\min}}^{\overline{N}} nr dn = \frac{\left(\overline{N} - (1-p)N_H - pN_L\right) z \left[(1-\gamma)v_H + v_L\right]}{2\overline{N}}(\overline{N} + N_{\min}).$$

It is increasing in $N_{\min}$, thus $N_{\min}^* \geq N_H$. $\blacksquare$

Proof of Proposition 1: (i) When observing x_L is not necessarily fatal for the project (Case 1), by (P1) the entrepreneur's profit π_E^C decreases with $N_{\min}$. We first assume $N_{\min}$ achieves the lower bound in constraint (5), and then check if the corresponding solution satisfies $\max(N_H, 0) \leq N_{\min} \leq N_L$. Evaluating (5) as equality yields:

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

Substituting it into the profit function yields:

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

$$+ \frac{p}{\overline{N}} \int_{N_L}^{\overline{N}} \delta[z\alpha v_L(hn + (1-h)x_L) - K]dn + \frac{(1-p)}{\overline{N}}\left[\delta z\alpha v_L(1-h)x_H - \delta K\right]\left(\overline{N} - N_{\min}\right).$$

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

$$N_{\min}^{int} = \frac{\frac{p}{2(1-p)}\left[(1-\gamma)v_H + v_L\right]\left(\overline{N} - N_L\right) + \delta h\alpha v_L N_H}{(1-\gamma)v_H + v_L + \delta h\alpha v_L}. \tag{13}$$

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

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

$$N_{\min}^{int} \leq N_L \Rightarrow p \leq p_U = \frac{((1-\gamma)v_H + v_L)N_L + \delta h\alpha v_L(N_L - N_H)}{((1-\gamma)v_H + v_L)\frac{(\overline{N} + N_L)}{2} + \delta h\alpha v_L(N_L - N_H)}.$$

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

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

Because the constraint (5) is binding at the optimum, we have

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

The highest pledge $r^* = z[(1-\gamma)v_H + v_L]$ 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 $N_L \geq \overline{N}$. By (P2), π_E^C decreases with $N_{\min}$ and increases with r. Thus, the optimal solution is reached at boundary with $N_{\min}^* = \max(N_H, 0)$, $r^* = z[(1-\gamma)v_H + v_L][1-p]$, $G^* = r^* N_{\min}^*$. 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 $(1-p)\left(1 - \frac{\max(N_H, 0)}{\overline{N}}\right)$. ∎

Proof of Lemma 3: (i) These results can be directly derived from Equations (3) and (4).

(ii) For the interior solution, taking the first order derivative with respect to h yields:

$$\frac{\partial N_{\min}^{int}}{\partial h} = \frac{\frac{1}{2}p[(1-\gamma)v_H + v_L](N_L - x_L)}{(1-p)[(1-\gamma)v_H + v_L + \delta\alpha v_L h]} + \frac{\delta\alpha v_L(x_H - N_{\min}^{int})}{(1-\gamma)v_H + v_L + \delta\alpha v_L h}. \tag{14}$$

Setting it equal to zero yields a quadratic equation in h, which has at most one positive root

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

when $H = z[\overline{N}p - 2(1-p)x_H - px_L]((1-\gamma)v_H + v_L) + \delta[K(2-p) - z\alpha v_L(2(1-p)x_H + px_L)] \geq 0$. If $H < 0$, $N_{\min}^{int}$ increases with h always. We have verified that the second order derivative at h^{int} is negative and thus, h^{int} is a maximizer. Therefore, $N_{\min}^{int}$ either increases or first increases then decreases with h on $h > 0$. ∎

Proof of Proposition 2: (i) When $0 \leq h \leq h_2$, we are in Case 2 where $N_{\min}^* = \max(N_H, 0)$ so that the optimal target number is non-decreasing with h. We now consider Case 1 where $h_2 < h \leq 1$.

(i.1) We first show that $N_{\min}^{int}$ and N_L cross at most once on $[h_2, 1]$ and $N_L > N_{\min}^{int}$ after they cross.

When $h > h_2$, we are in Case 1 where p_U strictly decreases with h because $N_L < \overline{N}$, N_L strictly decreases with h, and N_H strictly increases with h. As h increases from h_2 to 1, p_U decreases from 1 to $2K/(\overline{N}z\alpha v_L + K) < 1$. Given any $p < 1$, if $p < 2K/(\overline{N}z\alpha v_L + K)$, then the boundary solution N_L never arises. Otherwise, if $p \geq 2K/(\overline{N}z\alpha v_L + K)$, then there exists a unique $h_U(p) \in [h_2, 1]$, such that $N_{\min}^{int} = N_L$ at $h = h_U(p)$ and the boundary solution N_L is valid on $h_U(p) \leq h \leq 1$. Therefore, $N_{\min}^{int}$ and N_L cross at most once and $N_{\min}^*$ strictly decreases with h after they cross.

(i.2) We next show that $N_{\min}^{int}$ and N_H cross at most once, and $N_{\min}^{int}$ is increasing with h when it crosses N_H. If $\overline{N} - x_L - 2(1-p)x_H/p \neq 0$,

$$N_{\min}^{int} = N_H \Leftrightarrow h = h_L = \frac{K - z\alpha v_L x_L - 2(1-p)(z\alpha v_L x_H - K)/p}{z\alpha v_L \left[\overline{N} - x_L - 2(1-p)x_H/p\right]}. \tag{15}$$

From (14), $\frac{\partial N_{\min}^{int}}{\partial h}|_{h=h_L} > 0$ because $N_L - x_L > 0$ and $x_H - N_H > 0$. If $\overline{N} - x_L - 2(1-p)x_H/p = 0$, then either N_H is dominated ($N_{\min}^{int} \geq N_H$ always) or $N_{\min}^{int}$ is dominated ($N_{\min}^{int} < N_H$ always). Therefore, $N_{\min}^{int}$ crosses N_H at most once and $N_{\min}^{int}$ is increasing with h when it crosses N_H.

Combining Lemma 3 and (i.1)-(i.2), we know that $N_{\min}^*$, if it ever strictly decreases with h, starts decreasing either at h^{int} or when $N_{\min}^{int}$ and N_L cross. In the former case, $N_{\min}^* = N_{\min}^{int} > \max(N_H, 0)$ at $h = h^{int}$. From Lemma 3, $N_{\min}^{int}$ decreases on $h > h^{int}$. From (i.2) $N_{\min}^{int}$ will not cross N_H on $h > h^{int}$. This implies that $N_{\min}^* = \min\{N_{\min}^{int}, N_L\}$ on $[h^{int}, 1]$ so that it strictly decreases with h on $[h^{int}, 1]$. In the latter case, from (i.1) we know $N_{\min}^* = N_L$ after they cross and therefore will keep decreasing afterwards.

Summarizing Case 2 and Case 1, the optimal target number is either a non-decreasing function of h over the entire interval $[0, 1]$, or is a single peak function of h. ∎

Proof of Corollary 1: The result follows from Lemma 3, Proposition 1, and Proposition 2. ∎

Proof of Proposition 3: For the interior solution, taking the first order derivative yields:

$$\frac{\partial N_{\min}^{int}}{\partial K} = \frac{-\frac{p}{2(1-p)}[(1-\gamma)v_H + r_L] + \delta h\alpha r_L}{h\alpha r_L z[(1-\gamma)v_H + r_L + \delta h\alpha r_L]} < 0 \Leftrightarrow h < \frac{p}{2(1-p)\delta\alpha r_L}[(1-\gamma)v_H + r_L].$$

We observe that this inequality can hold for sufficiently small values of h.

Differentiating $N_{\min}^{int}$ with respect to p $(\overline{N})$, we verify that $N_{\min}^{int}$ increases with p and $\overline{N}$. To show $\frac{\partial N_{\min}^{int}}{\partial \delta} \leq 0$ we need $N_H(1-p) \leq \frac{1}{2}p\left(\overline{N} - N_L\right)$, which holds when $N_H < 0$. When $N_H > 0$, this condition reduces to $\frac{2N_H}{2N_H + \overline{N} - N_L} \leq p$. This is equivalent to the condition $p_L \leq p$ when $N_H > 0$. Therefore, $N_{\min}^{int}$ decreases with δ over the region that supports the interior solution.

Define $w \equiv (1-\gamma)v_H$. $\frac{\partial N_{\min}^{int}}{\partial w} = [\delta z \alpha v_L h] \frac{\frac{1}{2}p(\overline{N}-N_L)-(1-p)N_H}{(1-p)z[w+v_L+\delta\alpha v_L h]^2} \geq 0$ always holds when $N_H \leq 0$. When $N_H > 0$, this inequality is equivalent to $p \geq p_L$, which holds when interior solution $N_{\min}^{int}$ arises as optimal.

When taking derivatives with respect to x_H and x_L, respectively, we obtain that $N_{\min}^{int}$ increases with x_L and decreases with x_H. Therefore, $N_{\min}^{int}$ decreases with the spread $x_H - x_L$ while keeping $\frac{x_H + x_L}{2}$ fixed. ∎

The Model of No Crowdfunding

Lemma 1 also applies to the negotiation under no crowdfunding, so δ and $1-\delta$ are the shares of the expected total surplus of the new venture that accrue to each party. The expected profits of the entrepreneur and VC depend on the realization of the external signal.

i) if $X = x_H$, the entrepreneur's expected profit under no crowdfunding is

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

The superscript "NC" designates for the no crowdfunding option. Note that $\pi_E^{NC}\big|_{X=x_H} \geq 0$ when $\overline{N} \geq \left(\frac{2\alpha h}{\alpha h + 1}\right) N_H$.

ii) If $X = x_L$, we have

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

Hences, $\pi_E^{NC}\big|_{X=x_L} \geq 0$ when $\overline{N} \geq \left(\frac{2\alpha h}{\alpha h + 1}\right) N_L$.

Therefore, three possible cases may arise:

a) if $\overline{N} > \left(\frac{2\alpha h}{\alpha h + 1}\right) N_L$, the VC always funds the project under no crowdfunding. The total expected profit from the project is:

$$\pi_E^{NC} + \pi_{VC}^{NC} = z\alpha v_L(h\frac{\overline{N}}{2} + (1-h)((1-p)x_H + px_L)) + zv_L\frac{\overline{N}}{2} - K. \tag{16}$$

This expected payoff is split between the entrepreneur and VC according to their bargaining power δ and $1 - \delta$, respectively.

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

$$\pi_E^{NC} + \pi_{VC}^{NC} = (1 - p)\left[z\alpha v_L(h\frac{\overline{N}}{2} + (1 - h)x_H) + zv_L\frac{\overline{N}}{2} - K\right], \tag{17}$$

which is split between the entrepreneur and VC according to their bargaining power.

c) if $\overline{N} < \left(\frac{2\alpha h}{\alpha h+1}\right) N_H$, the VC will never fund the project, and the expected profits of the entrepreneur and the VC are zero. $\blacksquare$

Proof of Lemma 4 and Proposition 4: We first prove Proposition 4 because its proof will be used to establish some results in Lemma 4.

When $\overline{N} < \left(\frac{2\alpha h}{\alpha h+1}\right) N_H$, the comparison is trivial because the profit is 0 under no crowdfunding.

When $\left(\frac{2\alpha h}{\alpha h+1}\right) N_H \leq \overline{N} \leq \left(\frac{2\alpha h}{\alpha h+1}\right) N_L$, from (17) the entrepreneur's profit under no crowdfunding is

$$\pi_E^{NC} = \delta z\alpha v_L h(1 - p)\left[\frac{\overline{N}}{2}\left(\frac{\alpha h + 1}{\alpha h}\right) - N_H\right]. \tag{18}$$

The profit comparison depends on whether Case 2 or Case 1 arises under crowdfunding.

Case 2 arises under crowdfunding: In this case $N_L > \overline{N}$ and from Proposition 1 $N_{min}^* = \max(N_H, 0)$. $N_L > \overline{N}$ is compatible with $\left(\frac{\alpha h}{\alpha h+1}\right) N_H \leq \frac{\overline{N}}{2} \leq \left(\frac{\alpha h}{\alpha h+1}\right) N_L$ if $N_L \geq 2\left(\frac{\alpha h}{\alpha h+1}\right) N_H$. From Problem (P2), the entrepreneur's profit under crowdfunding is

$$\pi_E^C = (1 - p)\left[\frac{z\left[v_H(1 - \gamma) + v_L\right]}{2\overline{N}}(\overline{N}^2 - (N_{min}^*)^2) + \frac{\delta z\alpha v_L h}{2\overline{N}}(\overline{N} - N_{min}^*)(\overline{N} + N_{min}^* - 2N_H)\right], \tag{19}$$

so that $\pi_E^C > \pi_E^{NC}$ is equivalent to

$$\left[\frac{\left[v_H(1 - \gamma) + v_L\right]}{2\delta\alpha v_L h}\right](\overline{N}^2 - (N_{min}^*)^2) > \frac{\overline{N}^2}{2}\left(\frac{1}{\alpha h}\right) - N_{min}^* N_H + \frac{(N_{min}^*)^2}{2}.$$

Entrepreneur's profit comparison $(\delta + \gamma < 2)$:

By (10), when $h < h_1$, we have $N_H < 0$, in which case $N_{min}^* = 0$ and the above inequality can be simplified to

$$v_H(1 - \gamma) + v_L(1 - \delta) > 0, \tag{20}$$

which always holds for $\delta + \gamma < 2$.

When $h \geq h_1$, we have $N^*_{\min} = N_H \geq 0$. From (18) and (19), $\pi^C_E > \pi^{NC}_E$ if:

$$[v_H(1-\gamma) + (1-\delta)v_L]\,\overline{N}^2 > [v_H(1-\gamma) + v_L - \delta\alpha v_L h]\,(N_H)^2 \tag{21}$$

which always holds if $v_H(1-\gamma) + v_L - \delta\alpha v_L h < 0$ because $v_H(1-\gamma) + (1-\delta)v_L > 0$ for $\delta + \gamma < 2$.

When $v_H(1-\gamma) + v_L - \delta\alpha v_L h \geq 0$, (21) reduces to:

$$\overline{N} > N_H \sqrt{\frac{v_H(1-\gamma) + v_L - \delta\alpha v_L h}{v_H(1-\gamma) + v_L - \delta v_L}}, \tag{22}$$

which holds when $h > 1/\alpha$. So the only region remains to be considered is $h \leq 1/\alpha$ and $h \geq h_1$.

Let

$$f(h) = \overline{N}\sqrt{v_H(1-\gamma) + v_L - \delta v_L} - N_H \sqrt{v_H(1-\gamma) + v_L - \delta\alpha v_L h}. \tag{23}$$

Then $f(h) \geq 0 \Leftrightarrow \pi^C_E \geq \pi^{NC}_E$. We verified that $f(h = 1/\alpha) > 0$ because $\overline{N} > N_H$, and $f(h = h_1) > 0$. Moreover, $f'(h) = 0$ is a quadratic with exactly one positive root

$$h_0 = \frac{-\left(\frac{z\alpha v_L x_H - K}{z x_H}\delta\right) + \sqrt{\left(\frac{z\alpha v_L x_H - K}{z x_H}\delta\right)^2 + 8\delta\left(\frac{z\alpha v_L x_H - K}{z x_H}\right)[v_H(1-\gamma) + v_L]}}{2\delta\alpha v_L} > 0.$$

The other root is negative, and therefore, is discarded. Taking the second order derivative with respect to h and evaluating it at h_0 yield

$$f''(h_0) = \left(2\frac{z\alpha v_L x_H - K}{h^3 z\alpha v_L}\right)[v_H(1-\gamma) + v_L] - \frac{z\alpha v_L x_H - K}{h^2 z}\frac{\delta}{2} > 0,$$

because we consider the case that $v_H(1-\gamma) + v_L - \delta\alpha v_L h \geq 0$. Therefore, $f(h)$ reaches the local minimum at $h_0 > 0$, with $f'(h) < 0$ on $0 < h < h_0$, and $f'(h) > 0$ on $h > h_0$. It is straightforward to verify $h_0 > h_1$. Because we only need to consider $h_1 \leq h \leq 1/\alpha$, there are two possible cases.

Case a) If $h_1 < 1/\alpha < h_0$, then $f(h) > 0$ on $[h_1, 1/\alpha]$ because $f(h)$ is decreasing over the region $[h_1, 1/\alpha]$ with both $f(h_1) > 0$ and $f(1/\alpha) > 0$. Then crowdfunding is always preferred.

Case b) If $h_1 < h_0 < 1/\alpha$, $f(h)$ is either positive on $h > 0$ or crosses 0 exactly twice on $[h_1, 1/\alpha]$.

Case b.1) $f(h) > 0$ on $h > 0$, then crowdfunding is always preferred.

Case b.2) $f(h)$ crosses 0 exactly twice. Let h_a and h_b be the two values of h such that $f(h_a) = f(h_b) = 0$. Then we must have $h_1 < h_a < h_0 < h_b < 1/\alpha$, such that $f(h) > 0$ except over

the region $[h_a, h_b]$. A necessary condition for this case is $h_0 < 1/\alpha$, which can be simplified to

$K > K_1$, where $K_1 = zv_Lx_H \left[\alpha - \frac{\delta v_L}{2v_H(1-\gamma)+2v_L-\delta v_L} \right]$. Note that $K_1 > (\alpha - 1)zv_Lx_H$ because

$v_H(1-\gamma) + (1-\delta)v_L > 0$. Using the envelope theorem, we verify that $f(h_0(K), K)$ is decreasing

in K because $\frac{\partial f(h_0(K),K)}{\partial K} = -\frac{\partial N_H}{\partial K}\sqrt{v_H(1-\gamma) + v_L - \delta\alpha v_L h} < 0$. Therefore, the entrepreneur may

prefer no crowdfunding when $K > K_1$ and $h \in [h_a, h_b]$.

Next we show that h_a (h_b), if exists, will decrease (increase) with δ and γ. Because $h_1 < h_a <$

$h_0 < h_b < 1/\alpha$, we know $f(h) > 0$ except over the region $[h_a, h_b]$. Therefore $f'(h_a) < 0$ and

$f'(h_b) > 0$. Because $f(h_b) = 0$, we have $\frac{\partial f(h_b)}{\partial \gamma} + f'(h_b)\frac{\partial h_b}{\partial \gamma} = 0$.

$$f(h_b) = 0 \Rightarrow \frac{\overline{N}}{\left(-\frac{z\alpha v_Lx_H-K}{h_bz\alpha v_L} + x_H\right)} = \sqrt{\frac{v_H(1-\gamma) + v_L - \delta\alpha v_L h_b}{v_H(1-\gamma) + v_L - \delta v_L}}. \tag{24}$$

Because $h_b < 1/\alpha$, if follows that

$$\sqrt{\frac{v_H(1-\gamma) + v_L - \delta\alpha v_L h_b}{v_H(1-\gamma) + v_L - \delta v_L}} > 1 > \sqrt{\frac{v_H(1-\gamma) + v_L - \delta v_L}{v_H(1-\gamma) + v_L - \delta\alpha v_L h_b}}. \tag{25}$$

Note that $\frac{\partial f(h)}{\partial \gamma}|_{h=h_b} < 0$ requires $\frac{\overline{N}}{\left(-\frac{z\alpha v_Lx_H-K}{h_bz\alpha v_L}+x_H\right)} > \sqrt{\frac{v_H(1-\gamma)+v_L-\delta v_L}{v_H(1-\gamma)+v_L-\delta\alpha v_L h_b}}$, which always holds

given (24) and (25). Thus, $f'(h_b) > 0$ implies that $\frac{\partial h_b}{\partial \gamma} > 0$. Similarly, we have $\frac{\partial h_a}{\partial \gamma} < 0$. Therefore,

the range $[h_a, h_b]$ expands as γ increases to 1.

The proof for $\frac{\partial h_b}{\partial \delta} > 0$ is similar. It suffices to show $\frac{\partial f(h)}{\partial \delta}|_{h=h_b} < 0$, which can be simplified

to $\alpha h_b \sqrt{\frac{v_H(1-\gamma)+v_L-\delta v_L}{v_H(1-\gamma)+v_L-\delta\alpha v_L h_b}} < 1$. This always holds given (25) and $h_b < 1/\alpha$. Similarly we prove

$\frac{\partial h_a}{\partial \delta} < 0$, so that $[h_a, h_b]$ expands as δ increases to 1.

Case 1 arises under crowdfunding:

In this case, we have $N_L \leq \overline{N}$, which is compatible with $\left(\frac{\alpha h}{\alpha h+1}\right) N_H \leq \frac{\overline{N}}{2} \leq \left(\frac{\alpha h}{\alpha h+1}\right) N_L$ only if

$\alpha h \geq 1$. From Problem (P1) the entrepreneur's profit under crowdfunding is

$$\pi_E^C = \frac{r}{2\overline{N}}(\overline{N}^2 - (N_{\min}^*)^2) + \frac{(1-p)\delta}{\overline{N}}\int_{N_{\min}^*}^{\overline{N}} [z\alpha v_L[hn + (1-h)x_H] - K]dn \tag{26}$$

$$+ \frac{p\delta}{\overline{N}}\int_{N_L}^{\overline{N}} [z\alpha v_L(hn + (1-h)x_L) - K]dn,$$

where $N_{\min}^*$ is given in Proposition 1. Next we show that $\pi_E^C \geq \pi_E^{NC}$ always holds for this case

because $\alpha h \geq 1$.

It suffices to show 1) $\pi_E^C\left(N_{\min}^* = \max(N_H, 0)\right) \geq \pi_E^{NC}$ always, and 2) $\pi_E^C\left(N_{\min}^* = N_L\right) \geq \pi_E^{NC}$ on $p_U < p \leq 1$. This is because $\pi_E^C\left(N_{\min}^* = \max(N_H, 0)\right) \geq \pi_E^{NC}$ implies that $\pi_E^C\left(N_{\min}^* = N_{\min}^{int}\right) \geq \pi_E^{NC}$, given that the interior solution $N_{\min}^{int}$ outperforms the boundary solution $\max(N_H, 0)$.

1) When $N_{\min}^* = \max(N_H, 0)$, from (26) π_E^C is increasing in x_L, whereas π_E^{NC} does not depend on x_L. Hence, it suffices to show $\pi_E^C \geq \pi_E^{NC}$ at the minimum value of x_L, where $N_L = \overline{N}$. However, this simply reduces to the comparison under Case 2, where we have shown that $\pi_E^C \geq \pi_E^{NC}$ as long as $\alpha h \geq 1$.

2) Consider $N_{\min}^* = N_L$, which is valid on $p_U < p \leq 1$. The entrepreneur's profit under crowdfunding is:

$$
\begin{aligned}
\pi_E^C\left(N_{\min}^* = N_L\right) \;=\; & \frac{(\overline{N} + N_L)(\overline{N} - N_L)}{2\overline{N}} z\left[(1-\gamma)v_H + v_L + \delta\alpha v_L h\right] \\
& + \frac{\delta z \alpha v_L (1-h)}{\overline{N}}[(1-p)x_H + p x_L](\overline{N} - N_L) - \frac{\delta}{\overline{N}} K(\overline{N} - N_L),
\end{aligned}
$$

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

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

Entrepreneur's profit comparison ($\gamma = 1$ and $\delta = 1$):

If Case 1 arises under crowdfunding, from the proof above, the entrepreneur always prefers crowdfunding.

If Case 2 arises under crowdfunding, then $N_L > \overline{N}$, and therefore, $h < h_2$ from (10). We next show $1/\alpha < h_2$.

Because the probability of getting funded by the VC without crowdfunding is less than 1, we have $\overline{N} < \left(\frac{2\alpha h}{\alpha h + 1}\right) N_L$. This implies that the development cost

$$
K > z\alpha v_L(h\frac{\overline{N}}{2} + (1-h)x_L) + z v_L \frac{\overline{N}}{2}. \tag{27}
$$

We next show that when this condition is satisfied, Case 2 always arises for $h < 1/\alpha$. That is, $N_L = \frac{K-(1-h)z\alpha v_L x_L}{hz\alpha v_L} > \overline{N}$ for $h < 1/\alpha$. From (27), it suffices to show $\frac{z\alpha v_L(h\frac{\overline{N}}{2}+(1-h)x_L)+zv_L\frac{\overline{N}}{2}-(1-h)z\alpha v_L x_L}{hz\alpha v_L} > \overline{N}$, which can be simplified to $(1 - \alpha h)\frac{\overline{N}}{2} > 0$, a condition that always holds for $h < 1/\alpha$. This implies that when $h < 1/\alpha$, Case 2 arises so we must have $h < h_2$. Therefore, $1/\alpha < h_2$.

If $h < h_1$, then $N_H < 0$. From (20) we have $\pi_E^C = \pi_E^{NC}$ if both $\gamma = 1$ and $\delta = 1$. In this case, the campaign is not informative ($h < min\{h_1, h_2\}$), the entire profit accrues to the entrepreneur ($\delta = 1$) and the campaign does not price discriminate ($\gamma = 1$). The optimal target number is equal to zero, thus removing the risk of campaign failure. As a result, the entrepreneur is indifferent between crowdfunding and no crowdfunding.

If $h \geq h_1$, then $N_H \geq 0$ and (22) can be written as $0 > [1 - \alpha h] (N_H)^2 v_L$, which holds if $h > 1/\alpha$.

If $1/\alpha < h_1$ then $\pi_E^C \geq \pi_E^{NC}$ if $h \geq h_1 > 1/\alpha$. In this case, the entrepreneur is indifferent between crowdfunding and no crowdfunding for $h \leq \min\{h_1, h_2\}$ and prefers crowdfunding for $h > \min\{h_1, h_2\}$.

Otherwise, if $h_1 < 1/\alpha$, then $h_1 < 1/\alpha < h_2$ so that $\min\{h_1, h_2\} = h_1$. Then $\pi_E^C < \pi_E^{NC}$ if $h_1 < h < 1/\alpha$ and $\pi_E^C \geq \pi_E^{NC}$ if $h \geq 1/\alpha$. In this case, crowdfunding is strictly preferred when h is large, but is inferior to no crowdfunding for relatively low values of h. The condition $h_1 < 1/\alpha$ can also be written as $K > (\alpha - 1)zv_L x_H$, suggesting that when K is large, no crowdfunding is better for relatively low value of h.

Combining Cases 1 and 2, we know that if $h \leq \min\{h_1, h_2\}$, the entrepreneur is indifferent between crowdfunding and no crowdfunding. If the entrepreneur prefers no crowdfunding, it must be the case that $K > (\alpha - 1)zv_L x_H$ and $h_1 < h < 1/\alpha$. In all other cases, the entrepreneur prefers crowdfunding. ∎

Proof of Proposition 5 (VC's Profit Comparison): When $\overline{N} < \left(\frac{2\alpha h}{\alpha h+1}\right) N_H$, the comparison is trivial because the profit is 0 under no crowdfunding. When $\left(\frac{2\alpha h}{\alpha h+1}\right) N_H \leq \overline{N} \leq \left(\frac{2\alpha h}{\alpha h+1}\right) N_L$, from (17) the VC's profit under no crowdfunding is

$$\pi_{VC}^{NC} = (1 - \delta) z\alpha v_L h (1 - p) \left[\frac{\overline{N}}{2}\left(\frac{\alpha h + 1}{\alpha h}\right) - N_H\right]. \tag{28}$$

Case 2. $N_L > \overline{N}$.

From (P2) and Lemma 1, the VC's profit under crowdfunding is $\pi_{VC}^C = \frac{z\alpha v_L h}{2\overline{N}}(1-\delta)(1-p)(\overline{N} - N_{\min}^*)(\overline{N} + N_{\min}^* - 2N_H)$. From (28), $\pi_{VC}^C > \pi_{VC}^{NC} \Leftrightarrow (2N_H - N_{\min}^*)N_{\min}^* > \frac{\overline{N}^2}{\alpha h}$, where $N_{\min}^* = \max(N_H, 0)$ because we are in Case 2. If $N_H \leq 0$, this condition is never satisfied so the VC never prefers crowdfunding. If $N_H > 0$, the condition can be simplified to $\alpha h > (\overline{N}/N_H)^2$. Thus, the VC's profit is higher under crowdfunding if $h > (\overline{N}/N_H)^2 / \alpha$. Because $\overline{N} \geq N_H$, the VC never prefers crowdfunding if $h < 1/\alpha$.

Case 1. $N_L \leq \overline{N}$.

$N_L \leq \overline{N}$ is compatible with $\left(\frac{\alpha h}{\alpha h + 1}\right) N_H \leq \frac{\overline{N}}{2} \leq \left(\frac{\alpha h}{\alpha h + 1}\right) N_L$ only if $\alpha h \geq 1$. Depending on the value of $N_{\min}^*$, there are three cases.

(I) $p \leq p_L$, so $N_{\min}^* = \max(N_H, 0)$. First consider $N_H \geq 0$. From (P1) and Lemma 1, the VC's profit under crowdfunding is: $\pi_{VC}^C (N_{\min}^* = N_H) = (1-\delta)\frac{z\alpha v_L h(1-p)(\overline{N} - N_H)^2}{2\overline{N}} + (1-\delta)\frac{pz\alpha v_L h}{2\overline{N}}(\overline{N} - N_L)^2$. From (28), $\pi_{VC}^C (N_{\min}^* = N_H) \geq \pi_{VC}^{NC}$ if and only if

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

If $\overline{N} \leq N_H\sqrt{\alpha h}$, this condition always holds. Otherwise, if $\overline{N} > N_H\sqrt{\alpha h}$, the VC prefers crowdfunding if $p > \frac{\overline{N}^2 - \alpha h N_H^2}{\overline{N}^2 - \alpha h N_H^2 + \alpha h (\overline{N} - N_L)^2}$.

When $N_H < 0$, then $N_{\min}^* = 0$. In this case, we have verified that when $1 - p - p\alpha h < 0$, crowdfunding leads to higher profit for the VC if $\overline{N}$ is sufficiently high, whereas under $1 - p - p\alpha h \geq 0$, the VC always prefers no crowdfunding.

(II) $p \geq p_U$, so $N_{\min}^* = N_L$. From (P1) and Lemma 1, the VC's profit under crowdfunding is:

$$\pi_{VC}^C (N_{\min}^* = N_L) = \frac{(1-\delta)z\alpha v_L h(\overline{N} - N_L)}{\overline{N}}\left[\frac{(\overline{N} + N_L)}{2} - (pN_L + (1-p)N_H)\right].$$

From (28), we can simplify the inequality $\pi_{VC}^C (N_{\min}^* = N_L) \geq \pi_{VC}^{NC}$ to:

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

If $(\overline{N} - N_L)^2 + \frac{1}{\alpha h}\overline{N}^2 + (N_L - N_H)^2 - N_H^2 > 0$, the VC prefers crowdfunding if

$$p \geq \frac{\frac{1}{\alpha h}\overline{N}^2 + (N_L - N_H)^2 - N_H^2}{(\overline{N} - N_L)^2 + \frac{1}{\alpha h}\overline{N}^2 + (N_L - N_H)^2 - N_H^2}.$$

Otherwise if $\left(\overline{N} - N_L\right)^2 + \frac{1}{\alpha h}\overline{N}^2 + (N_L - N_H)^2 - N_H^2 < 0$, then the VC always prefers crowdfunding.

(III) $p_L \leq p \leq p_U$, so that $N_{\min}^* = N_{\min}^{int}$. The inequality $\pi_{VC}^C \left(N_{\min}^* = N_{\min}^{int}\right) \geq \pi_{VC}^{NC}$ can be simplified to $\frac{p}{1-p}\left(\overline{N} - N_L\right)^2 - \frac{\overline{N}^2}{\alpha h} \geq \left(N_{\min}^{int} - N_H\right)^2 - N_H^2$. By noting

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

we can rewrite the inequality above as

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

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

$$\left[\frac{4p - (4+A)p^2}{4(1-p)} - \frac{(1-p)}{\alpha h}\right]\overline{N}^2 + \overline{N}B + C \geq 0 \tag{29}$$

where $B = ApN_H - \frac{4p-(4+A)p^2}{2(1-p)}N_L$ and $C = \frac{4p-(4+A)p^2}{4(1-p)}(N_L)^2 - ApN_H N_L - (1-p)(A-1)(N_H)^2$. Evaluating (29) as equality yields two roots:

$$\overline{N}_{1,2} = \frac{-B \pm \sqrt{B^2 - 4\left[\frac{4p-(4+A)p^2}{4(1-p)} - \frac{(1-p)}{\alpha h}\right]C}}{2\left[\frac{4p-(4+A)p^2}{4(1-p)} - \frac{(1-p)}{\alpha h}\right]}. \tag{30}$$

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

When $\frac{4p-(4+A)p^2}{4(1-p)} - \frac{(1-p)}{\alpha h} < 0$, the VC makes higher profit under crowdfunding if $\overline{N}$ falls within the two roots in (30)

When $\frac{4p-(4+A)p^2}{4(1-p)} - \frac{(1-p)}{\alpha h} > 0$, the VC makes higher profit under crowdfunding if $\overline{N}$ is either above the bigger root or below the smaller root in (30) and also satisfies $\left(\frac{\alpha h}{\alpha h+1}\right)N_H \leq \frac{\overline{N}}{2} \leq \left(\frac{\alpha h}{\alpha h+1}\right)N_L$.

Summarizing Cases 1 and 2, we conclude that when $\left(\frac{\alpha h}{\alpha h+1}\right)N_H \leq \frac{\overline{N}}{2} \leq \left(\frac{\alpha h}{\alpha h+1}\right)N_L$, the VC never prefers crowdfunding when $\alpha h < 1$, whereas his preference is ambiguous when $\alpha h \geq 1$. From Proposition 4, the entrepreneur always prefers crowdfunding when $\alpha h \geq 1$. This completes the proof. ∎