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The Crowdfunding Effects on Venture Capital Investment

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Abstract. We examine the impact of crowdfunding on venture capital (VC) investments in the presence of competition among VC firms. Our economic model comprises a startup, a crowdfunding platform, and two VC firms, each with its own perception of the startup's potential. The startup seeks equity funding from the VC firms and decides on the size of its equity offer. If the VC firms decline to invest, the startup pivots to crowdfunding. Following the crowdfunding campaign, all firms update their beliefs about the startup's likelihood of success based on the crowdfunding outcome, prompting the VC firms to revisit their investment decisions, now with a reduced equity offer if the crowdfunding outcome was positive. This study provides theoretical underpinnings at the firm level for the observed aggregate-level empirical relationships, both positive and negative, between crowdfunding and VC investments. Specifically, based on our model, the positive relationship, where increased crowdfunding activity leads to a rise in subsequent VC investments, is attributed to startups that fail to secure VC funding in the absence of a crowdfunding platform but succeed in attracting VC attention after a successful crowdfunding campaign. In contrast, the negative relationship is attributed to highly valued startups that could have secured VC funding without crowdfunding, but with crowdfunding, VC firms choose to defer their investment decision until after the crowdfunding campaign's result is known; on the one hand, a successful crowdfunding outcome lowers their post-crowdfunding VC investment demand, and on the other hand, an unsuccessful outcome deters potential VC investors. Besides these relationships, we also identify another dynamic, where the option of accessing crowdfunding raises VC investment, even if the startup does not actually launch a crowdfunding campaign.

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1. Introduction

Crowdfunding is the practice of funding a project or venture by raising small amounts of money from a large number of people via online platforms. Traditionally, startups raise capital through venture capital (VC) firms, but the number of startups that receive VC investment is limited. Crowdfunding provides startups with an alternative source of funding. However, the typical funding amount through crowdfunding is small. For instance, the majority of successful fundraising projects on Kickstarter, the largest reward-based crowdfunding platform in the United States, have raised less than $10,000. Therefore, for capital-thirsty projects, crowdfunding cannot replace VC investments, let alone the additional value that VC firms bring to startups, such as industry knowledge, relationships, and status (Hsu 2004).

Currently, tens of thousands of VC investors use crowdfunding to leverage the "wisdom of the crowd" to vet deals.[1] Moreover, VC firms have started collaborating with crowdfunding platforms to fund startups.[2] By analyzing the data of Kickstarter campaigns and VC investments in the United States from 2009–2015, Sorenson et al. (2016) find consistent evidence that an increase in the number of crowdfunding campaigns in a U.S. county leads to a subsequent increase in the number of VC investments in the same county. In other words, crowdfunding expands VC funding to a broader range of regions beyond the concentrated areas of Boston and Silicon Valley. Nevertheless, D'Ambrosio and Gianfrate (2016) find the opposite of this positive relationship between crowdfunding and VC investments, discovering that an increase in crowdfunding leads to decreased

future VC seed funding, possibly because of the different granularity levels of the time series data and metrics for the VC and crowdfunding activities from Sorenson et al. (2016).

Motivated by the empirical evidence of the relationship between crowdfunding and VC investments at an aggregate level, we build a theory model to study the strategic interaction between potential VC investors and an individual startup that can initiate a crowdfunding campaign. By analyzing the equilibrium outcome, we investigate how the crowdfunding option affects VC investments. Specifically, we build a stylized model involving a startup seeking VC investment to fund its business operations and two competing VC firms with their own prior beliefs about the startup's potential for success. The ground-truth state of the startup, whether it will succeed or fail, remains unobservable to the startup and the VC firms. If the startup succeeds, it delivers the end product, leading to a profitable investment return. However, if the startup fails to deliver the product as planned, the investment results in a loss to investors. Prior to approaching the VC firms, the startup decides on the size of its equity offering. Subsequently, both the VC firms decide on whether to invest in the startup. The level of investment in the startup is determined by the competition between the two VC firms and the relative negotiation power of the startup and the VC firms. There are two distinctive time epochs during which the VC firms can make their investment decisions: before and after the crowdfunding phase. If the startup successfully secures VC funding before crowdfunding, it forgoes further funding efforts and proceeds directly to the production stage. However, if funding from the VC firms is not secured, the startup initiates a crowdfunding campaign on a dedicated platform such as Kickstarter. The campaign's outcome may result in either obtaining some funding or receiving no funding, serving as a public signal of the startup's potential for success. Thus, based on the crowdfunding outcome, the VC firms update their beliefs about the startup's likelihood of success and then revisit their investment decision.

We begin by examining a benchmark model in which there is no crowdfunding option. In this setting, the startup strategically sets the size of its equity offering to entice the more optimistic VC firm, among the two competing VC firms, to invest and meet the startup's minimum funding requirement. Next, we introduce crowdfunding and allow the startup to launch a crowdfunding campaign. We find that if the startup offers a large-enough equity share, the VC firms tend to invest and prevent the startup from launching a crowdfunding campaign. In anticipation of this, the startup faces a trade-off in determining the size of the equity offer, that is, whether to make a large-enough equity offer to encourage early investment (without launching any crowdfunding campaign) or to offer a smaller equity share, which prompts the VC firms to delay their investment after observing the crowdfunding outcome. We show that in the presence of the crowdfunding option, the competition between the VC firms, stimulated by observing the public signal of the crowdfunding outcome, influences the VC firms' and the startup's decisions. Specifically, when the competing VC firms' beliefs on the startup's success become more convergent, the startup is more inclined to induce the VC firms' preemptive investment (i.e., inducing the VC firms to invest with the threat of launching a crowdfunding campaign).

We further compare the scenarios with and without crowdfunding and analyze how crowdfunding affects the two critical metrics of VC investment: the size of the startup's equity offer and the VC investment level. For the startup's equity offer, we find that the startup offers a larger equity size when inducing the VC firms' preemptive investment in the presence of crowdfunding than in its absence; otherwise, when causing the VC firms' delay, its offered equity size is smaller with crowdfunding than without. This is because if and only if the equity size is large enough, the VC investors would find it profitable to prevent the startup from launching a crowdfunding campaign. For the investment level, because the earlier papers have empirically examined the correlation between crowdfunding and VC investments at the aggregated level, we aim to ascertain whether our theoretical findings at the individual startup level can be used to explain the earlier empirical observations. We have three findings about the effects of crowdfunding on the VC investment level. First, by our model, the positive relationship between crowdfunding and VC investment reported in Sorenson et al. (2016) can be driven by those startups that cannot secure a VC investment without crowdfunding but manage to attract VC firms' attention following a successful crowdfunding campaign. Second, we offer a plausible explanation for the negative relationship between crowdfunding and VC investment discovered in D'Ambrosio and Gianfrate (2016). This negative relationship is attributed to highly valued startups that could have secured VC funding without crowdfunding, but with crowdfunding, VC firms choose to defer their investment decision until after the crowdfunding campaign's result is known; on the one hand, a successful crowdfunding outcome lowers their post-crowdfunding VC investment demand, and on the other hand, an unsuccessful outcome deters potential VC investors. Finally, we show that crowdfunding can raise the VC investment level when VC firms make a preemptive investment. In this case, the startup does not really initiate a crowdfunding campaign, but the crowdfunding option acts as a threat to potential VC investors. Such a crowdfunding effect on pre-crowdfunding investment is not captured in the earlier empirical research.

The rest of the paper is organized as follows. In Section 2, we review the related literature on crowdfunding. Section 3 presents the model. Next, in Section 4, we analyze the benchmark model without the crowdfunding option. Then, in Section 5, we present the analysis of the main model in the presence of a crowdfunding platform. By comparing the settings with and without crowdfunding in Section 6, we demonstrate the crowdfunding effects on VC investments. Finally, in Section 7, we conclude the paper. We relegate the proofs and extensions to the online appendices.

2. Literature Review

Crowdfunding typically provides small-scale funding for startups. In the field of entrepreneurship and innovation, numerous studies delve into the role crowdfunding plays in entrepreneurial finance. For instance, Mollick and Kuppuswamy (2014) find that crowdfunding offers several potential benefits beyond just raising funds. Consistent with this, Xu (2018) proposes that crowdfunding extends early feedback to entrepreneurs regarding the market demand for their projects, whereas Mollick and Robb (2016) assert that crowdfunding may democratize both the commercialization of innovation and its financing. Yu and Fleming (2022) explore how crowdfunding impacts regional venture formation and reveal that crowdfunding promotes high-tech entrepreneurship through financial and nonpecuniary support. Furthermore, Cornelius and Gokpinar (2020) argue that crowdfunders can influence product development, which benefits entrepreneurs. Given the multifaceted roles crowdfunders play, Kim et al. (2020) investigate their dynamic decision-making process. In this stream of literature, several papers study the relationship between crowdfunding and startups' subsequent funding from professional investors. For example, Sorenson et al. (2016) find that an increase in crowdfunding campaigns in a region promotes VC investments in the same region in subsequent years. D'Ambrosio and Gianfrate (2016) show that crowdfunding serves as a substitute for seed-round VC investments whereas it complements post-seed-round VC investments. Thies et al. (2019) discover that a successful crowdfunding campaign leads to a higher likelihood of receiving follow-up VC financing. Mollick and Nanda (2016) show that VC firms and crowdfunders assess entrepreneurial quality similarly, but relative to VC funding, crowdfunding reduces geographic and gender biases to some extent. Ryu et al. (2023) report that a successful crowdfunding campaign is positively associated with subsequent corporate investments but not with independent VC investments. Roma et al. (2017) demonstrate that raising a larger amount of money via crowdfunding positively correlates with attracting professional investors in subsequent funding rounds.

At the operational level, several theoretical papers examine the mechanism design and operational decisions in crowdfunding campaigns. Allon and Babich (2020) review the recent literature in this area and propose open research questions. Most theoretical papers on crowdfunding analyze optimal campaign design for entrepreneurs or optimal mechanism design for crowdfunding platforms. From the entrepreneurs' perspective, the key campaign parameters are the reward price and the funding target (see Chemla and Tinn 2020, Kumar et al. 2020, Chakraborty and Swinney 2021, Liu et al. 2022, and Zhang et al. 2023). Moreover, Hu et al. (2015) study an entrepreneur's product decisions, including quality and product line, whereas Zhang et al. (2023) analyze an entrepreneur's decision on campaign duration. Fatehi and Wagner (2019) study a crowdfunding model in which an entrepreneur shares a portion of its revenue with crowdfunding investors and decides the revenue-sharing fraction. Several papers adopt the perspective of crowdfunding platforms. For instance, Strausz (2017) studies the role of deferred payments in managing the information asymmetry between entrepreneurs and potential investors on a crowdfunding platform. Belavina et al. (2020) propose two novel designs to deter misconduct and improve crowdfunding efficiency.

In contrast to the aforementioned operations literature, our study examines how crowdfunding, as both an informational and financing source to the startup, affects VC investments. We build a stylized model that collaborates with the existing empirical findings. Two closely related modeling papers consider the informational impact of crowdfunding campaigns on VC firms. Babich et al. (2021) study how the presence of crowdfunding changes the strategic interactions between an entrepreneur, a bank investor, and a VC firm. We supplement their study by considering two competing VC firms with heterogeneous beliefs about the entrepreneur's success. We also allow the startup to decide the size of its equity offering. The startup's decision and the competition between the VC firms significantly affect the interaction between the VC firms and the startup and, hence, the crowdfunding effects. Roma et al. (2018) develop a three-stage model where an entrepreneur decides how to design a crowdfunding campaign, taking into account future access to VC investments. The campaign design naturally affects its outcome, which in turn influences the VC firm's perception of the market potential. We adopt the comprehensive framework that was proposed by Roma et al. (2018) to study both the informational and financing roles of crowdfunding. Our paper differs from Roma et al. (2018) in three aspects. First, whereas Roma et al. (2018) consider only one VC firm, we show that competition between the VC firms substantially influences the firms' decisions under the crowdfunding option. Second, in Roma et al. (2018),

the VC firm has only one opportunity to invest in the startup. In contrast, in our paper, the VC firms have both pre-crowdfunding and post-crowdfunding investment opportunities. The VC firms in our model have a trade-off between an early investment with a bigger equity offer and a delayed investment with a smaller equity offer. This naturally results in different trade-offs and equilibrium outcomes compared with those in Roma et al. (2018). Finally, in our paper, the startup interacts with the VC firms by deciding the size of the equity offer, whereas in Roma et al. (2018), the startup focuses on deciding the funding goal and pledge level of a crowdfunding campaign while leaving the profit division between the startup and the investing VC firm as exogenous.

In the literature of corporate finance, several authors study the classical preemption game, which discusses the oligopolistic investors' investing time (see, e.g., Fudenberg and Tirole 1985 and Grenadier 1996). Grenadier (1996) examines real estate development timing decisions by owners, considering rent revenue and the impact of redevelopment on both rents and costs. The study evaluates whether owners redevelop properties simultaneously or sequentially, balancing the benefits of delayed redevelopment (i.e., more information but lower rents) against early redevelopment (i.e., less information but quicker, higher rents). Our paper draws a parallel with VC investment timing, where delaying investment until after crowdfunding provides more accurate startup information but results in a smaller equity share, whereas immediate investment grants a larger share with less information. Unlike the focus of Grenadier (1996) on equilibrium timing based on exogenous factors like discount rates, our study concentrates on the influence of crowdfunding on the VC firms' and startup's decisions, driven by the endogenous variable of the startup's equity offer. We extend the investment preemption game discussion by integrating crowdfunding, considering a simplified model with heterogeneous VC firms and startup-determined equity offers, and thus exploring a novel research question related to crowdfunding. The above differences of our paper from Grenadier (1996) also apply to other papers in this research stream.

3. Model

We consider an economy consisting of two VC firms, one crowdfunding platform, and one startup. The VC firms in our model can represent any type of investor (including angel investors) as long as they can make an equity investment in the startup. Such a term is consistent with the related literature (see, e.g., Roma et al. 2017, Strausz 2017, and Babich et al. 2021). The startup has a creative idea but lacks funding for research, development, production, and marketing. The process of seeking funding typically involves several steps. We adopt the same sequence of events as Strausz (2017, p. 5). The startup first approaches the VC firms, and a VC firm makes an investment only if it is convinced that the investment is expected to be profitable enough. If no VC firm makes an investment, the startup launches a crowdfunding campaign. Then, if the startup does not collect enough money from the campaign, it will approach the VC firms again, and the VC firms will revisit their investment decisions after observing the campaign's outcome. In this process, there are two critical time points: the pre-crowdfunding time t_0 and the post-crowdfunding time t_1.

3.1. Startup

The startup requires a minimum funding requirement of R_0 at the cost of a portion α of its equity. In other words, if the startup receives an investment of at least R_0, it will launch the project and proceed with production and marketing. Because of market uncertainty, neither the startup nor the VC firms know for sure whether the startup's product will succeed in the market. We model this uncertainty regarding the startup's success using a binary underlying state denoted by θ, which can be either success (s) or failure (f), each with a probability of $P(\theta = s) = P(\theta = f) = 1/2$. Thus, the startup faces a 50% chance of either success or failure. Conditional on the underlying state θ, the revenue of the entire project is R_θ, and we assume $R_f < R_0 < R_s$. This implies that if the minimum funding requirement of R_0 is invested, the project will yield a profit if it turns out to be a success, whereas there will be a financial loss if it fails. R_0 can be correlated with R_s and R_f because the startup utilizes the collected funding to generate revenue. Typically, those startups that require more initial funding also tend to recoup more revenue if successful. We treat the three parameters R_0, R_s, and R_f as exogenous to make the model more general, allowing for different correlation structures among these parameters. All entities have their own initial beliefs on the startup's likelihood of success. The startup has an initial belief about the likelihood of its own success, denoted by p_a, which is private information. Therefore, the startup's expected revenue of the project is $e_a = p_a R_s + (1 - p_a)R_f$. We clarify that after each funding round, the startup may be owned by a combination of founders and investors with varying shares. When referring to the startup's revenue in the following discussion, we mean the revenue of the founders (entrepreneurs) who created the startup; that is, we subtract the revenue earned by the investors accounting for their equity share.

3.2. VC Firms

VC_i ($i = 1, 2$) holds a prior belief $p_i \in [0, 1]$ regarding the startup's likelihood of success. Without loss of generality, let $p_1 \geq p_2$, meaning that VC_1 initially holds a more

optimistic view of the startup's prospect than VC_2. These beliefs of the VC firms are assumed to be public information, which can reflect that VC firms may have publicly known expertise or preferences. VC_i entertains the idea of investing in the startup once its valuation of the startup's equity exceeds the investment cost. If both VC firms find it profitable to invest in the startup, competition arises, which naturally affects the investment level (see, e.g., Inderst and Müller 2004).

From VC_i's perspective, the anticipated revenue of the entire project is $e_i = p_i R_s + (1-p_i)R_f$, and with an equity share α, its valuation of the investment is $v_i = \alpha e_i$. Given the competing VC firms' valuations as $v_1 \geq v_2$ and the minimum funding requirement as R_0, we assume that the investment level to acquire the equity share is determined by

$$\kappa(v_1, v_2, R_0) = \begin{cases} 0 & \text{if } v_1 < R_0, \\ \beta v_1 + (1-\beta)\max\{v_2, R_0\} & \text{if } v_1 \geq R_0, \end{cases} \tag{1}$$

where $\beta \in [0,1]$ represents the negotiation power of the startup relative to the VC firms. This investment-level function (1) indicates that when the VC firms' valuations are higher, the cost of acquiring the equity share in the startup is also higher, and similarly, when the minimum investment requirement is higher, or the startup has a stronger negotiation power relative to the VC firms, the cost of obtaining the equity share is also higher.

We justify the form of investment-level function $\kappa(\cdot)$ as follows: When the startup approaches the VC firms, the startup does not accept any funding amount less than R_0. Thus, when both the VC firms' valuations for the equity share are lower than R_0 (i.e., $v_2 \leq v_1 \leq R_0$), no one invests in the startup, and the investment level is zero. Otherwise, when the valuation of the more optimistic VC firm (i.e., VC_1) exceeds R_0, its investment level is negotiated between the startup and VC_1, which may be influenced by the startup's potential alternative funding source, VC_2. Specifically, when VC_2's valuation is lower than R_0, the startup does not have an outside option. In this case, the startup may potentially accept any investment level greater than R_0. However, if VC_2's valuation is greater than R_0, the startup does have an outside option of valuation v_2 from VC_2. Then, during its negotiation with VC_1, the minimum investment level it demands from VC_1 is boosted to v_2. From the above discussion, VC_1 can potentially agree on any investment level which is no higher than v_1 whereas the startup can potentially accept any investment level greater than $\max\{v_2, R_0\}$. The final investment level is given by $\beta v_1 + (1-\beta)\max\{v_2, R_0\}$ and is between v_1 and $\max\{v_2, R_0\}$ depending on the startup's negotiation power β. Consider the two special cases where $\beta = 1$ and $\beta = 0$. On the one hand, if the startup provides a take-it-or-leave-it contract to the VC firms, the startup can set the investment level as v_1, which corresponds to $\beta = 1$, and retain all the surplus. On the other hand, if the investment level is determined through a second-price auction with a reservation value of R_0, truthful bidding constitutes a weakly dominant Nash equilibrium for the VC firms (see, e.g., Krishna 2009, chapter 2.2); therefore, the investment level by VC_1 becomes $\max\{v_2, R_0\}$, which corresponds to $\beta = 0$, and VC_1 retains all the surplus.

3.3. Crowdfunding

Crowdfunding serves dual roles in generating market information for the public and providing potential financing to the startup. First, the outcome of a crowdfunding campaign yields information concerning the underlying state θ for all observers in the market. More specifically, the crowdfunding process generates a signal Θ that pertains to the startup's underlying state. The signal Θ takes on values of either S or F, denoting whether the underlying state θ is s or f, respectively. Given the potential lack of full accuracy in the signal, we have $P(S|s) = P(F|f) = 1/2 + \rho/2$ and $P(F|s) = P(S|f) = 1/2 - \rho/2$, where $\rho \in [0,1]$ gauges the signal's accuracy (see also Iyer et al. 2007). A higher ρ indicates a more accurate information output from the crowdfunding campaign. With $\rho = 1$, the signal fully discloses the startup's underlying state, and at $\rho = 0$, the signal provides no meaningful information. The accuracy of the signal is assumed to be common knowledge. Second, crowdfunding potentially serves as a financing source for the startup. Specifically, the signal Θ corresponds to the total pledged funds from the crowdfunding campaign. In light of the all-or-nothing scheme commonly employed by crowdfunding platforms (such as Kickstarter), the signal S corresponds to the campaign successfully collecting the targeted amount denoted by K. Alternatively, the signal F corresponds to a total collection of zero funds. We assume the crowdfunding target of K is common knowledge for the industry and assume away potential overfunding beyond the target. We also assume $K \in (0, R_0)$, implying that even if the crowdfunding campaign succeeds, the pledged funds do not meet the startup's minimum funding requirement. This arises from the observation mentioned in Section 1 that crowdfunding often involves relatively modest funding amounts, insufficient to support the startup's expansive development and large-scale manufacturing needs (see also, e.g., Roma et al. 2018).

3.4. Timeline

Prior to time t_0, the startup decides the equity share $\alpha \in [0,1]$ offered to an investing VC firm, which represents the fraction of the total issued stocks when normalized to one. Subsequently, at time t_0, both VC firms determine whether to invest in the startup. If VC_1 entertains the idea of investing at time t_0 ($v_1 \geq R_0$) and the investment level is $\kappa(v_1, v_2, R_0)$ as specified earlier, only VC_1 can become the investor in the startup. This is because

VC_2's valuation of the investment, v_2, invariably remains lower than the investment cost $\kappa(v_1, v_2, R_0)$ given that VC_2 holds a less optimistic initial belief about the startup's success in comparison with VC_1. Should the startup secure VC funding, the game would conclude, marking the startup's entry into the production stage. In practice, because of the large scale of VC investment, those startups that are successfully funded by VC firms seldom seek further funding from crowdfunders. This is why the startup terminates the fundraising after a VC investment, which is also a typical assumption in the literature (see, e.g., Strausz 2017).

With no VC funding secured, the startup decides whether to start a crowdfunding campaign. As the startup pays no cost to launch a crowdfunding campaign, it will always do so because then it will have an opportunity to get VC funded after the campaign. As mentioned, the crowdfunding campaign will generate the signal Θ. The VC firms and the startup adjust their beliefs upon observing the signal Θ, resulting in updated beliefs $\tilde{p}_1|\Theta, \tilde{p}_2|\Theta$, and $\tilde{p}_a|\Theta$, respectively. Here, the beliefs are updated based on Bayes' rule. Once the crowdfunding campaign collects the funding target of K, the startup's minimum VC funding requirement becomes $R_0 - K$. Subsequently, at time t_1, the VC firms reevaluate their investment decisions with the reduced minimum investment prerequisite of $R_0 - K$ and an updated equity share $\alpha' = (R_0 - K)\alpha/R_0$ that scales proportionally with α. Hence, as the startup collects more funds from the crowdfunding campaign, it offers a smaller fraction of equity to the VC firms. This is because the startup now needs less capital from the VC firms (Babich et al. (2021) note that when the crowdfunding campaign is very successful, there is not enough upside left for VC firms). Conversely, should the crowdfunding campaign fail (resulting in zero funds collected), the startup's minimal requirement for VC investment at time t_1 would remain R_0 in exchange for an equity share of α. Notably, as all participants observe the same crowdfunding signal, VC_1 maintains a more optimistic updated belief about the startup compared with VC_2. Therefore, if VC_1 finds it profitable to invest at time t_1, it would beat VC_2 and become the startup's investor by acquiring equities.

We remark on the form $\alpha' = (R_0 - K)\alpha/R_0$ of the offered equity share by the startup after a successful crowdfunding campaign that collects the target K. In one round of VC financing, a startup and a VC firm usually take several months to negotiate the price of the deal, which determines "how much the VC firm will pay for what percentage of the startup" (see, e.g., Bagley and Dauchy 2012, p. 444). Because the startup approaches different VC firms at different times during this round, the price it offers, serving as a starting point for further negotiations, usually remains constant in this round. Bagley and Dauchy (2012, p. 483) also provide a term sheet[3] during the negotiation between a VC firm and a startup, with a fixed price while leaving the investment scale to be determined. In our model, because of the shorter duration of a crowdfunding campaign compared with one round of VC financing, the period between t_0 and t_1 is considered within a single round of financing (seed or A round). Thus, we assume the startup's offered price, R_0/α, remains unchanged during this period. Then, after a successful crowdfunding campaign, the startup's offered equity share adjusts to $\alpha' = (R_0 - K)\alpha/R_0$ because of a smaller funding requirement $(R_0 - K)$. The corresponding negotiation situation, in reality, tends to look like this: The startup approaches VC_1, stating that the minimum price it can accept is R_0/α. It also informs VC_1 that another VC, VC_2, is interested in investing. Meanwhile, the startup plans to launch a crowdfunding campaign, which may alter the funding scale depending on the campaign's outcome. We believe such a setting follows closer to the VC-startup interaction, consistent with the term sheet illustration in Bagley and Dauchy (2012, p. 483). Note that although the startup's offered price is assumed to be constant between t_0 and t_1, it can achieve a higher final transaction price than its reservation price through two mechanisms: one is to introduce competition among VC firms, and the other is to start a crowdfunding campaign and achieve success, which increases VC firms' beliefs and valuations. More details of the above justification are provided at the end of Online Appendix A. In Online Appendix A, we extend our model by allowing the startup to optimize the equity offer α' after crowdfunding at time t_1, that is, to adjust the reservation price. We find most of the relationships between crowdfunding and the VC investment level discussed in the main paper carry over to this extended setting.

3.5. Notation and Assumption

To emphasize the impacts of crowdfunding, we initially examine a baseline scenario without a crowdfunding platform and then introduce the presence of the crowdfunding platform. The superscripts o and c signify settings without and with crowdfunding, respectively. The subscript $i \in 1, 2$ pertains to VC_i, whereas the subscript a pertains to the startup. As we analyze two time epochs, pre-crowdfunding time t_0 and post-crowdfunding time t_1, any term with (respectively, without) a tilde corresponds to the post-crowdfunding time t_1 (respectively, pre-crowdfunding time t_0). We summarize the notation used in the paper in Table D.1 of Online Appendix D.

Finally, we make an assumption on the parameters. Denote by $\tilde{e}_1|S = (\tilde{p}_1|S)R_s + (1 - \tilde{p}_1|S)R_f$ the revenue of the entire project under VC_1's updated belief after a successful crowdfunding campaign.

Assumption 1. *Assume* $\tilde{e}_1|S \geq R_0$.

Assumption 1 means that the more optimistic VC firm's belief (p_1) on the startup cannot be too low, so that

no VC firm would invest even if the startup's offered equity share equals one and the crowdfunding campaign was successful. This assumption rules out the trivial case in which there is no VC investment in both scenarios with and without crowdfunding.

4. No Crowdfunding

Without a crowdfunding platform, there is no opportunity to update information on the startup's success, which makes the situation boil down to a single decision point, referred to as t_0. Because VC_2's valuation is always lower than the investment level once VC_1 entertains the idea of investing (i.e., $v_1 \geq R_0$), making VC_2 ineffective as an investor, we will focus solely on discussing VC_1's investment decision henceforth. VC_1 will invest in the startup if and only if its valuation v_1 exceeds the investment level $\kappa(v_1, v_2, R_0)$ to acquire the equity share.

Given the expression of $\kappa(v_1, v_2, R_0)$ and the condition $v_1 \geq v_2$ resulting from $p_1 \geq p_2$, we obtain that VC_1 invests only if $v_1 \geq R_0$, which is equivalent to $\alpha \geq R_0/e_1$. This implies that VC_1 will invest only when the equity share provided to the VC firms is sufficiently high for it to perceive the offer as a good deal, that is, the investment's valuation exceeds the minimum funding requirement.

Using backward induction, we solve the startup's optimization problem to decide the equity share to offer. If VC_1 invests, the startup's expected payoff with respect to its own belief is $(1-\alpha)e_a$. If VC_1 does not invest, the startup gains nothing. Therefore, the startup's optimization problem can be stated as follows:

$$\max_{\alpha} \ \mathbb{I}_{\{R_0/e_1 \leq \alpha \leq 1\}}(1-\alpha)e_a.$$

Here, the $\mathbb{I}$ operator accounts for the individual rationality constraint the startup faces when making a decision to induce investment from VC firms. Solving this problem, we obtain the startup's optimal equity offer decision in Proposition 1.

Proposition 1. *Without a crowdfunding platform, if p_1 is low enough such that $e_1 < R_0$, there is no VC investment. Otherwise, if p_1 is high enough such that $e_1 \geq R_0$, the startup sets the optimal equity share $\alpha^o = R_0/e_1$, and VC_1 makes an investment of R_0.*

Proposition 1 shows that when VC_1's prior belief p_1 is pessimistic enough, even if the startup gives up all of its equity, VC_1 still believes such an investment is nonprofitable. As a result, no investment takes place in this scenario. Alternatively, when VC_1's prior belief p_1 is sufficiently optimistic, the startup sets $\alpha = R_0/e_1$. This is because, from the startup's perspective, the expected revenue of the entire project is e_a, attainable once the minimum funding requirement is met. However, it prefers the equity share provided to the investing VC firm to be as low as possible. Thus, the startup sets the equity share as the boundary level R_0/e_1 while still retaining the minimum funding requirement. With the equity share $\alpha = R_0/e_1$, we obtain the competitor VC_2's valuation $v_2 \leq R_0$ in the absence of crowdfunding opportunities. This implies that the startup sets an equity share such that the VC firm with the more optimistic prior belief achieves zero expected surplus, and the VC firm with the more pessimistic belief has no impact on the investment level.

5. Crowdfunding Option

In this section, we analyze the VC firms' investment decisions and the startup's equity share decision in the presence of the crowdfunding option. First, we analyze the VC firms' investment decisions given the startup's equity share. Then, we analyze the startup's optimal equity share decision.

5.1. VC Firms' Investment Decisions

With a crowdfunding campaign, all the firms' beliefs can be updated according to the outcome of the campaign. By Bayes' rule, a firm's updated belief given its prior belief p and signal S or F is given by

$$\tilde{p}|S = \frac{(1+\rho)p}{2\rho p + 1 - \rho} \quad \text{or} \quad \tilde{p}|F = \frac{(1-\rho)p}{-2\rho p + 1 + \rho}.$$

Accordingly, at time t_1, the expected revenue of the entire project with respect to the beliefs of the VC firms and the startup is $\tilde{e}_i|\Theta = (\tilde{p}_i|\Theta)R_s + (1-\tilde{p}_i|\Theta)R_f$, where $i = 1, 2, a$ and $\Theta = S, F$. Recall that with signal S, the startup secures funding of K amounts from the crowdfunding campaign, reducing the offered equity share to $\alpha' = (R_0 - K)\alpha/R_0$ at time t_1. In contrast, when signal F arises, the startup does not collect any funds from the campaign, leaving the offered equity share at time t_1 unchanged at α. Then, for the VC firms, the valuation of the offered equity share under different signals is as follows: $\tilde{v}_i|S = \alpha'\tilde{e}_i|S$ and $\tilde{v}_i|F = \alpha\tilde{e}_i|F$. Therefore, the investment levels to acquire the equity share at time t_1 under different signals are $\kappa(\tilde{v}_1|S, \tilde{v}_2|S, R_0 - K)$ and $\kappa(\tilde{v}_1|F, \tilde{v}_2|F, R_0)$, respectively. Moreover, both VC firms observe the same signal from the crowdfunding outcome. After the update, VC_1's belief $\tilde{p}_1|\Theta$ remains more optimistic than that of VC_2. Thus, similar to the previous section, at time t_1, VC_1 opts for investment only if its valuation exceeds the investment level. As a result, VC_1's expected surplus at time t_1, contingent on the signal $\Theta = S, F$, can be expressed as follows:

$$\tilde{\pi}_1|S = \max\{\tilde{v}_1|S - \kappa(\tilde{v}_1|S, \tilde{v}_2|S, R_0 - K), 0\},$$
$$\tilde{\pi}_1|F = \max\{\tilde{v}_1|F - \kappa(\tilde{v}_1|F, \tilde{v}_2|F, R_0), 0\}.$$

Then, on the one hand, VC_1's expected surplus at time t_1 through waiting and observing the crowdfunding outcome is given by

$$\tilde{\pi}_1 = P(S|p_1)\tilde{\pi}_1|S + P(F|p_1)\tilde{\pi}_1|F,$$

where $P(S|p_1)$ (respectively, $P(F|p_1)$) represents the

probability of observing signal S (respectively, signal F) according to VC_1's belief. On the other hand, if VC_1 does not wait and instead invests at time t_0, its expected surplus is $\pi_1 = v_1 - \kappa(v_1, v_2, R_0)$.

Even if VC_1 could have achieved a positive surplus through investing at time t_0, that is, $\pi_1 \geq 0$, it may choose to wait strategically until time t_1. For VC_1, whether to invest now or wait later hinges on the value of waiting, defined as follows:

$$\text{The value of waiting for VC}_1: \quad \Delta_1 = \tilde{\pi}_1 - \pi_1.$$

VC_1 would opt to delay its investment decision when the value of waiting is positive, that is, $\Delta_1 > 0$. (We choose the tie-breaking rule that if a VC is indifferent between investing now and delaying its investment, the VC would choose to invest now.) Babich et al. (2021) demonstrate three fundamental components of the economic value of crowdfunding from the perspective of the startup company: cash flow gains, avoided costs, and updated payoff probability. From the standpoint of VC_1, the value of waiting in our paper also encompasses the avoided costs and the updated payoff probability. The former component means that VC_1 can avoid the investment cost altogether if the crowdfunding campaign proves unsuccessful. The latter component means that VC_1 might have an opportunity to invest when the crowdfunding campaign succeeds, despite not investing before crowdfunding. Nevertheless, the two components may have a *reduced* size in our model. For the former component, because of the reduction in the equity share after crowdfunding, by choosing to wait, VC_1 exposes itself to the event that the crowdfunding campaign succeeds, and, as a result, the startup secures K and offers a *smaller* equity share. In our model, the latter component is linked to the asymmetric beliefs of the two VC firms. As VC_1 possesses a more optimistic prior belief than VC_2, the likelihood of receiving a positive signal in the crowdfunding campaign according to VC_1's belief at time t_0 is greater than that according to VC_2's belief. As a result, VC_1 would contemplate the VC_2's pre- and post-crowdfunding chances of making a competitive offer and find the expected post-crowdfunding investment cost to be *higher* than the pre-crowdfunding investment cost if it chooses to strategically delay its investment to time t_1.

Next, we show that the value of waiting for VC_1 is significantly influenced by the initial equity share offered by the startup at time t_0. We encapsulate the impact of α on VC_1's investment strategy in the following proposition.

Proposition 2.

i. *At time t_0, VC_1 chooses to invest (i.e., $\Delta_1 \leq 0$) if and only if $\alpha \geq \alpha_0$, where*

$$\alpha_0 = \begin{cases} T_2 & \text{if } \tilde{e}_2|S \leq R_0/T_2, \\ T_1 & \text{otherwise,} \end{cases}$$

and

$$T_1 = \frac{R_0}{e_1 - P(S|p_1)\frac{R_0-K}{R_0}(\tilde{e}_1|S - \tilde{e}_2|S)},$$

$$T_2 = \frac{R_0 - P(S|p_1)(R_0 - K)}{e_1 - P(S|p_1)\tilde{e}_1|S\frac{R_0-K}{R_0}}.$$

ii. *If VC_1 chooses to wait, then, at time t_1, it invests if and only if the crowdfunding signal is S and $\alpha \geq R_0/(\tilde{e}_1|S)$ (or equivalently, $\alpha' \geq (R_0 - K)/(\tilde{e}_1|S)$).*

Proposition 2(i) shows that when the initially offered equity share α is high enough, VC_1 invests at the pre-crowdfunding time t_0. This result can be illustrated as follows. It is known that the marginal return of VC_1's investment (αe_1) increases with α. Although this advantage of securing a larger equity share of the startup is applicable to both the pre- and post-crowdfunding time epochs, such a benefit is smaller at time t_1 than time t_0 because of the following two reasons. First, VC_1 might opt not to invest upon receiving a negative signal at time t_1. Second, if the crowdfunding campaign collects funds of an amount of K, the investment requirement after the crowdfunding is reduced, leading to an equity share smaller than α. These two reasons explain why, with a sufficiently high α, VC_1 would prefer to invest before the crowdfunding.

Moreover, Proposition 2(ii) illustrates VC_1's investment strategy after the crowdfunding if it did not invest before the crowdfunding. On the one hand, when the crowdfunding campaign fails, VC_1 would not invest. This is because to ensure that VC_1, who ends up being less enthusiastic after observing signal F, invests, an exceedingly high equity share is necessary for its valuation to exceed the minimum funding requirement R_0. Moreover, according to Proposition 2(i), when the equity share is sufficiently high ($\alpha \geq \alpha_0$), VC_1 would have already invested before the crowdfunding. On the other hand, when the crowdfunding campaign is successful, similar to the analysis from the previous section, VC_1 chooses to invest if its valuation exceeds the minimum funding requirement, that is, $\alpha'\tilde{e}_1|S \geq R_0 - K$, which can be equivalently stated as $\alpha \geq R_0/(\tilde{e}_1|S)$.

Proposition 2 characterizes VC_1's investment strategies in terms of two minimum equity shares offered by the startup before and after crowdfunding. Comparing these two equity shares (i.e., the minimum equity share α_0 for VC_1's pre-crowdfunding investment and the minimum equity share $R_0/(\tilde{e}_1|S)$ for VC_1's post-crowdfunding investment with signal S), we obtain the following result.

Corollary 1. *We have: $\alpha_0 \geq R_0/(\tilde{e}_1|S)$.*

Corollary 1 says that the minimum equity share the startup gives up to the pre-crowdfunding investing VC firm is larger than that to the post-crowdfunding investing one, even if we do not account for a smaller funding

requirement after a successful crowdfunding campaign. This is because, to ensure VC_1's pre-crowdfunding investment rather than waiting, there is an incentive compatibility constraint. That is, VC_1 finds it more profitable to invest before crowdfunding than waiting to see the outcome of crowdfunding. This constraint has a higher bar than that to ensure VC_1's post-crowdfunding investment, which is an individual rationality constraint after a successful crowdfunding campaign. Thus, the startup needs to provide a higher equity share to attract pre-crowdfunding VC investment than that after successful crowdfunding.

We further investigate the threshold α_0, which characterizes VC_1's investment strategy at the pre-crowdfunding time t_0 given in Proposition 2.

Proposition 3. *We have that* (i) $R_0/e_1 \le \alpha_0 \le R_0/e_2$ *and* (ii) α_0 *decreases in* p_2.

The former part of Proposition 3(i), that is, $R_0/e_1 \le \alpha_0$, asserts that the minimum equity share required to induce pre-crowdfunding VC investment in the presence of crowdfunding exceeds the level needed in the absence of crowdfunding (recall that without crowdfunding, the startup secures VC investment if and only if $\alpha \ge R_0/e_1$). This implies that, with crowdfunding, VC_1 is motivated to postpone its investment decision, manifesting a "strategic delay" behavior. With crowdfunding, VC firms can amass more information about the startup by waiting and observing the crowdfunding outcome before committing to invest. This informational value of crowdfunding induces VC_1 to delay its investment decision strategically, which demands a larger equity share to induce pre-crowdfunding VC investment than that without crowdfunding.

The latter part of Proposition 3(i), that is, $\alpha_0 < R_0/e_2$, demonstrates that when the equity share α is sufficiently high such that VC_2's valuation exceeds the minimum funding requirement (i.e., $v_2 = \alpha e_2 \ge R_0$), given this equity share of α, VC_1 opts to invest at time t_0. Within this range of α where $\alpha e_2 \ge R_0$, two forces drive VC_1's pre-crowdfunding investment decision. First, post-crowdfunding, the attainable equity share for the VC firm might potentially diminish to a lower level α'. Second, as mentioned, owing to VC_1 possessing a more optimistic prior belief compared with VC_2, VC_1 holds a belief of a higher investment cost after the crowdfunding than before. Overall, Proposition 3(i) suggests that in order to induce pre-crowdfunding VC investment, the minimum equity share that the startup must offer is such that VC_1 is willing to invest more than the minimum funding requirement R_0, although not high enough for VC_2 to invest.

Proposition 3(ii) shows how VC_2's prior belief p_2 impacts the threshold α_0. When VC_2's prior belief p_2 is higher, the two VC firms' prior beliefs are more convergent. Then, the startup has a better outside funding option of VC_2 when negotiating with VC_1, resulting in a higher investment level (see (1)). As a result, Proposition 3(ii) demonstrates that as VC_2's prior belief gets closer to that of VC_1, VC_1 is inclined to postpone its investment decision, because of VC_2 becoming a more viable competitor after crowdfunding. Figure 1 illustrates the impact of p_2 on α_0. When p_2 is low enough such that $\tilde{e}_2|S \le R_0/T_2$, $\alpha_0 = T_2$ which does not depend on p_2 (see Proposition 2). That is, when VC_2 is sufficiently pessimistic, VC_1 effectively becomes the only VC funding option in the market, and therefore the interaction between the startup and VC_1 is independent of VC_2's prior belief.

5.2. Startup's Equity Offer Decision

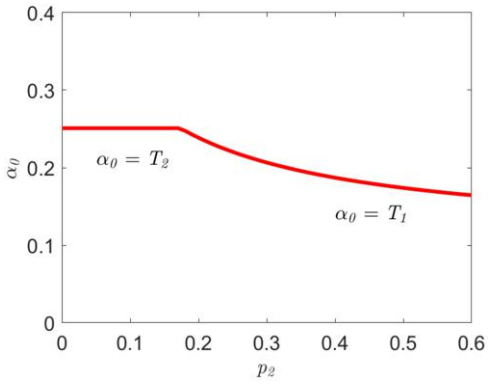
We now delve into the optimal equity share decision by the startup at time t_0. In anticipation of VC_1's optimal investment strategy (see Proposition 2), the startup solves the following optimization problem:

$$\max_{\alpha} \ \mathbb{I}_{\{\alpha_0 \le \alpha \le 1\}}(1-\alpha)e_a + \mathbb{I}_{\{\frac{R_0}{\tilde{e}_1|S} \le \alpha < \alpha_0\}}\left(1 - \frac{R_0 - K}{R_0}\alpha\right)\tilde{e}_a|S \cdot P(S|p_a).$$

According to Proposition 2, the first $\mathbb{I}$ operator signifies that to induce VC investment before crowdfunding (i.e., at time t_0), the startup should set the equity share as $\alpha \ge \alpha_0$, where α_0 is the minimum equity share the startup offers to induce pre-crowdfunding VC investment (see Proposition 2). With pre-crowdfunding VC investment, the expected payoff for the startup with respect to its own belief is $(1-\alpha)e_a$. Consequently, when the startup's intention is to induce the VC firms' preemptive investment, it sets $\alpha = \alpha_0$, which is the lowest equity share to induce a pre-crowdfunding VC investment.

The second $\mathbb{I}$ operator accounts for the startup's strategy of encouraging post-crowdfunding VC investment.

Figure 1. (Color online) The Effect of VC_2's Prior Belief p_2 on the Minimum Equity Share α_0 to Induce VC_1's Pre-crowdfunding Investment



Note. The parameter values are as follows: $R_s = 100, R_f = 2, R_0 = 10, K = 1, p_1 = 0.6$, and $\rho = 0.5$.

Specifically, when the equity share is set below α_0, VC_1 opts to delay the investment. By Proposition 2(ii), VC_1 will only invest after crowdfunding if the crowdfunding campaign is successful and the equity share is large enough, that is, $\alpha \geq R_0/(\tilde{e}_1|S)$. After a successful crowdfunding campaign, because of a smaller funding requirement, the startup's offered equity share is reduced to α'. Meanwhile, the startup updates its belief of the entire project's revenue to $\tilde{e}_a|S$. Moreover, the startup's expected payoff if it induces VC_1 to wait can be expressed as $(1-\alpha')\tilde{e}_a|S \cdot P(S|p_a)$, where $P(S|p_a)$ is the likelihood that the crowdfunding campaign is successful with respect to the startup's belief. As before, the startup sets the equity share at the minimum level, that is, $R_0/(\tilde{e}_1|S)$, to ensure post-crowdfunding investment after a successful crowdfunding campaign.

To summarize, when determining the equity share, the startup has two options. One is to offer a high equity share (i.e., $\alpha = \alpha_0$) to incentivize VC_1 to make a preemptive investment at time t_0, with the startup's anticipated payoff denoted by π_a as

$$\pi_a = (1-\alpha_0)e_a.$$

The other option is to offer a low equity share (i.e., $\alpha = R_0/(\tilde{e}_1|S)$) to induce VC_1's post-crowdfunding investment after a successful crowdfunding. The equity share being low in the latter option has two aspects. The first is that because of the VC firms' strengthened beliefs in the startup's success after successful crowdfunding, the equity share to attract such post-crowdfunding VC investment is lower than that to attract pre-crowdfunding investment (see Corollary 1). The second aspect is that because of a smaller funding requirement after a successful crowdfunding campaign, the equity share α is further reduced to α'. This is driven by a key advantage of reward-based crowdfunding: the startup secures pledged funds from a fan base without giving up equity. Thus, to attain the same required investment amount, the startup only needs to offer a smaller equity share to the VC firms. The payoff associated with the option of offering a low equity share denoted by $\tilde{\pi}_a$, with a possibility that the startup might not secure any VC investment because of a negative crowdfunding outcome, is given by

$$\tilde{\pi}_a = \left(1 - \frac{R_0 - K}{\tilde{e}_1|S}\right)\tilde{e}_a|S \cdot P(S|p_a).$$

The startup's optimal equity share decision with crowdfunding, α^c, is formally provided in the following proposition.

Proposition 4. *The startup sets the optimal equity share α^c as follows:*

$$\alpha^c = \begin{cases} \alpha_0 & \text{if } \Delta_a \leq 0, \\ R_0/(\tilde{e}_1|S) & \text{if } \Delta_a > 0, \end{cases}$$

where $\Delta_a = \tilde{\pi}_a - \pi_a$ is the value of waiting for the startup.

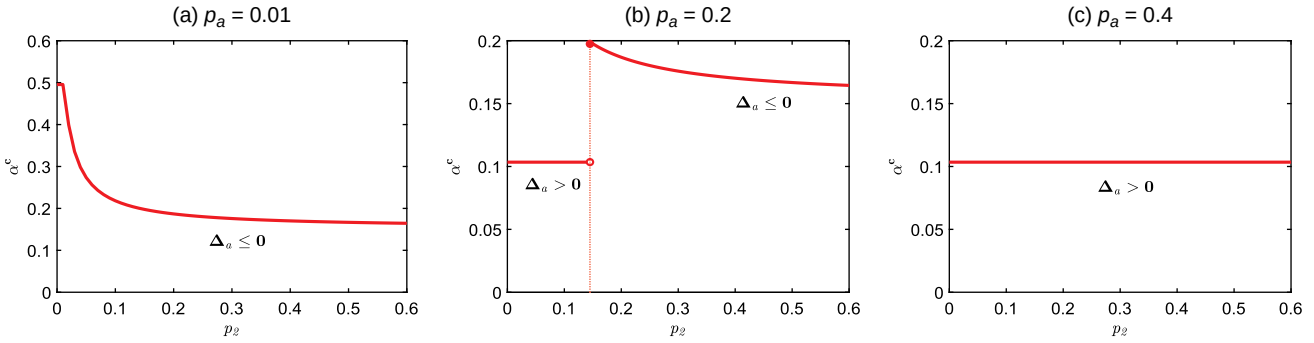
The optimal equity share, α^c, is affected by various parameters. Because of the complexity, in the main text, we primarily focus on discussing the impact of p_2, which captures whether the VC firms' beliefs are divergent. The impacts of other parameters (e.g., the crowdfunding target K and the crowdfunding signal's accuracy ρ) are discussed in Online Appendix C.

Proposition 5. *The value of waiting for the startup, Δ_a, decreases in p_2.*

Proposition 5 says that when the VC firms' beliefs are more convergent, the value of waiting for the startup is lower. Proposition 5 can be explained as follows. According to Proposition 3(ii), when the VC firms' beliefs are more convergent, the startup only needs to offer a smaller equity share to induce the VC firms' preemptive investment. Therefore, the startup's expected payoff under a preemptive investment increases in p_2. In contrast, when VC_1 chooses to delay, the post-crowdfunding equity share, that is, $R_0/(\tilde{e}_1|S)$, remains unaffected by p_2. Thus, the startup's expected payoff under a post-crowdfunding investment remains independent of p_2. As a result, for the startup, the value of waiting decreases when VC_2's belief gets closer to that of VC_1, implying that the startup is more likely to encourage the VC firms' preemptive investment with the threat of launching a crowdfunding campaign.

Now we continue to explore how p_2 impacts the optimal equity share offered by the startup, α_c. By Proposition 4, the optimal equity share equals either the minimum equity share that induces pre-crowdfunding investment (i.e., $\alpha^c = \alpha_0$, which decreases in p_2) or the minimum equity share that induces post-crowdfunding investment (i.e., $\alpha^c = R_0/(\tilde{e}_1|S)$, which is independent of p_2), depending on the value of waiting for the startup. Furthermore, by Proposition 5, the value of waiting for the startup also decreases in p_2. Thus, there are three cases of how the optimal equity share depends on p_2, which are illustrated in Figure 2. The first case is shown in Figure 2(a); that is, the startup chooses $\alpha^c = \alpha_0$ because it prefers a pre-crowdfunding VC investment (i.e., $\Delta_a \leq 0$). Thus, we observe that when VC_2's belief is closer to VC_1's, the startup's offered equity share decreases. Kagan et al. (2021) show that the startup offers a lower equity share to competing investors than to a single investor, which is consistent with our first case. That is, in our setting, when the startup determines to induce the VC firms' pre-crowdfunding investment, the offered equity share when p_2 is low enough such that VC_1 is effectively a sole potential investor (as VC_2 is too pessimistic) is higher than that when p_2 is large enough and VC_2 becomes a viable competitor. Figure 2(b) illustrates the second case. When the VC firms' prior beliefs become more convergent, the startup's offered equity share is nonmonotone in p_2, with a jump

Figure 2. (Color online) The Effect of VC_2's Prior Belief p_2 on the Startup's Optimal Equity Share α^c



Note. The parameter values are as follows: $R_s = 100, R_f = 2, R_0 = 10, K = 1, p_1 = 0.6$, and $\rho = 0.9$.

from $\alpha^c = R_0/(\tilde{e}_1|S)$ to $\alpha^c = \alpha_0$ as the startup's timing preference shifts from post-crowdfunding to pre-crowdfunding (i.e., from $\Delta_a > 0$ to $\Delta_a \le 0$). Figure 2(c) shows the third case. The startup sets $\alpha^c = R_0/(\tilde{e}_1|S)$ that is independent of p_2 because it prefers a post-crowdfunding VC investment (i.e., $\Delta_a > 0$).

Figure 2 also shows that the first case takes place when the startup's prior belief on its success, p_a, is low enough, whereas the second and third cases take place when this belief is relatively moderate and high, respectively. We can theoretically prove that when the startup holds a more optimistic belief, case (b) is more likely to occur than case (a); meanwhile, case (c) is more likely to occur than case (b). This is because, with a more optimistic prior belief, the startup expects a higher opportunity to experience a successful crowdfunding outcome, which makes its expected payoff after crowdfunding higher than that before crowdfunding. Therefore, the startup is more likely to set a low equity share to induce the VC firms to delay investment and then start a crowdfunding campaign. The proof is provided in Online Appendix D.

6. Crowdfunding Effects

So far, we have obtained the optimal decisions of the VC firms and the startup with and without the crowdfunding option. In this section, we will proceed to explore the effects of crowdfunding on VC investments. More specifically, we will analyze these effects in terms of (1) the equity share offered by the startup and (2) the expected VC investment level by comparing two scenarios: one with the option of crowdfunding and one without. These two metrics are important performance metrics for VC investments. The equity share measures how much control the startup gives up to obtain VC investments, and the expected VC investment level measures the scale of the VC investments. In Online Appendix B, we also analyze the crowdfunding effects on the startup and the VC firms' profitability.

6.1. Equity Share

The equity share measures the portion of the startup owned by the investing VC firm. Through this equity share, the investing VC firm not only benefits from the startup's profits but also influences the startup's business decisions. Therefore, our interest lies in understanding how crowdfunding impacts the equity share offered to the investing VC firm. This helps shed light on whether crowdfunding strengthens or weakens the control that VC firms exert over startups. Though we have discussed the optimal equity share in Propositions 1 and 3, we now formally show how crowdfunding affects the equity share offered by the startup to the investing VC firm. When comparing the equity shares with and without the option of crowdfunding, we assume that $e_1 \ge R_0$, because there is no VC investment without crowdfunding if $e_1 < R_0$.

Corollary 2. *If $e_1 \ge R_0$, the crowdfunding option raises (respectively, reduces) the equity share the startup offers to the investing VC firm when $\Delta_a \le 0$ (respectively, $\Delta_a > 0$). Otherwise, if $e_1 < R_0$, there is no VC investment without crowdfunding.*

Corollary 2 compares the equity shares with and without the option of crowdfunding. When the startup decides to encourage the VC firms' preemptive investment (i.e., $\Delta_a \le 0$), it needs to offer a higher equity share than what would be required without crowdfunding to prevent a strategic investment delay by VC_1 until post-crowdfunding. Conversely, if the startup aims to induce a delay by VC_1, it would set a lower initial equity share compared with that without crowdfunding. This is because, after crowdfunding, the offered equity share only needs to ensure VC_1's investment under a successful crowdfunding campaign. Given that the VC firm's updated belief after a successful crowdfunding campaign is boosted from its prior belief, the offered equity share needed to induce an investment is lower with crowdfunding than without. Corollary 2 implies that the crowdfunding option may either enhance or

diminish the control of the investing VC firm over the startup. This outcome hinges on whether the VC investment occurs before or after the crowdfunding campaign.

6.2. VC Investment Level

We proceed to compare the expected VC investment levels with respect to the unconditional belief (i.e., $P(\theta = s) = P(\theta = f) = 1/2$) with and without the crowdfunding option. We encapsulate this comparison in the following proposition.

Proposition 6. *If $e_1 \geq R_0$ and $\Delta_a > 0$, the crowdfunding option reduces the expected VC investment level. Otherwise, if $e_1 < R_0$ or $\Delta_a \leq 0$, the crowdfunding option raises the expected VC investment level.*

Proposition 6 demonstrates that the crowdfunding option reduces the expected VC investment level when VC_1's prior belief is sufficiently optimistic to trigger an investment even without crowdfunding (i.e., $e_1 \geq R_0$), yet the firm chooses to delay the investment decision after crowdfunding (i.e., $\Delta_a > 0$). Conversely, crowdfunding enhances the expected VC investment level in the rest of the cases. Proposition 6 can be explained as follows. In the absence of crowdfunding, a startup secures VC investment when the more optimistic VC firm finds it profitable to invest (i.e., $v_1 \geq R_0$). If the condition $e_1 \geq R_0$ holds, the startup sets the equity share as low as possible to just fulfill the minimum funding requirement (i.e., setting $\alpha = R_0/e_1$). As a result, the investment level matches the minimum funding needs of R_0. Conversely, if $e_1 < R_0$, the startup never receives a VC investment because even the more optimistic VC firm does not think the investment is profitable, even if the startup gives up all of its equity. However, in the presence of the crowdfunding option, on the one hand, the startup receives a pre-crowdfunding VC investment under a negative value of waiting (i.e., $\Delta_a \leq 0$). Because the startup's offered equity share that induces pre-crowdfunding VC investment is larger than the one that ensures VC investment without crowdfunding (see Proposition 3(i)), the VC firms' valuations are also higher with crowdfunding than without. This further leads to a higher VC investment level with crowdfunding than without. On the other hand, if the value of waiting for the startup is positive (i.e., $\Delta_a > 0$), the startup receives a VC investment only if the crowdfunding campaign is successful, that is, a collection of a K amount of funding through the campaign. This leads to a post-crowdfunding VC investment of the amount of $R_0 - K$ (with a successful crowdfunding campaign) or zero (with a failed crowdfunding campaign), both of which are less than the startup's collected funding in the absence of the crowdfunding option. Therefore, when VC_1's prior belief is optimistic enough to launch investment even without crowdfunding (i.e., $e_1 \geq R_0$) but the startup opts to delay the VC fundraising with the option of crowdfunding (i.e., $\Delta_a > 0$), the crowdfunding option decreases the startup's chance of receiving a VC investment and also the expected VC investment received but allows the startup entrepreneur to retain more equity share.

Proposition 6 speaks to the central research question of this paper, namely, how the presence of crowdfunding impacts VC investments. As discussed in Section 2, earlier papers, such as Sorenson et al. (2016) and D'Ambrosio and Gianfrate (2016), have empirically examined the correlation between crowdfunding and VC investments at an aggregated level. Here, we aim to ascertain whether our theoretical findings at an individual startup level can be used to explain the empirical observations outlined in these earlier studies.

Sorenson et al. (2016) show that an increase in crowdfunding campaigns in a region is associated with a subsequent rise in VC investment campaigns in the following years in the same region.[4] Our theoretical analysis suggests that this phenomenon can be driven by those startups that cannot secure a VC investment without crowdfunding but manage to attract VC firms' attention after a successful crowdfunding campaign (i.e., when the condition $e_1 < R_0$ in Proposition 6 holds). For instance, Roma et al. (2018) note that Pebble Technology's founder was initially rejected by VC firms but secured VC investment after a remarkably successful crowdfunding campaign. Through a case study, Bessière et al. (2020) report that the success of an initial reward-based campaign acts as an accreditation mechanism to signal the project's intrinsic quality for future shareholders.

However, D'Ambrosio and Gianfrate (2016) find the opposite of this positive relationship between crowdfunding and VC investments. The authors discover that an increase in crowdfunding today leads to decreased future VC seed funding. They attribute this outcome to crowdfunding as a substitute for VC investments in seed financing. We complement their observation by offering a plausible explanation for the negative relationship between crowdfunding and subsequent VC investments, even when crowdfunding is not a complete substitute for VC investments. That is, launching a crowdfunding campaign may hurt those startups that have a high likelihood of attracting a VC investment even without the crowdfunding option because a successful campaign results in a reduced VC funding amount, whereas an unsuccessful campaign leads potential VC investors to withdraw their investment interest (i.e., when the conditions of $e_1 \geq R_0$ and $\Delta_a > 0$ in Proposition 6 hold).[5]

Furthermore, in our theoretical results, we also show that the presence of crowdfunding can raise more funding through a VC's preemptive investment in anticipation of a potential crowdfunding campaign (i.e., when

the condition $\Delta_a \leq 0$ in Proposition 6 holds). Because such a VC investment takes place without a crowdfunding campaign ever being initiated, this impact of crowdfunding on VC investments is not captured by the empirical design of Sorenson et al. (2016) and D'Ambrosio and Gianfrate (2016). As discussed earlier, they analyze the relationship between crowdfunding and *subsequent* VC investments. Through our theoretical model, we unveil that crowdfunding can also influence *pre*-crowdfunding VC investments. Specifically, anticipating the startup will start a crowdfunding campaign, a potential VC firm is forced to make a big investment before the campaign. As a result, no crowdfunding activity is observed, but the startup secures more VC funding than without a crowdfunding platform. Investigating the crowdfunding effect on pre-crowdfunding investments poses challenges for empirical research, but we believe that a well-designed case study could provide evidence for such an effect.

7. Conclusions

Inspired by the empirical interplay between crowdfunding and VC investments, our theoretical model explores the impact of crowdfunding access on competing VC investments. Crowdfunding not only offers a source of funding for startups but also acts as a barometer of public opinion for investors, including VC firms. The additional insight provided by crowdfunding campaigns might lead VC firms to defer investment decisions until after the campaign's results are known. However, such strategic delays due to the presence of crowdfunding are tempered by the competitive dynamics among VC firms.

Our analysis distinguishes scenarios with and without access to crowdfunding, identifying conditions that influence the startup's equity offer and investment received. Although entrepreneurs usually prefer to maintain control, the availability of crowdfunding may lead them to offer a larger equity share to secure a higher VC investment preemptively, sometimes forgoing the crowdfunding option. We also align our findings with those from empirical studies on crowdfunding and VC investments, offering firm-level perspectives. First, we note that the positive correlation observed between crowdfunding and subsequent VC investments often reflects the situation of startups that would struggle to secure VC funding without crowdfunding platforms. Second, we present a negative result for startups that might lose potential VC investment after an unsuccessful crowdfunding campaign. Third, empirical studies tend to focus on the effects of actual crowdfunding campaigns; our model also considers the influence of the mere option of crowdfunding on preemptive VC investments, highlighting a dynamic not directly observable in empirical data. This could be investigated through targeted case studies.

Our study is not without limitations. We assume VC firms' prior beliefs are public knowledge for simplicity, whereas, in reality, they may be private. We also simplify the funding landscape, considering only crowdfunding and VC investments, excluding other sources such as bank loans. Furthermore, we postulate that startups cannot initiate crowdfunding after receiving a VC investment, ignoring the possibility of using crowdfunding to supplement insufficient VC funds. Lastly, we do not delve into the startup-crowdfunder relationship, which could further influence campaign parameters such as the funding target, potentially signaling the startup's prospects. These limitations present opportunities for future research to build upon our findings.

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Endnotes

[1] See https://vc-list.com/vcs-using-crowdfunding-vet-deals/.

[2] See https://crowdsourcingweek.com/blog/crowdfunding-and-venture-capital-working-together/.

[3] A term sheet is a bullet-point document outlining the material terms and conditions of a potential business agreement, establishing the basis for future negotiations between a seller and buyer (Wikipedia, https://en.wikipedia.org/wiki/Term_sheet).

[4] In their research, the authors utilize the number of crowdfunding campaigns and VC investment rounds as indicators of crowdfunding and VC investment activities. In the supplemental material of their paper, they also use the dollars collected from these campaigns to represent these activities. In a private communication, one of the authors told us that the reason to use the number of campaigns is that the dollar amounts of investments fluctuate significantly across the campaigns.

[5] Sorenson et al. (2016) and D'Ambrosio and Gianfrate (2016) present diverging empirical results regarding the relationship between crowdfunding and VC investments. Several factors could contribute to these discrepancies. For instance, whereas Sorenson et al. (2016) use the number of campaigns as a measure, D'Ambrosio and Gianfrate (2016) adopt the dollar amounts of investments. Although Sorenson et al. (2016) adjust the measures in their supplementary materials, they do not control other variables as they do in the main paper. Furthermore, Sorenson et al. (2016) focus on VC investments made in seed and early stages, whereas D'Ambrosio and Gianfrate (2016) concentrate on seed investments. Lastly, Sorenson et al. (2016) base their analysis on yearly data, whereas the analysis of D'Ambrosio and Gianfrate (2016) relies on monthly data.

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