Raising capital under demand uncertainty *

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Abstract

We study an environment where an entrepreneur seeks capital to finance the development of a new product whose future demand is uncertain. We explore how the entrepreneur can capitalize on information produced by potential investors. Under the optimal contract (i) investors take their backing decisions sequentially, and (ii) the project is financed only if it receives enough financial support; otherwise, the entrepreneur does not raise capital. Our work provides testable insights for security-based crowdfunding (CF) that help us understand its economic value and the conditions under which it can be a valuable method of financing. We argue that CF can be a valuable alternative to VC when it comes to seed financing, but at a later stage, CF and VC can work hand-in-hand.

JEL Classification: D82, D83, and G32

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1 Introduction

Raising capital via crowdfunding platforms (CFPs) has become increasingly popular,[1] with the amount of capital raised in 2015 exceeding \$10 billion and the size of the addressable market estimated at \$1.2 trillion.[2] In 2016, crowdfunding (CF) received an additional boost by JOBS Act, which created an exemption under the federal securities laws so that CF can be used to offer and sell securities to the general public. CF has attracted growing interest from scholars and practitioners not only because it is becoming one of the main sources of seed financing, but also because it differs significantly from the traditional methods of raising capital. A key distinction is that the creditworthiness of a project is determined mainly by non-professional investors who lack expertise in evaluating investment opportunities or providing business advice. Another difference is that the capital-raising process is facilitated by an online platform. These unique characteristics imply that applying the insights of conventional methods of financing to CF is not straightforward. First, it is not obvious what the optimal capital-raising process in CFPs is. In practice, the capital-raising process seems to vary from platform to platform. Second, it is not clear how CFPs can create economic value. For instance, in contrast to traditional intermediaries like banks, CFPs do not select projects; this is done by the crowd. Answering these questions can help us understand which type of agents and projects would find CF attractive, and when CF can be a valuable alternative to other sources of financing.

We explore the problem of a cashless entrepreneur who seeks capital to finance the development of a new product whose future demand is uncertain. What lies at the heart of this paper is that demand uncertainty can be alleviated by learning through market participants who can invest in the project; importantly, the entrepreneur can capitalize on information produced by the market to improve her financing terms. However, achieving that is a challenging task. First, market participants are not necessarily endowed with useful information; in fact, the lack of relevant expertise implies that learning about the prospects of a product is costly and rather

[1]The number of platforms exceeds 2,200, with presence in 191 countries (Rau, 2020).

[2]*The Future of Finance - The Socialization of Finance* (Goldman Sachs, 2015). The size of the addressable market is based on the combination of the most popular sources of funding for small business owners, such as bank card loans, home equity loans, venture capital, and angel investors.

marginal. In addition, information acquisition involves strategic complementarities; this can lead to free-riding incentives, which hurt information production.

The contribution of this paper is twofold. First, we show how to optimally design the capital-raising process that allows the entrepreneur to coordinate the behavior of self-centered investors and maximize profits. Second, we produce testable insights for CF and CFPs that help us understand under what conditions CF can be a valuable method of financing.

In short, we find that the optimal capital-raising process features sequential backing decisions by investors and an All-or-Nothing (AON) financing rule. Second, we show that CF can create economic value by aggregating information about future demand and alleviating the problem of under-financing, which is of first-order importance for entrepreneurs and small businesses (Carpenter and Petersen, 2002; Cosh, Cumming, and Hughes, 2009). Third, we argue that CF can be attractive for startups and retail investors who have limited commitment power. Finally, our study indicates that CF can be a valuable alternative to VC when it comes to seed financing, but at a later stage, CF and VC can work hand-in-hand.

Our model consists of two types of risk neutral players: an entrepreneur and a mass of investors. The entrepreneur is cashless and seeks capital to finance the development of a product. The return of the investment depends on the uncertain future demand for the underlying product. Investors have access to costly, imperfect, and conditionally independent signals about the future demand for the product. Investors' private information consists of the signal acquisition and its realization. We focus on the case where the project becomes creditworthy as long as at least two investors observe signals indicating high future demand. The underlying rationale is twofold. First, it captures the idea that consumers are reluctant to adopt new products (status-quo bias). Second, it reflects the idea that, due to lack of expertise, each individual's information is incremental. Thus, the optimal capital-raising process should provide a mechanism that allows self-centered investors to coordinate. An important insight is that if access to information is costly, even if agents move sequentially, learning from peers might *help instead of hurt* information production. This finding is the opposite to the information cascade idea (Banerjee, 1992; Welch, 1992; Bikhchandani, Hirshleifer, and Welch, 1992).

The first two features of the optimal capital-raising process are that (i) investors take their backing decisions sequentially, and (ii) financing goes through only if the project receives enough financial support; otherwise, the capital-raising process is terminated with the entrepreneur not raising any funds. Therefore, the optimal contract exhibits an AON feature. The sequential feature alleviates over-production of information and allows the entrepreneur to use favorable information produced by early investors to attract late investors (*beliefs boosting channel*). The AON feature protects investors against financing a negative-NPV project (*insurance channel*); thus, the AON feature allows the entrepreneur to use favorable information produced by late investors to attract early investors. The intuition is that for an entrepreneur of a product of unknown quality, it is easier to attract an investor when the latter knows that: i) more investors are already on board (*beliefs boosting channel*); and ii) the project is financed only if more investors join (*insurance channel*).

The third feature of the optimal capital-raising process regards the target of financial support that the project needs to reach to be financed. The latter can be measured by the number of investors backing the project. We show that the AON feature can facilitate information production only if it is accompanied by the *right* target of financial support. If this target is too high, each investor has an incentive to back the project without acquiring information. This is because each investor believes that if the project receives enough support, it must have a positive NPV; thus, acquiring an additional (costly) signal is not valuable. Such free-riding incentives could lead to information acquisition breakdown. In contrast, if the financing target is too low, the project never becomes creditworthy; thus, no one is willing to invest.

Summing up, our model generates two key empirical implications regarding the platform design. First, in security-based CFPs, the total backing amount and the number of backers should be publicly observable, and the backers should take their backing decisions sequentially. Second, in security-based CFPs, the AON rule where the financing target is set at the beginning of the campaign dominates the Keep-it-All (KIA) rule.[3] Both implications find empirical support (Schwienbacher, 2019; Cumming, Leboeuf, and Schwienbacher, 2020).

[3]The KIA rule implies that the entrepreneur keeps the entire pledged amount regardless of whether or not the capital raising goal is reached.

The second part of the paper explores the insights of our model for (i) the economic value of CF, (ii) the type of economic agents and projects that would find CF attractive, and (iii) the relative advantages of CF compared to other methods of financing.

A crucial assumption in the analysis is that investors can commit to their backing amounts, and the entrepreneur can commit to raising capital from backers only if the project receives enough financial support. Lack of commitment has a detrimental role in financing opportunities of socially valuable projects. This lack of commitment can be alleviated by CFPs, which can allow the market to determine whether a project is creditworthy and lead to the financing of positive-NPV projects that would not be financed otherwise. This channel is consistent with Mollick and Nanda (2015) who provide evidence that CF can play an important role by allowing projects to receive multiple evaluations that decrease the incidence of a "false negative". In addition, we show that when the entrepreneur is cashless, CF might be the only way to learn about future demand for the underlying product.

Our work generates a set of empirical implications for CF and CFPs. First, CFPs can be an attractive alternative for startups and retail investors who might have limited commitment power (Hervé, Manthé, Sannajust, and Schwienbacher, 2019; Block, Colombo, Cumming, and Vismara, 2018). Second, CF has a comparative advantage in early stages of the development of new products, for which demand uncertainty is more prominent and information production by market participants is more valuable (Walthoff-Borm, Vanacker, and Collewaert, 2018). Third, CF could be a substitute to VC when it comes to seed financing. However, *testing the waters* via CFPs could allow the entrepreneur to signal the potential of her product to a VC. Thus, once we focus on a longer horizon, CF and VC can work hand-in-hand. The latter is supported by Hornuf and Schmitt (2017), and Signori and Vismara (2018) who show that it is common for crowdfunded startups to receive follow-up funding from professional investors. Two examples are Oculus Rift and Revolut. Oculus Rift raised $2.4 million on Kickstarter in 2012. The latter attracted the attention of VCs, who provided $75 million in 2013. Finally, Oculus Rift was acquired by Facebook for $3 billion in 2014. Similar, Revolut raised £1 million on Crowdcube in 2016 and was later backed by Index Ventures and its valuation exceeds $5.5 billion in 2020.

Related Literature. This paper pertains to the literature following the seminal papers of Banerjee (1992), Welch (1992), Bikhchandani et al. (1992), and Smith and Sørensen (2000) on herding and information cascade. The herding incentives are studied also by Åstebro, Fernández Sierra, Lovo, and Vulkan (2017), who provide evidence of rational herding in CF. We contribute to this literature in four dimensions. First, agents are not endowed with private information and information acquisition is costly. This creates new insights; learning from peers might *help instead of hurt* information aggregation, which is the opposite to information cascade. Second, the order in which agents move is endogenously determined, which allows us to capture the agents' incentives to move late and free-ride on their peers' information. Third, in our setting, each agent's payoff is realized *after* all agents take their decisions; thus, each agent affects *and* gets affected by the actions of agents who move later. This feature differentiates us from the literature on dynamic experimentation (Glazer, Kremer, and Perry, 2015). Fourth, in our setting, there is a principal whose implicit goal is to gather and communicate information.

We pertain to the literature studying the behavior of potentially informed investors. Our setting is close to Axelson (2007) and Axelson and Makarov (2016), but as opposed to these studies, information is costly. Similar to our paper, in Axelson and Makarov (2016) investors are approached sequentially, but in our setting, the project is financed by multiple investors. This allows us to shed light on the information complementarities between investors, and explore the dynamics of the problem. The interaction between firms and informed market participants is also studied in Boot and Thakor (1993), Allen and Gale (1999), Goldstein and Guembel (2008), Bond, Edmans, and Goldstein (2012), and Terovitis and Vladimirov (2020).

Our work contributes to the growing literature on CF. A key feature of CF is the AON rule. Chemla and Tinn (2020), who focus on reward-based CF, show that an AON feature might alleviate the moral hazard problem. A similar setting is studied by Strausz (2017). We differ from these papers and Kumar, Langberg, and Zvilichovsky (2020) as we focus on the investment rather than the consumption motives of backers.[4] Also, the value of the underlying product/project is common. Finally, information acquisition is costly, which allows us to

[4]Cholakova and Clarysse (2015) and Vismara (2018) show that participants in security-based CFPs are driven mostly by financial motivations.

capture the impact of the AON feature on free-riding incentives. Brown and Davies (2020), in a security-based CF setting, show that the AON feature might be responsible for investors backing the project even when having negative information. This negative externality of the AON feature arises in our setting as well, but the entrepreneur finds it optimal to prevent it. A key difference compared to Brown and Davies (2020), Strausz (2017), Chemla and Tinn (2020), Kumar et al. (2020) and Li (2017) is that we explore a setting where agents take their backing decisions sequentially, which is a fundamental characteristic of CF. Apart from the fact that the sequential feature arises endogenously, focusing on a setting where agents move sequentially allows us to explore the dynamics in the agents' incentives to acquire information.

Similar to our work, Cong and Xiao (2019) highlights the insurance aspects of the AON feature. A key difference is that in our setting investors are not endowed with private information, and they have to be incentivized to gather costly signals. Thus, we focus not only on information aggregation but also on information production, which allows us to show that learning from peers could, in fact, encourage information acquisition. The latter has important implications for the entrepreneur who can capitalize on this feature to improve her financing terms. Furthermore, in contrast with Cong and Xiao (2019), in our setting investors choose when to move. The latter is crucial because it allows us to incorporate a fundamental characteristic of CF, namely, the agents' incentive to move late and benefit from their peers' information (Hornuf and Schwienbacher, 2018; Åstebro et al., 2017). Finally, we show that when information acquisition is costly, an information cascade never arises under the optimal contract.

Finally, this work relates to the literature on book-building in IPOs, following Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990). Our paper is closer to Sherman and Titman (2002), but there are two crucial differences: the focus and the timing. Our focus is on how the entrepreneur can capitalize on information produced by investors to maximize profits, whereas Sherman and Titman (2002) focus on the implications of book-building for underpricing. Also, in our setting investment decisions are sequential and investors observe the actions of preceding investors. This setting not only better represents the capital-raising method in CFPs, but importantly, it arises endogenously as part of the optimal contract.

2 Model

2.1 Model Description

Environment. We explore an environment that consists of a risk neutral entrepreneur and a mass of risk neutral investors. The entrepreneur is cashless and aims to raise capital I to finance the development of a new product that generates a cash flow, R. The realized cash flow depends on the level of future demand, θ, which is either high ($\theta = H$) or low ($\theta = L$). If future demand is high, the cash flow is $R = 1$, whereas if future demand is low, the cash flow is $R = 0$. A key feature of the model is that future demand is unknown. We denote as p_0 the ex-ante probability that demand is high, where p_0 is common knowledge.

Information Technology. Investors have access to a costly information production technology.[5] Each investor, by incurring cost c, can acquire a signal σ. The signal is either good ($\sigma = \sigma_G$) or bad ($\sigma = \sigma_B$), where $Pr(\sigma = \sigma_G|\theta = H) \equiv s_G > s_B \equiv Pr(\sigma = \sigma_G|\theta = L)$. Thus, a good (bad) signal increases (decreases) the posterior beliefs that future demand is high. We assume that investors' signals are conditionally independent.

Assumption 1: *The signal acquisition and realization is investor's private information.*

Assumption 2: *Each investor can acquire up to one signal, whereas, for the project to have a positive NPV, at least $k \geq 2$ good signals are required, i.e., $p_k - I > 0$ and $p_{k-1} - I < 0$, where $p_k = Pr(\theta = H|\sigma_1 = \sigma_G, ..., \sigma_k = \sigma_G)$.*[6]

Assumption 1 implies that neither the entrepreneur nor other investors can observe i) whether an investor has gathered information, and ii) the evidence the investor has collected.[7]

The rationale behind Assumption 2 is twofold. First, it captures the idea that the information of each investor is incremental.[8] Second, it reflects the idea that, consistent with the

[5]This assumption differentiates us from Cong and Xiao (2019) and the main strand of the literature building on Banerjee (1992) and Welch (1992), which assumes that agents are endowed with private information.

[6]Therefore, k is the lowest natural number satisfying $\frac{p_0 s_G^k}{p_0 s_G^k + (1-p_0) s_B^k} > I$. We focus on the interesting case where gathering k signals is socially valuable. As it becomes clear by Definition 1, the latter is the case when $[p_0 s_G^k + (1-p_0) s_B^k][\frac{p_0 s_G^k}{[p_0 s_G^k + (1-p_0) s_B^k]} - I] - c\Sigma_{j=1}^k [p_0 s_G^{j-1} + (1-p_0) s_B^{j-1}] \geq 0$.

[7]This is particularly applicable to CF, where there is limited interaction among the parties involved.

[8]CFPs are dominated by retail investors with limited expertise at evaluating projects (Block et al., 2018).

status-quo bias, consumers are reluctant to adopt new products.[9] Therefore, unless favorable information is observed, investing in the development of a new product has a negative NPV. Assumptions 1 and 2 allow us to shed light on the information complementarities among investors, and explore the implications for the capital-raising process.

Actions. The entrepreneur designs the contract offered to potential investors. Conditional on accepting it, each investor i chooses (i) whether to acquire information, (ii) whether to back the project, and (iii) the backing amount. We denote as $d_i = B_i$ the case where agent i backs the project and as $d_i = N_i$ the case where agent i decides not to back the project. It is critical to highlight that *backing* the project does not necessarily imply *investing* in the project. *Backing* the project means that an agent commits to investing in the project as long as the predetermined conditions are fulfilled. Those conditions are specified in the contract.

Contracting. We start by exploring contracts that allow potential investors to move sequentially. We assume that each agent observes the backing decisions of preceding agents. This assumption is without loss; the entrepreneur would always have an incentive to disclose it when an agent backs the project, because the latter reflects favorable information about the product demand.[10] In Section 3.2 we explore the case where potential investors move simultaneously; the optimality of allowing investors to take their backing decision sequentially or simultaneously remains to be determined in equilibrium.[11] We assume competitive capital markets, where investors' outside option is normalized to zero. Also, there is no time discounting. Consistently with the assumptions above, we focus on take-or-leave-it contracts.

In the sequential-move setting, the history at period t, denoted as $\mathcal{H}_t$, reflects the backing decisions of the agents who moved in periods 1 to $t-1$. Besides, $\mathcal{H}$ denotes the set of all possible histories. In this environment, the contract consists of three components. First, the contract

[9]The status-quo bias is discussed thoroughly in Kahneman, Knetsch, and Thaler (1991), Samuelson and Zeckhauser (1988), Burmeister and Schade (2007), and Dean, Kıbrıs, and Masatlioglu (2017).

[10]The implicit assumption is that agents know their position in the line (order of moving). This assumption is consistent with Banerjee (1992), Bikhchandani et al. (1992), and Cong and Xiao (2019).

[11]This differs from Brown and Davies (2020), Strausz (2017), Chemla and Tinn (2020), Li (2017), Kumar et al. (2020), and Sherman and Titman (2002), where investors take their decisions simultaneously. Sequential backing decisions not only better represents the capital-raising method in CFPs, but as we show, it arises endogenously as part of the optimal contract.

characterizes the financing rule, i.e., the set of histories for which the project is financed, denoted as $\mathcal{H}'$. Second, for *each* history in the set $\mathcal{H}'$, the contract characterizes: i) the total equity distributed to investors, denoted as $\alpha(\mathcal{H}')$; and, ii) the amount that *each* investor can invest in the project as a function of the time of backing, denoted as $I(\mathcal{H}')$. We focus on contracts where the equity per unit invested is constant. Alternatively, we could focus on contracts where agents invest the same amount but do not necessarily receive the same amount of equity. These two representations generate qualitatively similar results.[12]

The contract can be interpreted as a menu of contracts characterized by the same financing rule but different combinations of the amount of investment - time of backing. Following that, we allow potential investors to choose their most preferred combination, or equivalently, when to move. This differs from the literature building on Banerjee (1992) and Bikhchandani et al. (1992), which assumes that the time each agent gets to move is exogenously determined. Thus, our setting sheds light on the agents' incentives to "wait and see", which allows them to free-ride on their peers' information. Based on the previous remarks, we can denote a contract C as:

$$C(\mathcal{FR}(\mathcal{H}),\ \alpha(\mathcal{H}'),\ \mathcal{I}(\mathcal{H}')),$$

where $\mathcal{FR}(\mathcal{H})$ stands for the financing rule, which is an indicator function that takes value 1 for histories for which the project is financed, and zero otherwise. Therefore, $\mathcal{H}'$ is the set of histories for which $\mathcal{FR}(\mathcal{H}) = 1$.

Comment on contracting space. Assuming that the contract characterizes the amount each backer can invest is for exposition purposes and it is not essential for the main findings. We show in Corollary 1 that for a given financing rule $\mathcal{FR}(\mathcal{H})$ and equity level $\alpha(\mathcal{H}')$, if backers were free to choose their backing amounts, they would choose the same as the ones prescribed by the optimal contract.

[12]Note that in Cong and Xiao (2019) the price that each agent pays, which is the analog of the individuals' investment in our setting, is constant. Relaxing this assumption and allowing investment to be time-dependent enables us to alleviate the problem that arises from the agents' incentive to wait and free-ride on their peers' information. Time-dependent financing terms are not uncommon in Fintech. For example, in Initial Coin Offerings, early backers receive significant discounts.

Objectives. The entrepreneur's objective is to maximize her expected profit, $\mathbb{E}\,\Pi$,[13] given by

$$\mathbb{E}[\sum_{H_J \in \mathcal{H}} Pr(H_J)\mathcal{FR}(H_J)Pr(\theta = H|H_J)(1-\alpha(H_J))|\Omega^{ent}]$$

where H_J denotes each possible history, i.e., every element in $\mathcal{H}$, and Ω^{ent} denotes the information set of the entrepreneur in period zero.[14] The objective of investor i is to maximize the expected profits, $\mathbb{E}\,U_i$, given by

$$\mathbb{E}[\sum_{H_J \in \mathcal{H}} Pr(H_J)\mathcal{FR}(H_J)Pr(\theta = H|H_J)(\frac{I_i(H_J)}{I}\alpha(H_J) - I_i(H_J)) - \mathbb{1}c|\Omega_i]$$

where $\mathbb{1}$ equals 1 if information is obtained, and zero otherwise. Also, Ω_i denotes the information set of agent i and $\frac{I_i}{I}$ is the share of the investment financed by agent i.

Timing. When potential investors move sequentially, the entrepreneur offers a take-or-leave-it contract to potential investors, who select their preferred time of moving. Each agent observes the backing decisions of preceding agents (if any) and decides (i) whether to gather information, (ii) whether to back the project, and (iii) the backing amount. After every investor takes her backing decision, and conditional that the terms of the contract regarding the project financing decision have been fulfilled, the entrepreneur raises capital from the agents who backed the project. Finally, the outcome is realized and the payments take place.

When investors move simultaneously the timing is the same, with the only exception that agents do not observe the backing decisions of other agents while taking theirs.

Equilibrium Concept. The equilibrium concept is *Perfect Bayesian Equilibrium*, where: i) the entrepreneur designs the contract to maximize her expected profits; ii) each potential investor chooses when to move and takes her information acquisition and backing decisions to maximize expected profits. Finally, players' beliefs about the equilibrium strategies of other players are correct.

[13]This differs from Sherman and Titman (2002) where the objective is to maximize a function consisting of the accuracy of the initial aftermarket price and the expected amount by which the shares must be underpriced.

[14]In words, the entrepreneur's expected profit equals the sum of the products of the probability of each history for which the project is financed, multiplied by the expected value of the project that accrues to the entrepreneur, conditional on that history.

2.2 Model Implications

By Assumption 2, at least k good signals must be generated for the project to have a positive NPV. However, by Assumption 1, neither the signal acquisition nor the signal realization is observable; thus, the contract cannot be contingent on them. In this setting, the entrepreneur can benefit from favorable information by potential investors and she is interested in finding the most efficient way of aggregating information, which, in turn, allows her to maximize profits.

A key feature of this setting is that all else equal, there are three critical areas in agents' beliefs, with different implications for their incentives to gather information.[15]

Lemma 1A. *It is not feasible to incentivize an agent to gather information when the latter is either very pessimistic or very optimistic about future demand, i.e., $p < \hat{p}$ or $p > \hat{\hat{p}}$.*[16]

The rationale is the following. Suppose that p_0 denotes the agent's beliefs *before* she acquires information. There always exists $\hat{p}$, such that, if $p_0 < \hat{p}$, the agent believes that (i) it is unlikely that she will observe a good signal, and/or (ii) even if a good signal is observed, financing the project will not be creditworthy. Thus, the dominant strategy is to pass on this investment, i.e., neither gather information nor back the project. In addition, there always exists $\hat{\hat{p}}$, such that, if $p_0 > \hat{\hat{p}}$, the agent believes that (i) it is unlikely that she will observe a bad signal, and/or (ii) even if a bad signal is observed, financing the project will be creditworthy. Thus, the dominant strategy is to back the project without acquiring information.[17] Finally, if the entrepreneur is neither too optimistic nor too pessimistic, i.e., $p_0 \in (\hat{p}, \hat{\hat{p}})$, acquiring information is likely to be pivotal. For this range of beliefs, incentivizing information acquisition is feasible.

Lemma 1B (Impact of learning from peers). *Allowing agents to learn from their peers could be beneficial for information production.*

[15] A similar feature arises in Glazer et al. (2015).

[16] Where $\hat{p}$ solves $(\hat{p}s_G + (1-\hat{p})s_B)V_G + (\hat{p}(1-s_G) + (1-\hat{p})(1-s_B)))V_B = c$, where V_G is the continuation value when a good signal is observed, and V_B is the continuation value when a good signal is observed. Similarly, $\hat{\hat{p}}$ solves $(\hat{\hat{p}}s_G + (1-\hat{\hat{p}})s_B)V'_G + (\hat{\hat{p}}(1-s_G) + (1-\hat{\hat{p}})(1-s_B)V'_B - c = V$, where V'_G is the continuation value when a good signal is observed, V'_B is the continuation value when a good signal is observed, and V is the continuation value when the agent remains uninformed.

[17] The latter sheds light on the empirical evidence provided by Zhang and Liu (2012), indicating that, in CFP, once a campaign reaches around 70% of the financing target, the probability of reaching the 100% of the target and fulfilling the financing requirements is close to one.

Lemma 1B builds on Lemma 1A. Suppose that $\tilde{p}$ denotes an agent's beliefs *after* learning good news from her peers, but *before* she acquires a signal. Learning good news from peers can motivate information production when $p_0 < \hat{p}$ and $\tilde{p} \in (\hat{p}, \hat{\hat{p}})$, i.e., when an agent, from very pessimistic, becomes moderately (but not overly) optimistic. On the other hand, learning good news from peers might give rise to free-riding motives that undermine the agents' incentives to gather information. This is true when $\tilde{p} > \hat{\hat{p}}$ and $p_0 \in (\hat{p}, \hat{\hat{p}})$, i.e., when an agent, from moderately optimistic, becomes overly optimistic.

Lemma 1A and Lemma 1B generate a key insight; if the entrepreneur wishes to aggregate information from investors, she has to design the capital-raising process such that agents are never too optimistic nor too pessimistic about the expected return of their investment. This can be illustrated in the example that follows.

2.3 Illustrative Example

We start by studying a simple numerical example, where we provide the optimal contract and shed light on its main features. To simplify the algebra, we assume that $p_0 = 0.1$, $s_G = 1$, $s_B = 0.25$, $c = 0.02$, and $I = 0.4$. Table 1 summarizes investors' beliefs and the corresponding expected NPV of the project for different signal realizations. Consistent with Assumption 2, for the project to have a positive NPV, at least two good signals must be realized. Note that given $s_G = 1$, the realization of a bad signal implies that the return of the project is zero.

Beliefs that demand is high	**NPV**
$Pr(\theta = H \mid 1 \text{ good signal}) = 0.31$	-0.09
$Pr(\theta = H \mid 2 \text{ good signals}) = 0.64$	0.25
$Pr(\theta = H \mid 3 \text{ good signals}) = 0.97$	0.57
$Pr(\theta = H \mid 1 \text{ bad signal}) = 0$	-0.4

Table 1: Beliefs & NPV for $p_0 = 0.1$, $s_G = 1$, $s_B = 0.25$, $c = 0.02$, $I = 0.4$.

Claim 1. *Under the optimal contract: i) investors take their* ***backing decisions sequentially****; and, ii) the project is financed as long as* ***two agents back the project****, otherwise, the entrepreneur does not raise any funds. Conditional on financing, the first investor invests* $I_1^* = 0.3$ *for* 66.6% *equity, whereas the second investor invests* $I_2^* = 0.1$ *for* 22.2% *equity.*

Below, we discuss briefly the intuition behind each feature of the optimal contract; a more thorough analysis is presented in the next section.

Financing Rule. Conditioning the project financing on the backing decisions of multiple agents can provide *insurance* to early investor(s) by guaranteeing that the project is financed only if the generated evidence indicates that it has a positive NPV. Being *insured* against the event of financing a negative-NPV project can encourage early movers to (i) gather costly information, and (ii) back the project when a good signal is observed.[18] However, conditioning the project financing on the backing decisions of multiple agents does not always provide protection to downside risk; the number of investors plays a critical role in that.

Two investors. For conditioning the project financing on the backing decisions of multiple agents to provide insurance, the number of agents who invest in the project for it to be financed cannot be greater than two; otherwise, when the information cost is non-trivial, all agents would have an incentive to free-ride, i.e., back the project without acquiring information. Suppose, for instance, that the project is financed only if three agents invest in it. Although three signals correspond to a better resource allocation,[19] such a contract is not feasible because each investor would have an incentive to deviate unilaterally, i.e., back the project without acquiring costly information, because they believe that – conditional on financing – investing in the project is profitable.[20] It is worth highlighting that it not always true that the number of investors under the optimal contract is equal to k; if the cost of acquiring information is not too large, more than k investors back the project under the optimal contract.

Sequential backing decisions. The intuition is twofold. First, allowing for sequential decisions enables the entrepreneur to use favorable information produced by the first investor to motivate the second investor. Conditionally that the first agent backs the project, the second agent believes that an additional good signal would reveal a positive-NPV investment opportu-

[18] If the financing condition is not contingent on the backing decision of the second investor, the first agent will not acquire information because even if a good signal is observed, the project has a negative NPV ($= -0.09$).

[19] Increasing experimentation from two to three signals increases surplus.

[20] Note that if two good signals are observed, the NPV of the project is positive ($= 0.25$).

nity; thus, acquiring information is valuable. Second, restricting agents to move simultaneously could lead to over-production of information; if a bad signal is observed, demand uncertainty is resolved, thus, acquisition of additional signals is socially wasteful.

Endogenizing Backing Amounts. Had it be endogenous, backers would choose the same backing amount as the one prescribed by the contract. Suppose that the first agent decreases the backing amount from I_1^* to $I_1^- < I_1^*$. Such a deviation would be suboptimal; investing I_1^- dominates I_1^* because – conditional on the project being financed – it has a positive NPV. Suppose now that the first backer increases the backing amount from I_1^* to $I_1^+ > I_1^*$. If this is the case, the second backer finds it suboptimal to acquire information and/or back the project, as the expected proceeds from investing $I - I_1^+$ do not cover the cost c of gathering information.[21] Thus, I_1^* dominates $I_1^+ > I_1^*$. Thus, Claim 1 and Claim 2 are equivalent.

Claim 2. *Under the optimal contract: i) the entrepreneur offers* 88.8% *equity, ii) potential investors take their backing decisions sequentially; and, iii) the project is financed as long as the total backing amount reaches* I*, otherwise, the entrepreneur does not raise any funds. When the project is financed, it is backed by two investors, with the first one investing* $I_1 = 0.3$ *and the second one investing* $I_2 = 0.1$.

3 Analysis

As the illustrative example shows, the project financing requires potential investors to coordinate their actions. The main problem is that because information acquisition is costly, free-riding incentives arise, which can have a detrimental effect on investors' efforts to coordinate. Thus, the optimal contract should provide a mechanism that allows self-centered investors to coordinate their actions. We start with the case where, by assumption, agents take their backing decisions sequentially. In Section 3.2, we verify that taking the backing decisions simultaneously is suboptimal.

[21]Thus, either the first backer invests $I_1^+ = 0.4$ and finances a negative-NPV project, or she chooses $I_1^+ \in (0.3, 0.4)$, the project is not financed, and she suffers a loss due to the sunk cost c.

3.1 Sequential Backing Decisions

The only way for the entrepreneur to facilitate gathering and communication of information is by offering a contract such that $x(\mathcal{H})$ agents find it optimal to (i) acquire information and (ii) back the project only when they observe a good signal. Offering a contract according to which backing decisions are information-sensitive allows agents to perfectly infer the preceding agents' private information by simply observing their backing decisions. We allow $x(\mathcal{H})$ to be a function of history. It is worth highlighting that the entrepreneur affects $x(\mathcal{H})$ only indirectly via the choice of $\alpha(\mathcal{H}')$ and $I(\mathcal{H}')$. Lemma 2 provides a set of properties that should hold in equilibrium and allows us to restrict the feasible values of $x(\mathcal{H})$.

Lemma 2. *For $c < \hat{c}$ (defined by (8) in the Appendix), the entrepreneur finds it optimal to offer a contract that i) incentivizes up to the first $x \in [k, z]$ agents to gather information and back the project only when observing a good signal, and ii) stops incentivizing information production when one of the first x agents decides not to back the project.*

Proof. See Appendix. □

Fundamental for the understanding of Lemma 2 is the finding that it is never optimal to raise capital from uninformed investors. The agents who benefit from investing in the project should be the ones who incurred the cost of learning about its profitability. If uninformed agents are allowed to invest in the project, given that the project is not scalable, the amount left to be financed by informed investors decreases; thus, the entrepreneur must distribute more equity to incentivize learning.[22]

Lemma 2 implies that the entrepreneur stops incentivizing information production after observing a history that is consistent with a bad signal. This is because either uncertainty is resolved (when $s_G = 1$) or the entrepreneur prefers to start a new capital-raising process, by reaching out to a new pool of potential investors (when $s_G < 1$ and $c > \hat{c}$).

[22] Note that in security-based CF, as opposed to reward-based CF, there is a negative externality among backers coming from the fact that the higher the investment by one agent, the lower the amount the remaining agents could invest, thus, the lower the marginal benefit of learning. In contrast to Cong and Xiao (2019), our work captures this negative externality among investors, which characterizes security-based CF.

Maximization Problem. Based on Lemma 2, we can build the entrepreneur's maximization problem. For a *given* financing rule $\bar{\mathcal{FR}}(\mathcal{H})$, the maximization problem is given by:

$$\underset{C(\bar{\mathcal{FR}}(\mathcal{H}),\ \alpha(\mathcal{H}'),\ \mathcal{I}(\mathcal{H}'))}{\text{Maximize}} \quad \mathbb{E}[\sum_{H_J \in \mathcal{H}} Pr(H_J)\bar{\mathcal{FR}}(\mathcal{H})(H_J)Pr(\theta = H|H_J)(1-\alpha(H_J))|\Omega^{ent}]$$

s.t. for each $t = \{1, ..., x\}$:

$$\mathbb{E}\,U_t(back|\sigma = \sigma_G, \Omega_t) \geq \mathbb{E}\,U_t(no\ back|\sigma = \sigma_G, \Omega_t) \tag{1}$$

$$\mathbb{E}\,U_t(no\ back|\sigma = \sigma_B, \Omega_t) \geq \mathbb{E}\,U_t(back|\sigma = \sigma_B, \Omega_t) \tag{2}$$

$$\mathbb{E}\,U_t(signal|\Omega_t) \geq \mathbb{E}\,U_t(no\ signal\ \&\ back|\Omega_t) \tag{3}$$

$$\mathbb{E}\,U_t(signal|\Omega_t) \geq \mathbb{E}\,U_t(no\ signal\ \&\ no\ back|\Omega_t) \tag{4}$$

$$\mathbb{E}\,U_t(signal|\Omega_t) = max\{\mathbb{E}\,U_1(signal|\Omega_0), ..., \mathbb{E}\,U_t(signal|\Omega_0)\} \tag{5}$$

$$\text{For each } H_J \in \mathcal{H}',\ I_1 + ... + I_x = I \tag{6}$$

Constraints (1) and (2) imply that conditional on being informed, agents prefer backing the project only if a good signal is observed. Constraints (3) and (4) imply that agents prefer gathering information instead of remaining uninformed and either backing or not backing the project. Note that constraints (3) and (4) take into consideration the backing decision that an agent expects to follow after acquiring information, i.e., back the project only if a good signal is observed. Constraint (5) guarantees that each agent is indifferent regarding the time her backing decision is taken, which eliminates the agents' incentives to "wait and see" that would kill information production. Finally, relation (6) is the feasibility constraint, i.e., for each history for which the project is financed, the total contribution should be equal to the level of capital the entrepreneur aims to raise.[23]

[23]Similar to Gromb and Martimort (2007), Inderst and Ottaviani (2009) and Terovitis (2017), we are interested in the optimal contract that incentivizes information production and disclosure. We contribute to this literature by exploring the case where each agent's information is incremental, and learning from their peers affects the incentives to gather and communicate information. A setting with information complementarities is also studied

Lemma 3. *Under the optimal contract, for $c < \hat{c}$, the project is financed only if the first x^* investors back the project, where x^* is the largest natural number that satisfies condition* (10) *in the Appendix.*

Proof. See Appendix. □

We start by providing the underlying intuition of Lemma 3 for the case where $x^* = k = 2$. A similar rationale extends to the case where $x^* > k > 2$. Suppose that the first agent acquires a good signal. By Assumption 2, observing just one good signal is not sufficient for the project to have a positive NPV. Therefore, the first agent would never find it optimal to finance the entire project, even in the extreme case where she receives the entire surplus. i.e., $\alpha = 1$.

Consider now a contract where the project is financed *independently* of the backing decision of the second agent.[24] That regime would imply that the first agent finances the *entire* project when the second agent observes a bad signal (thus, when the project has a negative NPV), whereas she finances *part* of the project when the second agent observes a good signal (thus, when the project has a positive NPV). In other words, without requiring both agents to back the project for financing to take place, the first agent would have to finance the entire project in the bad state of the world, but only a part of the project in the good state of the world. Therefore, the expected return associated with this contract is *lower* than the expected return when the investor finances the entire project. Hence, the first agent would find it suboptimal to invest. Also, as the first agent finds it suboptimal to invest in the project independently of her signal realization, she will not have an incentive to acquire information in the first place. In contrast, requiring both agents to back the project for financing to take place, effectively, protects against downside risk, because the second agent does not finance the project when she observes a bad signal. This strengthens the incentives of agents to gather information, and subsequently invest in the project had them observed a good signal.

A natural question to ask is whether the entrepreneur will ever find it optimal to incentivize more than k agents to acquire information. Although incentivizing more than z agents (defined

in Biais and Perotti (2008).

[24]This would be equivalent to the *Take-it-All* financing rule, encountered mainly in donation-based CFPs.

in the Appendix) to gather information is socially wasteful, it can be that $x^* \in (k, z]$. We show in Lemma 5 in the Appendix that x^* *cannot be much larger than* k; otherwise, each agent would be tempted to back the project without gathering costly information, and, effectively, free-ride on the information produced by other agents. The latter cannot arise in equilibrium because players' beliefs would not be consistent.

Building on Lemma 2 and Lemma 3, Proposition 1 characterizes the optimal capital-raising process.

Proposition 1. *Under the optimal contract, if $c < \hat{c}$, the entrepreneur sells α^* of her equity in exchange for I. Investors take their backing decisions sequentially and the project is financed only if x^* agents back the project. Otherwise, the capital-raising process is terminated. The optimal level of equity α^* is given by*

$$\alpha^* = \frac{I[p_0 s_G^{x^*} + (1-p_0)s_B^{x^*}] + c\Sigma_{j=1}^{x^*}[p_0 s_G^{j-1} + (1-p_0)s_B^{j-1}]}{p_0 s_G^{x^*}},$$

For α^*, the optimal backing amount of the agent who moves in period $t \in \{1, ..., x^*\}$ is given by

$$I_t^* = I\frac{p_0 s_G^{t-1} + (1-p_0)s_B^{t-1}}{\Sigma_{j=1}^{x^*}[p_0 s_G^{j-1} + (1-p_0)s_B^{j-1}]}, \tag{7}$$

where x^* is characterized in Lemma 3.

Proof. See Appendix. □

Corollary 1 shows that it is without loss to assume that the contract determines the amount each backer is allowed to invest. Hence, this assumption can be relaxed without affecting the optimal equity, the equilibrium number of backers, and their backing amount.

Corollary 1. *If backers were free to choose the backing amount that maximizes their expected profit, they would find it optimal to choose the same amount as the one characterized in the optimal contract, given by* (7).

Proof. See Appendix. □

The intuition behind Corollary 1 is that backers would be worse off if they choose a backing amount that differs from the one described by (7). Choosing a smaller amount corresponds to a lower expected profit because, effectively, it implies financing a smaller fraction of a positive-NPV investment. On the other hand, choosing a larger amount discourages subsequent agents from backing the project; thus, the project is not reaching the financing stage, or it is financed although it has a negative return. A direct implication of Corollary 1 is Corollary 2.

Corollary 2. *Under the optimal contract, when backers are free to choose the backing amount that maximizes their expected profit, the project is financed only if the total backing amount covers I. Thus, the optimal contract exhibits an All-or-Nothing (AON) feature.*

The AON rule is a key feature in most security-based crowdfunding platforms (CFP), according to which, the funds become available to the entrepreneur only if the total backing amount reaches the amount that the entrepreneur sets at the beginning of the campaign.

Corollary 3 sheds light on the dynamics and shows how the optimal backing amount of each agent changes over time.

Corollary 3. *Under the optimal contract, the marginal backing amount decreases over time, i.e., for $t \in [1, x^* - 1]$, $I_t > I_{t+1}$.*

Corollary 3 implies that early backers will end up financing a higher share of the project. The latter relates to the feature that moving later has an information advantage, given that backers can always free-ride on the information provided by preceding backers. Hence, all else equal, the agents who move earlier must receive a higher revenue in the event where the project is finally financed, to perfectly counteract their incentive to "wait and see".

3.2 Simultaneous backing decisions

In Proposition 2, we characterize the optimal contract when, by assumption, the backing decisions are taken simultaneously.

Proposition 2. *Assuming that potential investors take their backing decision simultaneously, under the optimal contract, the entrepreneur approaches $\tilde{x}^*$ agents and the project is financed only if all of them back the project. Otherwise, the capital-raising process is terminated with the entrepreneur not raising any funds. Conditional on project financing, each agent invests $I_i = I/\tilde{x}^*$, and the equity distributed to investors is given by*

$$\tilde{\alpha}^* = \frac{I[p_0 s_G^{\tilde{x}^*} + (1-p_0)s_B^{\tilde{x}^*}] + c\tilde{x}^*}{p_0 s_G^{\tilde{x}^*}}.$$

where $\tilde{x}^*$ is characterized in Lemma 6 in the Appendix.

Proof. See Appendix. □

The comparison of the optimal equity level distributed to investors, characterized in Propositions 1 and 2, results in the following Corollaries.

Corollary 4. *Conditional on raising capital, the equity distributed to investors under the optimal contract is lower when they take their backing decisions sequentially, i.e., $\alpha^* < \tilde{\alpha}^*$.*

Corollary 5. *The entrepreneur always prefers the backing decisions to be taken sequentially.*

The underlying intuition in Corollaries 4 and 5 is twofold. First, when the backing decisions are taken sequentially, the entrepreneur can use the information produced by early investors to motivate late investors. As a result, allowing investors to learn from each other enables the entrepreneur to motivate information production at a lower cost, i.e., lower equity distributed to investors. Second, restricting agents to move simultaneously might lead to over-production of costly information. For instance, if posterior beliefs are either too high or too low, further information production becomes socially wasteful. Therefore, acquiring information sequentially leads to better allocations of resources and a higher surplus. Note that the party that benefits from the better resource allocation (thus, the higher surplus) is the entrepreneur because, under the optimal contract, investors break-even.

4 Link with security-based crowdfunding

The goal of this section is to explore how the insights of Section 3 extend to security-based CF. First, we provide a rationale for the emergence of CFPs. Second, we present the implications of our study for the design of the capital-raising process in CFPs. Finally, we discuss the type of economic agents and projects that can benefit from CF.

4.1 Economic Value of Crowdfunding Platforms

4.1.1 Impact of Commitment Power

An important assumption that we adopt throughout the analysis is that the entrepreneur and investors have commitment power. More specifically, we assume that investors can commit to their backing amounts and the entrepreneur can commit to raising capital from the backers only if the project finds enough financial support.

Lemma 4. *Relaxing the assumption that the entrepreneur and investors can commit leads to information aggregation breakdown, and prevents project financing.*

The rationale of Lemma 4 is the following. The project financing requires investors to coordinate their actions. However, in a setting with costly information acquisition and information complementarities, free-riding incentives arise: each agent has an incentive to follow a "back and see" strategy that consists of two steps; first, back the project, in an attempt to motivate the peers to gather information, and second, withdraw backing when there is not enough support. Hence, if investors cannot commit to their backing amounts, their backing decisions are not credible and the agents' incentive to "back and see" kills information production. As a result, lack of commitment can prevent the financing of socially valuable projects that would be financed if investors could *put their money where their mouth is.* The assumption that the entrepreneur can commit to raising capital from the backers only if the project finds enough financial support is also important, as it can protect against the downside risk. Otherwise, early investors would find it suboptimal to engage in costly information acquisition which would, in turn, prevents project financing.

4.1.2 Crowdfunding Platforms: Role of Commitment

Proposition 1 highlights that if the entrepreneur and investors can commit, information about future demand can be aggregated and communicated efficiently. However, Lemma 4 shows that this finding does not go through when agents have limited commitment. Therefore, introducing a third party that allows economic agents to commit could lead to better allocations of resources and a higher surplus. The role of a third party can be played by a CFP.

A CFP can provide an environment that i) the project is financed only if it receives enough financial support; and, ii) potential investors cannot withdraw their backing decisions. The former deals with the entrepreneur's lack of commitment, whereas the latter with investors'. It is worth highlighting that apart from the design of the optimal contract, there is no additional action taken by the entrepreneur during the capital-raising process. Therefore, the implementation of the contract can be easily delegated to a platform. As a result, we suggest the following mechanism through which CFPs can create economic value.

Corollary 6. *By overcoming the agents' lack of commitment, CFPs can create an environment that allows market participants to determine whether a project is creditworthy. The latter could eventually lead to financing of positive-NPV projects that would not be financed otherwise.*

Therefore, CFPs can generate value even when they do not possess any screening technology, or provide any value-enhancing services; CFPs can implement the wisdom of the crowd. This channel is consistent with Mollick and Nanda (2015), who provide evidence that CF can create economic value by allowing projects the option to receive multiple evaluations that decrease the incidence of a "false negative", i.e., not financing a creditworthy project. The learning channel is supported by Lee, Li, and Shin (2018) in an Initial Coin Offering setting, which shares similar features with security-based CF.

4.2 Design of capital-raising process in CFPs

The main findings of the paper produce useful implications for the optimal design of the capital-raising process in CFPs. We discuss the empirical support of Corollary 7 in the next subsection.

Corollary 7 (Design of capital-raising process in CFPs). *Conditional that the objective of a CFP is to maximize entrepreneurs' expected profit,*[25] *Proposition 1 implies that:*

(i) *Backing decisions should be taken sequentially and should be publicly observable.*

(ii) *Financing should go through only if the campaign finds enough financial support; otherwise, the campaign should be canceled (AON feature).*

(iii) *The financing target should be determined at the beginning of the campaign and it should not be subject to changes.*

4.3 Discussion and Empirical Implications

Although our setting adopts several simplifying assumptions, our model generates a series of empirical implications, which are consistent with what is common practice in CFPs.

Implication 1 (sequential vs simultaneous). *In CFPs, the total backing amount and the number of backers should be publicly observable, and backers should take their decisions sequentially.*

Although CFPs have the technology to implement it, in none of the major CFPs the backing decisions are taken simultaneously. In fact, the campaign is active for 30 to 60 days and the number of backers and/or the total backing amount is publicly observable. Thus, compared to the regime with simultaneous backing decisions, the regime of sequential backing decisions reflects more closely the way backing decisions are taken in CFPs.

Implication 2 (AON vs KIA). *In security-based CFPs, AON dominates KIA.*

As we show in Lemma 3, the AON financing rule capitalizes on the information produced by all investors and can protect against the downside risk of financing a negative-NPV project. This insurance aspect can not arise under a Keep-it-All (KIA) financing rule, where the entrepreneur can keep the entire pledged amount, regardless of whether or not the stated capital raising goal is reached. Interestingly, all major security-based CFPs adopt an AON financing

[25] Note that the main source of revenue for CFPs is a commission of 4% to 5% based on the amount raised via the platform. Following that, it seems plausible that platforms aim to attract high-quality entrepreneurs, where this can be done by facilitating entrepreneurs' objective of maximizing profits.

rule[26] where the financing target is determined when the capital-raising process is initiated, whereas all major donation-based CFPs adopt a KIA rule. Based on our model, this is not a surprising result. When it comes to profit-maximizing backers, as in security-based CFP, the insurance nature of AON is a desirable property.[27] In contrast, in donation-based CFP, the backers' main objective is not to maximize profits, but instead, to provide financial support.

Implication 3 (type of economic agents). *Security-based CFPs can be attractive to cashless entrepreneurs and investors with limited commitment power.*

This implication relates to the idea that cashless entrepreneurs/startups and retail investors might fail to raise capital, due to their limited commitment power. Alleviating the problem of under-financing is of first-order importance for entrepreneurs and small businesses (Carpenter and Petersen, 2002; Cosh et al., 2009). Thus, CFPs can help these economic agents (i) overcome the lack of commitment, (ii) aggregate information, and (iii) finance socially valuable projects that would not be financed otherwise. This implication is consistent with the types of economic agents in CFPs, namely, retail investors and startups (Block et al., 2018).[28] Finally, we show in Lemma 7 in the Appendix that CF might be the only way for cashless entrepreneurs to learn about future demand for their product.

Implication 4 (type of projects). *Security-based CFP can be an attractive alternative for the financing of new products, which are characterized by demand uncertainty.*

This relates to the observation that, all else equal, demand uncertainty is more prominent for new products; thus, the benefit of using CF to gather information is larger. This is in line with Walthoff-Borm et al. (2018) who show that equity crowdfunded startups are, on average, more innovative but also riskier. In addition, this is consistent with the idea that when it comes

[26] Or they provide the option of such a rule, such as in Indiegogo.

[27] Cholakova and Clarysse (2015) and Vismara (2018) show that participants in security-based CFPs are driven mostly by financial motivations.

[28] The report *The Future of Finance - The Socialization of Finance* (2015) by Goldman Sachs provides a review of the crowdfunding industry, capturing the type of projects that have raised capital via CFPs and the type of investors involved in crowdfunding. Block et al. (2018) find that crowd investors are not professional investors and thus are more likely passive.

to new products, the information provided by potential customers is particularly valuable.

Implication 5 (CF vs VC). *Security-based CFPs can be a substitute to VC financing when it comes to seed financing, but it can complement VC financing at later stages.*

The intuition behind Implication 5 is the following. Suppose that an entrepreneur has two options: either to raise capital from a venture capitalist (VC) or to raise capital via a CFP. There is a large literature arguing that raising capital via a VC might improve the probability of success of the project, due to the support that an experienced investor can provide.[29] However, by raising capital via a CFP, an entrepreneur can utilize favorable information produced by the market and get better financing terms. Therefore, on one hand, raising capital from a VC can increase the surplus that the project generates, but on the other hand, raising capital via a CFP allows the entrepreneur to retain a larger part of the, arguably, smaller surplus. If this is the case, the preferred method of raising capital depends on which force dominates. It is crucial to note that comparing CF with VC could be misleading. The present paper indicates that CF might be a good alternative for raising seed financing when there is uncertainty about future demand for the underlying product. However, as the uncertainty is resolved, raising capital from a VC and benefiting from the latter's network and business advice, might be preferred. Also, *testing the waters* via CF, could allow the entrepreneur to signal the potential of her product to a VC. Consistent with that, Hornuf and Schmitt (2017) find that 19% of crowdfunded startups have received follow-up funding from professional investors, whereas Signori and Vismara (2018) show that 35% were able to secure follow-up funding either from professional investors or again from crowd investors. Drover, Wood, and Zacharakis (2017) find similar results. Hence, the main message of our study is that CF could be an alternative to VC when it comes to seed financing, but at a later stage CF and VC can work hand-in-hand.[30]

[29]For instance, Gompers (1995) and Lerner (1995) focus on the monitoring function of VC. Also, Hellmann and Puri (2002) show that VC professionalize their management teams, whereas Lindsey (2008) find that VC foster collaborative relationships through strategic alliances among their portfolio firms.

[30]Two examples are Oculus Rift and Revolut. Oculus Rift raised $2.4 million on Kickstarter in 2012. The latter attracted the attention of VCs, who provided $75 million in 2013. Finally, Oculus Rift was acquired by Facebook for $3 billion in 2014. Similar, Revolut raised £1 million on Crowdcube in 2016 and was later backed by Index Ventures and its valuation exceeds $5.5 billion in 2020.

5 Concluding Remarks

This paper studies how an entrepreneur can capitalize on information produced by potential investors. The contribution of is twofold. First, we characterize the optimal design of the capital-raising process that allows the entrepreneur to coordinate the behavior of self-centered investors and maximize profits. Second, we generate testable insights for CF and CFPs that help us understand under what conditions CF can be a valuable method of financing.

The present paper builds on two observations. First, new products are characterized by demand uncertainty. Second, economic agents might have access to relevant information about future demand for the underlying product, but the information each individual has is costly and incremental. Following these two observations, we show that there is room for learning from the market. The latter has consequences for the capital-raising process and the allocation of resources. We highlight that, in this setting, there are information complementarities and the project is financed only if potential investors can coordinate their actions.

We show that the optimal contract has three features: i) backing decisions are taken sequentially and they are publicly observable; ii) the project is financed only if a sufficient number of investors back the project; and, iii) the financing target is determined at the beginning of the campaign and it is not subject to changes.

We argue that CFP can be attractive to startups and retail investors with limited commitment power. Finally, we conclude that CFP can be a substitute to VC financing when it comes to seed capital, but it can complement VC financing at later stages.

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Appendix A:

A.1 Proof of Lemma 2

First, we explore why it is optimal for the entrepreneur to stop incentivizing agents to gather information after observing a history that is consistent with a bad signal (part one). Second, we determine the lower and the upper bound on the number x of investors that the entrepreneur finds it optimal to incentivize to gather information (part two).

Part one: Optimality of stopping incentivizing information acquisition after a bad signal. First, we consider the case where $s_G = 1$. For $s_G = 1$, a bad signal can be observed only if future demand is low. Thus, a bad signal resolves demand uncertainty and implies that the project has a negative NPV. There is no feasible contract that incentivizes an agent to acquire information and invest in the project when the latter observes a history that is consistent with a bad signal; acquiring information and investing in the project generates negative profits, as the project return is zero and information acquisition is costly.

Now, we consider the case where $s_G < 1$, for which demand uncertainty is never resolved. We denote with p_0 the prior beliefs that demand is high. Consider a history that is consistent with $m \in [0, k-1]$ good signals followed by one bad signal, with $\bar{p}$ denoting the posterior beliefs for such history. Given that the entrepreneur has limited liability and does not incur the cost of learning, she wishes to continue the experimentation. To do so, she has two options. Either to renegotiate the contract with the m existing backers and seek additional backers (Option A) or to terminate the ongoing capital-raising process and start a new campaign targeting a new pool of potential investors (Option B).

As long as the cost c of gathering information is not prohibitively large, Option B is preferred by the entrepreneur. The latter relates to the observation that the equity an investor requires to break-even is negatively related to the amount she invests in the project. To see this, note that when the project is financed, the expected profit of investor i is given by

$$I_i \underbrace{\left(\frac{p_i \alpha}{I} - 1\right)}_{>0} - c$$

where p_i is her beliefs that demand is high (conditional on financing). From the relation above, it becomes clear that investor i's benefit from being informed is increasing in the amount that she invests in the project, I_i. Equivalent, the lower the amount that she invests, the higher the equity α that she requires to have an incentive to gather information.

Note that if the entrepreneur chooses Option A, a part of the investment is already "reserved" by early backers.[31] The latter decreases the amount left to be covered by the new investors, which, all else equal, weakens their incentive to gather information. Thus, the entrepreneur has to offer these new investors a higher equity amount. For instance, think of the extreme case where 99% of I is covered by existing backers. This implies that even if the project has a positive NPV conditional on financing, the amount that an agent can invest in it is very limited; thus, the entrepreneur, to incentivize an agent to gather information, has to promise a significant amount of equity.

Therefore, raising capital from a new pool of investors is optimal as is a more efficient way to incentivize information acquisition. However, this argument goes through as long as the entrepreneur can raise capital even when the capital-raising process is terminated after a bad signal. This is true as long as the optimal equity (derived in Proposition 1) is feasible, i.e., $\alpha^* \leq 1$. Solving $\alpha^* \leq 1$ with respect to c we find that the latter holds if c is not prohibitively large, i.e.,

$$c \leq \hat{c} \equiv \frac{(s_B - 1)(s_G - 1)\left(I(p_0 - 1)s_B^{x^*} - Ip_0 s_G^{x^*} + p_0 s_G^{x^*}\right)}{p_0\left(-(s_G - 1)s_B^{x^*} + s_B\left(s_G^{x^*} - 1\right) - s_G^{x^*} + s_G\right) + (s_G - 1)\left(s_B^{x^*} - 1\right)}. \tag{8}$$

where x^* is characterized in Lemma 3. Thus, as long as (8) is satisfied, after an agent decides not to back the project, the capital-raising process is terminated and a new capital-raising process starts, targeting a new pool of potential investors. The optimal contract in the *new* campaign resembles the optimal contract characterized in Proposition 1; the main difference is that in the new optimal contract the prior beliefs p_0 are replaced by the updated beliefs $\bar{p}$ that are consistent with the history for which the initial capital-raising process was terminated.

[31] We exclude the not realistic case where backing amounts are adjusted downwards after one of the subsequent agents decides not to back the project.

If condition (8) is violated, the entrepreneur has to promise a positive payoff for a subset of the histories for which one of the potential investors decides not to back the project. Otherwise, potential investors are not compensated enough to gather costly information. This case increases the complexity of the analysis significantly, without affecting the main features of the optimal contract. Note that there might be a large number of histories for which the project has a positive NPV, although bad signals have been observed. The latter implies that there is a large number of histories for which the project could be financed. For each of the histories for which the project is financed, the entrepreneur should offer an investment scheme and the corresponding equity distributed to investors. Therefore, the size of the contract increases tremendously. However, for each history that the project is financed, the incentives of the agents involved in the capital-raising process remain the same as in Section 3. Thus, the main features of the optimal contract are unchanged: i) backing decisions are taken sequentially and are observable; and, ii) for each history, there is a *unique* financing target. A feature that does not always go through is that late backers are associated with smaller investments.

Part two: Lower and upper bound on experimentation. Before we derive the lower and the upper bound on experimentation, it is useful to shed light on the case where there is no agency problem. To this end, suppose that the entrepreneur had enough cash to acquire costly (conditionally independent) signals and finance the project if she decides that it is optimal to do so. Definition 1 shows the extent of experimentation that the entrepreneur would undertake if there was no agency problem and she had deep pockets.

Definition 1. *Suppose that there is no agency problem and the entrepreneur acquires signals sequentially. Conditional that no bad signal is observed, the entrepreneur finds it optimal to keep gathering signals as long as*

$$(p_{x-1}s_G + (1-p_{x-1})s_B)(p_x - I) - (p_{x-1} - I) \geq c, \tag{9}$$

where p_j stands for the posterior beliefs that $\theta = H$, given that j consecutive good signals have been observed. We define as z the largest natural number x which satisfies (9).

Note that the first term of the LHS of (9) corresponds to the expected benefit of gathering x signals, whereas the second term corresponds to the expected benefit of gathering $x-1$ signals. Also, simple algebra shows that the LHS of (9) is decreasing in x.

Now, we consider the case where the entrepreneur is cashless and wishes to gather information via investors. The entrepreneur would never find it optimal to incentivize more than $x = z$ agents to gather information. By Definition 1, under the first best, $x = z$ corresponds to a better allocation of resources compared to $x > z$. Thus, under the second best, $x = z$ continues to correspond to a better allocation of resources compared to $x > z$, because the cost of information production is weakly higher due to the agency problem. In addition, the entrepreneur would never find it optimal to incentivize fewer than $x = k$ agents to gather information. Note that $x = k$ dominates any $x < k$, because $x < k$ would imply financing a negative-NPV project. Therefore, $x^* \in [k, z]$, where the optimal value of x^* depends on the financing rule (determined in Lemma 3) and the optimal equity (determined in Proposition 1).

A.2 Proof of Lemma 3

First, we characterize the optimal number x^* of agents being incentivized to gather information given the financing rule (part one). Second, we explain why the project is financed only if the first x^* investors back the project (part two).

Part one: Optimal value x^*. Before we explore the optimal value x^*, we shed more light on the feasible values of x, where by Lemma 2, we already know that $x^* \in [k, z]$. We build on Lemma 5 which implies that there is no equilibrium where the agents' option of backing the project without acquiring information corresponds to positive profit.

Lemma 5. *There is no feasible contract which satisfies constraints* (1), (2), (3), (4), (5), *and* (6) *of the maximization problem of Section 3.1, where* $\mathbb{E}U(\textit{no signal}\ \&\ \textit{back}|\Omega_x) > 0$. *Hence, under the optimal contract, the backers' participation constraint* (4) *binds.*

Proof. For now, we ignore condition (3) and consider the relaxed maximization problem. In this relaxed problem, the entrepreneur's profit is maximized when, for the contract that implements x, the participation constraint of each agent binds, i.e., $\mathbb{E}U[\textit{signal}|\Omega_t] = 0$. We denote the equity distributed by this contract as $\alpha^\dagger$. Given $\alpha^\dagger$, suppose that for the agent that moves in period $t = x$, it holds that $\mathbb{E}\, U_{t=x}(no\ signal\ \&\ back|\Omega_x) > 0$, which is the case when $p_{x-1}\alpha^\dagger > I$. The latter implies that condition (3) is violated, since $\mathbb{E}\, U_{t=x}[signal|\Omega_x] < \mathbb{E}\, U_{t=x}(no\ signal\ \&\ back|\Omega_x)$.

Starting, now, from $\mathbb{E}\, U_{t=x}[signal|\Omega_x] < \mathbb{E}\, U_{t=x}(no\ signal\ \&\ back|\Omega_x)$, there are two ways to restore (3); I_x has to increase and/or $\alpha^\dagger$ has to decrease. However, I_x cannot increase because it is determined by condition (5) and it depends on the value of signals acquired in equilibrium. Therefore, if I_x increases, potential investors would not be indifferent regarding when to move; each potential investor would have a strict preference towards moving in period $t = x$. In addition, $\alpha^\dagger$ cannot decrease because then $\mathbb{E}\, U_{t=x}[signal|\Omega_x]$ will drop below zero, therefore, it would violate agents' participation constraint, given by (4).

The previous analysis implies that under the optimal contract condition (3) is slack, thus, condition (4) is the most restrictive one, i.e., backers' participation constraint binds. □

It can be shown that the entrepreneur's profit is hump-shaped in x, and it is maximized for $x = z$, where z is given in Definition 1.[32] Recall also that by Lemma 2, $x^* \in [k, z]$. As a result, the optimal value x^* corresponds to the largest natural number n that satisfies $\mathbb{E}\, U(no\ signal\ \&\ back|\Omega_t) \leq 0$, which coincides with the largest natural number n which satisfies

$$p_{n-1}\alpha_n^* \leq I \tag{10}$$

where

$$\alpha_n^* = \frac{I[p_0 s_G^n + (1-p_0)s_B^n] + c\Sigma_{j=1}^n [p_0 s_G^{j-1} + (1-p_0)s_B^{j-1}]}{p_0 s_G^n}.$$

Note that we do not need to check condition (10) for each possible value, because $p_{n-1}\alpha_n^*$ is increasing in n, hence, if $p_{n-1}\alpha_n^* \leq I$ then $p_{n-2}\alpha_{n-1}^* \leq I$.

Part two: Financing Rule. Following the analysis above, it is easy to show why the project is financed only if the first x^* agents back the project. If the project was financed when fewer agents back the project (i.e., $x^* - 1$), the project would generate negative expected profits for

[32]This relies on two observations. First, as Definition 1 indicates, $x = z$ corresponds to the best allocation of resources, both in terms of experimentation and in terms of project financing. Second, under the optimal contract, investors break-even, thus, the entire surplus is reaped by the entrepreneur.

backers (recall that backers' expected profit is zero when x^* agents back the project); thus, backers would not have an incentive to gather information, neither to back the project.

A.3 Proof of Proposition 1

Following Lemmas 2 and 5, we can eliminate a series of constraints in the maximization problem presented in Section 3.1. Based on Lemma 5, we can explore without loss the relaxed problem where constraint (3) is omitted. By Lemma 2 and Lemma 5, for each $t = \{0, ..., x^*\}$ it holds

$$\mathbb{E}\, U_t(no\ signal\ \&\ back|\Omega_t) < 0,$$

$$\mathbb{E}\, U_t(back|\sigma = \sigma_B, \Omega_t) < 0.$$

The latter relation implies that (2) is redundant. In addition, given that observing a favorable signal is the best-case scenario when it comes to the decision to acquire information and given that the RHS of (1) is negative, relation (1) is redundant by (4). Finally, based on Lemma 5, under the optimal contract, the participation constraint of each agent (4) binds, therefore, the expected profit of each agent is zero. A consequence of the latter is that constraint (5) becomes redundant. Thus, the maximization problem simplifies to:

$$\underset{C(\bar{\mathcal{FR}}(\mathcal{H}),\ \alpha(\mathcal{H}'),\ \mathcal{I}(\mathcal{H}'))}{\text{Maximize}} \quad \mathbb{E}[\sum_{H_J \in \mathcal{H}} Pr(H_J)\bar{\mathcal{FR}}(\mathcal{H})(H_J)Pr(\theta = H|H_J)(1 - \alpha(H_J))|\Omega^{ent}]$$

s.t. for each $t = \{1, ..., x^*\}$:

$$\mathbb{E}\, U_t(signal|\Omega_t) \geq 0. \tag{11}$$

$$\text{For each } H_J \in \mathcal{H}',\ I_1 + ... + I_{x^*} = I. \tag{12}$$

Taking into consideration the financing rule characterized in Lemma 3, the maximization problem simplifies to

$$\underset{\alpha,\ I_1 ... I_{x^*}}{\text{Maximize}} \quad \mathbb{E}[Pr(\sigma_1 = \sigma_G \cap \sigma_1 = \sigma_G \cap ... \cap \sigma_{x^*} = \sigma_G)|p_0][p_{x^*}(1 - \alpha)]$$

s.t. for each $t = \{1, ..., x^*\}$:

$$\mathbb{E}\, U_t(signal|\Omega_t) \geq 0. \tag{13}$$

$$I_1 + ... + I_{x^*} = I. \tag{14}$$

where,

$$\mathbb{E}[Pr(\sigma_1 = \sigma_G \cap \sigma_1 = \sigma_G \cap ... \cap \sigma_{x^*} = \sigma_G)|p_0][p_{x^*}(1-\alpha)] = [p_0 s_G^{x^*} + (1-p_0) s_B^{x^*}](1-\alpha),$$

and,

$$\mathbb{E}\, U_t(signal|\Omega_t) = \mathbb{E}[Pr(\sigma_t = \sigma_G \cap \sigma_{t+1} = \sigma_G \cap ... \cap \sigma_{x^*} = \sigma_G|p_{t-1}][p_{x^*}\alpha \frac{I_t}{I} - I_t] - c \geq 0, \quad (15)$$

which simplifies further to

$$\mathbb{E}\, U_t(signal|\Omega_t) = [p_{t-1} s_G^{x^*-t+1} + (1-p_{t-1}) s_B^{x^*-t+1}][p_{x^*}\alpha \frac{I_t}{I} - I_t] - c \geq 0, \quad (16)$$

where p_{t-1} indicates the beliefs of the agent who moves in period t given that all preceding agents back the project. Thus, solving the maximization problem coincides with deriving: i) the minimum value of equity the entrepreneur needs to offer; and, ii) the corresponding amount that each agent $t \in \{1, ..., x^*\}$ should invest I_t, such that the participation constraint binds. The optimal contract is given in Proposition 1.

A.4 Proof of Corollary 1

Suppose that the contract does not determine the backing amount of each agent. First, we show that an agent who moves in period t does not have an incentive to choose a backing amount $I_t < I_t^*$, where I_t^* is given by (7). If $I_t < I_t^*$, then, all else equal, agent t's participation constraint (16) would be violated as the LHS of (16) is decreasing in I_t (as $p_{x^*}\alpha^* > I$) and the RHS of (16) is independent of I_t and always equal to zero. Second, agent t finds it suboptimal to choose a backing amount $I_t > I_t^*$. The intuition is different than in the case where $I_t < I_t^*$. Note that if $I_t > I_t^*$, the amount $I - I_t$ that is left to be covered by other backers decreases. Note that the LHS of (16) is a decreasing function of the backing amount; thus, the lower amount left to be covered by the remaining backers discourages them to gather information and back the project, and, as a result, the project fails to reach the necessary number of backers, thus, its financing does not take place. Therefore, $I_t > I_t^*$ corresponds to negative expected profits, as the project is not financed but agent t suffers the cost c of gathering information. The only case where the project is financed is when $I_t > I_t^*$ and $I_1 + ... + I_t = I$, but in this case, investing in the project generates a negative return.

A.5 Proof of Proposition 2

A crucial feature of the optimal contract, provided in Proposition 1, is the financing target. A similar target arises in this setting as well. In Proposition 1, the target refers to the number of backers that are required for the project to be financed. In contrast, in a setting where agents move simultaneously, this target refers to the number of potential investors that the entrepreneur approaches, i.e., offers a contract to. Definition 2 sheds light on the feasible values of this target. Definition 2 is the analog of Definition 1, with the only exception that the entrepreneur gathers signals simultaneously.

Definition 2. *Suppose that there is no agency problem and the entrepreneur acquires signals simultaneously. The entrepreneur finds it optimal to gather the largest number of signals for which the following condition is satisfied*

$$(p_0 s_G^x + (1-p_0)s_B^x)(p_x - I) - xc - ((p_0 s_G^x + (1-p_0)s_B^x)(p_{x-1} - I) - (x-1)c) > 0 \qquad (17)$$

where p_j stands for the posterior beliefs that $\theta = H$, given that j consecutive good signals have been observed. We define as $\underline{z}$ the largest natural number x which satisfies (17)*.*

Lemma 6. *Under the optimal contact, the number of potential investors that the entrepreneur approaches is $\tilde{x} \in [k, \underline{z}]$, and the project is financed if all agents back the project. The optimal value $\tilde{x}^*$ is the largest natural number n that satisfies*

$$p_{n-1}\tilde{\alpha}_n^* \leq I \qquad (18)$$

where

$$\tilde{\alpha}_n^* = \frac{I[p_0 s_G^n + (1-p_0)s_B^n] + cn}{p_0 s_G^n}.$$

The intuition behind Lemma 6 is identical to the intuition in Lemma 2 and Lemma 3.

Finally, as the game is symmetric, $I_i = \frac{I}{\tilde{x}^*}$ for each $i \in \{1, .., \tilde{x}^*\}$. Combining Lemma 6 with symmetry, the maximization problem pins down to:

$$\underset{\tilde{\alpha}}{\text{Maximize}} \quad \mathbb{E}[Pr(\sigma_1 = \sigma_G \cap \sigma_1 = \sigma_G \cap ... \cap \sigma_{\tilde{x}^*} = \sigma_G)|p_0][p_{\tilde{x}^*}(1-\tilde{\alpha})]$$

$$\mathbb{E}\, U_i(signal|\Omega_i)) \geq 0, \tag{19}$$

where

$$\mathbb{E}[Pr(\sigma_1 = \sigma_G \cap \sigma_1 = \sigma_G \cap ... \cap \sigma_{\tilde{x}^*} = \sigma_G)|p_0][p_{\tilde{x}^*}(1-\tilde{\alpha})] = [p_0 s_G^{\tilde{x}^*} + (1-p_0)s_B^{\tilde{x}^*}](1-\tilde{\alpha}),$$

$$\mathbb{E}\, U_i(signal) = Pr(\sigma_1 = \sigma_G \cap \sigma_2 = \sigma_G \cap ... \cap \sigma_{\tilde{x}^*} = \sigma_G|p_0)[p_{\tilde{x}^*}\tilde{\alpha}\frac{1}{\tilde{x}^*} - \frac{I}{\tilde{x}^*}] - c \geq 0, \tag{20}$$

which simplifies further to:

$$\mathbb{E}\, U_t(signal) = [p_0 s_G^{\tilde{x}^*} + (1-p_0)s_B^{\tilde{x}^*}][p_{\tilde{x}^*}\tilde{\alpha}\frac{1}{\tilde{x}^*} - \frac{I}{\tilde{x}^*}] - c \geq 0. \tag{21}$$

The solution to the maximization problem is summarized in Proposition 2.

A.6 Lemma 7

Lemma 7. *When the entrepreneur is cashless and negative transfers are not allowed, it is not feasible for the entrepreneur to gather information from a market analyst, unless the latter invests in the project in exchange for equity.*

Proof. Recall that, by Assumption 1, neither the signal acquisition nor the signal realization is observable; thus, the entrepreneur needs to provide incentives to the analyst. Similar to the benchmark model, the entrepreneur should offer a contract that satisfies two sets of constraints. First, the analyst should have an incentive to gather information. Also, conditionally on gathering a signal, the analyst should find it optimal to reveal it truthfully. Finally, note that the entrepreneur finds it optimal to incentivize information acquisition only if the recommendation is pivotal, i.e., the project has a positive NPV if the signal is good, and a negative NPV otherwise.

To be consistent with the main model, suppose that conditional on acquiring information, the analyst observes a good ($\sigma = \sigma_G$) or bad ($\sigma = \sigma_G$) signal, where $Pr(\theta = H|\sigma = \sigma_G) > Pr(\theta = H|\sigma = \sigma_B)$. We consider contracts which are contingent on the observables, namely, the recommendation of the analyst, $\tilde{\sigma} = \{\tilde{\sigma}_G, \tilde{\sigma}_B\}$ and the realized demand, θ. First, note that, by construction, the demand is realized only if the project is implemented. Second, note that the project is implemented only when the recommendation is good, conditionally that the analyst reveals her signal truthfully. Therefore, the contract the entrepreneur offers to the analyst consists of three components, $W = \{w_H, w_L, w\}$, where w_H (w_L) stands for the payment when the analyst issues a good recommendation, the project is implemented, and the demand turns out to be high (low). Also, w stands for the payment when the analyst issues a bad recommendation, which cannot be contingent on future demand. The latter is true because the project is not implemented; thus, the demand is not realized. Based on those remarks, an informed analyst has an incentive to reveal her private signal truthfully, as long as the incentive compatibility constraints below are satisfied, i.e.,

$$\mathbb{E}\,U(\tilde{\sigma} = \tilde{\sigma}_G|\sigma = \sigma_G) \geq \mathbb{E}\,U(\tilde{\sigma} = \tilde{\sigma}_B|\sigma = \sigma_G) \implies Pr(\theta = H|\sigma = \sigma_G)w_S + Pr(\theta = L|\sigma = \sigma_G)w_F \geq w$$

$$\mathbb{E}\,U(\tilde{\sigma} = \tilde{\sigma}_B|\sigma = \sigma_B) \geq \mathbb{E}\,U(\tilde{\sigma} = \tilde{\sigma}_G|\sigma = \sigma_B) \implies w \geq Pr(\theta = H|\sigma = \sigma_B)w_S + Pr(\theta = L|\sigma = \sigma_B)w_F$$

Combining these two constraints pins down to:

$$Pr(\theta = H|\sigma = \sigma_G)w_S + Pr(\theta = L|\sigma = \sigma_G)w_F \geq w \geq Pr(\theta = H|\sigma = \sigma_B)w_S + Pr(\theta = L|\sigma = \sigma_B)w_F \tag{22}$$

Note that the optimal payment when the recommendation is bad is $w^* = 0$. This is the case because negative transfers are not allowed, and, following a bad recommendation, the entrepreneur drops the product; thus, she remains cashless. Therefore, given that $Pr(\theta = H|\sigma = \sigma_G) > Pr(\theta = H|\sigma = \sigma_B)$, the only way for condition (22) to hold is if $w_F < 0$, which would imply negative transfers. Thus, there is no feasible contract that induces the analyst to reveal her private signal truthfully. As a result, if the entrepreneur is cashless, she cannot gather information via an analyst, unless the latter invests in the project in exchange for a stake in the company. Note that this is the case because $w_F^* < 0$ could be interpreted as the analyst investing the absolute value of w_F^* in the project, in exchange for w_S^*, if the project turns out to have high demand. □