Rethinking Crowdfunding Platform Design: Mechanisms to Deter Misconduct and Improve Efficiency

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Abstract

Lacking credible rule enforcement mechanisms to punish misconduct, existing reward-based crowdfunding platforms can leave backers exposed to two risks: entrepreneurs may run away with backers' money (funds misappropriation) and product specifications may be misrepresented (performance opacity). We show that each of these risks can materially impact crowdfunding efficiency, and when jointly present, they interact with each other in ways that can dampen or, more worryingly, amplify their individual adverse effects. To mitigate these risks, we propose two mechanisms based on deferred payments. The first involves stopping the campaign once the funding goal is reached, and servicing any unmet demand in the aftermarket. The second involves escrowing any funds raised in excess of the goal, as insurance for backers. We show that early stopping dominates escrow and boosts platform revenues. Pairing these deferred-payment designs with (costly) performance verification contingencies can bring additional gains, but doing so can flip their relative performance, with escrow coming out on top. Overall, by accounting for different timing (pre- vs. post-campaign) and enforcement rules (mandatory vs. optional) of the verification contingencies, we analyze a total of ten different designs and show that two of them dominate: the early stopping design, and the escrow design with mandatory ex-post verification. We conclude by providing recommendations for which design works best under different conditions, and exploring the potential of crowdsourced performance checks.

Keywords: Crowdfunding, New Business Models, Online Platforms, Moral Hazard, Entrepreneurship.

1 Introduction

Long before the Apple Watch, there was Pebble, the first smartwatch, brought to the world via the largest reward-crowdfunding platform, Kickstarter. Pebble's campaign raised over $10 million dollars directly from consumers (aka "backers"), who were promised a future reward (e.g., a smartwatch) in exchange for their money (Pebble Campaign 2012). Similar success stories have become increasingly commonplace over the past few years, attesting to the remarkable growth that

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reward-based crowdfunding (henceforth crowdfunding) has experienced and to its viability as an alternative means of financing for early-stage ventures.

Inevitably, we tend to hear mostly about the success stories, but not all crowdfunding projects end so. For every ten or so success stories on Kickstarter, there is one that does not end well, one in which customers who pledged money on a given project either get a product that is not in line with what was promised, or get nothing altogether (Kickstarter.com 2015). Take for example Zano, the drone project whose Kickstarter campaign raised over $3.5 million in 2015, making it the most successful Kickstarter in Europe at the time. Unfortunately for its backers, the Zano project had advertised performance specifications during the campaign that the company was never able to meet. In fact, there is evidence suggesting that the company doctored campaign materials to claim advanced features, such as automatic obstacle avoidance, that were never there to begin with. In the end, backers were dismayed to find out that the drones lacked many of the promised features (Harris 2016).[1] There are, however, even worse outcomes. The campaign for Popslate2, a multi-function smart case for iPhone, raised over $1.1 million in early 2016. Backers were thus highly disappointed when, one year later, the entrepreneur informed them that no product would be delivered, citing insurmountable technical problems, and no refunds would be issued: backers lost their money, and yet received no product (Torres 2017).[2]

In some ways, it is quite an achievement for Kickstarter that about nine projects out of ten deliver satisfactorily. After all, pledging money on a crowdfunding campaign is not the same as buying online from an established vendor: financing an ongoing project comes at a risk, a fact that Kickstarter makes abundantly clear to backers in its marketing materials. This achievement is all the more surprising considering platforms do not vet campaigns in depth, and when things go bad there is limited accountability: platforms tend to absolve themselves from any responsibility, leaving individual backers to find an unlikely compromise with the entrepreneur. In these cases (Mollick 2015) ˜90% of the time backers received no form of compensation. Further compounding the issue is that the current regulatory framework is highly uncertain, and the legal landscape surrounding failed crowdfunding projects is still largely untested. As a result, lawsuits are also very rare.

These facts highlight two of the main risks that crowdfunding backers face. The first relates to

[1] Other extremely well-funded campaigns that substantially under-delivered on the promised features include: the 15-features Baubax jacket ($9.1 million), the Gravity weighted blanket ($4.7 million), and the Kreyos Meteor watch ($1.5 million).

[2] Other projects that are yet to provide information for when the product will be ready years after their campaign ended include: Project Phoenix ($1 million), The Dragonfly Futurefön ($726,000), iBackPack ($720,000) and Yogventures ($576,000).

information asymmetry regarding the claimed performance of the product, as in the Zano example above. Backers do not get a chance to see or try the product, having to rely instead on what the entrepreneur chooses to report in the campaign page---and since this information is not verified by the platform, there is ample room for misrepresentation of product features and performance. Henceforth, we refer to this risk as *performance opacity.* The second risk relates to moral hazard: once funds are raised, entrepreneurs may not act in the best interest of their backers. For instance, funds could be misappropriated as soon as the campaign ends, before product development is attempted. And even when development is attempted in good faith, there is always a risk that development hits a roadblock that prevents the entrepreneur from completing and delivering the product — and using the remaining funds to refund backers may not always be the most profitable option for the entrepreneur. We refer to the risk that the entrepreneur keeps backers' money despite not delivering the product as *funds misappropriation.* These are alarming facts for crowdfunding as a business model, which crucially hinges on the premise that backers trust with their money entrepreneurs they have never met and products they have never seen. Misconduct enacted on the part of some entrepreneurs may erode the trust that people place in crowdfunding platforms and threaten the very existence of this business model.

An unintended catalyst for these misconduct risks may be the somewhat simplistic mechanism used by platforms to regulate how entrepreneurs collect money from the crowd. Currently, all major crowdfunding platforms operate using an all-or-nothing mechanism. The way it works is simple. The entrepreneur creates a campaign page on the platform's site, choosing a pledge price and a funding goal. Any visitor may decide to back the project by paying the pledge price before the campaign ends, usually after a month. If at the end of the campaign the sum of all the pledges is equal to or higher than the goal, then the project is a success—the entrepreneur receives all the pledges minus a percentage fee that goes to the platform, usually around 5%, and promises each backer a unit of the product once it becomes available, typically months later. If instead the goal is not reached, backers are refunded in full, and the entrepreneur and the platform receive nothing.

At a first glance, the all-or-nothing mechanism appears an ideal choice for crowdfunding platforms, given its successful application in other crowdsourcing context --- notably group buying schemes, where an established vendor sells an existing product or service at a discount only if a certain number of customers decide to buy it (Edelman et al. (2016),Marinesi et al. (2017)). In hindsight, however, it is apparent that group buying and crowdfunding differ in several important ways, with the latter exhibiting a much higher uncertainty in terms of product performance, development and delivery, not to mention the surrounding regulatory framework. From this perspective, the all-or-nothing mechanism appears ill-equipped to deal with these types of risks.

Despite the relation that inevitably exists between crowdfunding platform mechanisms, the entrepreneur's incentive for misconduct, and the consequent risk that is born by backers, there is surprisingly little research that seeks to study the details of their interactions and inform on more efficient platform design choices. This paper seeks to shed light on this issue. In particular, we analyze the two aforementioned sources of misconduct risk, the inefficiencies they create, and their implications on entrepreneur profits and total welfare. We then propose and compare simple and implementable platform design improvements aimed at restoring the efficiency lost due to such risks. In a nutshell, and as we will lay out throughout the course of the paper, our study shows that in the presence of strategic agents, typical crowdfunding platform rules can lead to a host of severe inefficiencies including untruthful claims, an adverse self-selection of entrepreneurs that choose crowdfunding over other sources of funding, and suboptimal decisions. Fortunately, our study also shows that these inefficiencies can be curbed by implementing relatively simple design changes at the platform level.

More specifically, we model an entrepreneur seeking to raise funds to finalize the development of a product, either via crowdfunding, or via an alternative funding channel, i.e., bank funding — the presence of an alternative channel is important to understand the full extent of misconduct risks and their implications. The project is subject to two risks typical of new product development: market risk, that is, the market size for the product is unknown, and development risk, that is, if financed, product development turns out to be infeasible with some probability. We first study a benchmark case that considers market and development risk, but does not consider misconduct risks. In this case, we show that crowdfunding is superior to bank funding because it provides the entrepreneur with an informational advantage that mitigates market risk: by leveraging consumer feedback, she can develop the product only when the underlying market for the product is large enough to justify the development cost.

We then introduce misconduct risks by allowing the entrepreneur to strategically exploit current crowdfunding platform rules (assuming lack of recourse and involvement of the crowdfunding platform, which is consistent with practice). First, we model the risk of *funds misappropriation* by giving the entrepreneur the choice, if development fails, to either use any remaining funds to refund backers, as she is supposed to, or instead keep the funds and incur a penalty cost (e.g., expected cost of a lawsuit). Second, we capture *performance opacity* by making product performance private information to the entrepreneur.

We establish that both risks reduce total welfare and entrepreneurs' aggregate profit, despite originating from the entrepreneurs' attempt to exploit platform rules to increase own profit. However, some individual entrepreneurs with particularly under-performing projects can benefit from performance opacity and earn a higher profit. We also find that the effect of the joint presence of funds misappropriation and performance opacity is not the mere sum of their individual effects: the two risks interact with one another. We show that the interaction between the two dampens their adverse effects in situations in which misconduct is severely punished; more worryingly, their interaction exacerbates their adverse effects in situations in which misconduct is at best mildly punished—which well represents the contemporary crowdfunding environment.

To mitigate entrepreneurial misconduct, we propose two deferred-payments mechanisms. The first, termed Maximum-Aftermarket (MA), involves stopping the campaign once the funding goal is reached, and servicing any unmet demand in the aftermarket. The second, termed Platform Escrow (PE), involves escrowing any funds raised in excess of the goal, as insurance for backers. Previous research has shown that deferred payments are optimal (can restore full efficiency) in the presence of funds misappropriation. We find that this message changes drastically once performance opacity is also taken into account: in our setting, neither MA nor PE can fully restore efficiency. Moreover, these two designs perform differently from one another, and in particular, MA outperforms PE.

In light of this result, we examine whether pairing deferred payments with (costly) inspections can further improve efficiency. We identify three design dimensions, the deferred payment mode (PE or MA), the timing of inspection (before the campaign is launched, or after development is completed), and the enforcement rules for inspections (required by the platform or as an option for the entrepreneur) and explore the full Cartesian product of this design space, for a total of eight designs. Evaluating all the mechanisms considered, both with and without inspections, would lead to over 40 pairwise comparisons and can thus be potentially quite involved. Fortunately, we can show that it is always possible to restrict the consideration set to only three mechanisms without any loss to welfare or aggregate entrepreneurs' profit, given that all the remaining mechanisms are always dominated. Moreover, we find that in most cases the consideration set can be further shrunk to just two mechanisms with no consequences. These are the Maximum Aftermarket design (MA), and the Platform Escrow design with ex-Post mandatory verification ($PE - V$). This pair of designs turn out to always dominate all other designs even when the objective function is not maximizing welfare or aggregate entrepreneurs' profit, but rather maximizing crowdfunding adoption. Thus, despite the fairly large number of mechanisms considered in our study, our search for the best crowdfunding mechanism yields a surprisingly neat result—that platforms need to consider just two designs.

We conclude by proposing a way to crowdsource performance checks in the $PE-V$ mechanism that holds the potential to make crowdsourced performance checks both very cheap and incentive-compatible, thus achieving full efficiency.

2 Literature Review

The literature on crowdfunding is recent but rapidly growing. Closest to our work is Strausz (2017). At a broad level, both his work and ours are concerned with entrepreneurial misconduct risk, and propose mechanisms aimed at deterring it. However, our works consider different risks, and reach different conclusions. We consider performance opacity, which is not studied in Strausz (2017). Moreover, while Strausz (2017) considers *pre*-development funds misappropriation, we consider *post*-development funds misappropriation, a different and more severe form a moral hazard. Among our findings, we show that the main takeaway from Strausz (2017), that (all) deferred payment schemes are optimal, no longer holds in the presence of performance opacity. Moreover, we show that the details of implementation are a key element that drives efficiency, and not all deferred payment schemes are created equal, which, in turn, motivates us to broaden our search and evaluate several additional designs.

Chakraborty and Swinney (2017), similarly to us, consider a setting in which product quality is private knowledge of the entrepreneur. Their focus is on whether and how an entrepreneur can, within the boundaries of *existing* crowdfunding rules, set the parameters of the campaign to signal, at a cost, the quality of her product to backers. Our focus is instead on the design of *new* crowdfunding rules in order to overcome misconduct risks and restore efficiency.

Other analytical works have considered relevant, albeit different problems in crowdfunding, including product line decisions (Hu et al. (2015)), informational cascades (Alaei et al. (2016)), demand sampling (Chemla and Tinn (2018)), price discrimination (Sayedi and Baghaie (2017)), how crowdfunding affects venture capital and bank financing (Babich et al. (2017)), information spillover effects (Chen et al. (2017)), the use of contingent stimuli (Du et al. (2017)), and revenue management (Zhang et al. (2017)). None of these papers focus on the design of platform mechanisms, which is the focus of our work. The empirical literature on crowdfunding is also rapidly growing and we do not attempt to provide an overview. For a recent, extensive review of crowdfunding papers, we refer the reader to Moritz and Block (2016).

More generally, beyond crowdsourcing funds, our paper is also related to the broader literature on crowdsourcing information (e.g Marinesi and Girotra (2012), Papanastasiou and Savva (2016), Marinesi et al. (2017), Falk and Tsoukalas (2018)) and/or innovation (e.g.Terwiesch and Xu (2008), Bimpikis et al. (2019)) directly from consumers.

Lastly, our work is related to the finance/OM interface literature which, among other things, examines how firms should be financing their operations in the presence of market frictions. Early works include (Babich and Sobel 2004), and (Xu and Birge 2004) who explore how financing constraints can affect a firm's capacity choice. We refer the reader to (Kouvelis et al. 2011) for early work in this area. More recent works include Boyabatlı et al. (2015), Iancu et al. (2016), Tang et al. (2017), Chod et al. (2018), Chod et al. (2019), Gan et al. (2019). In contrast to our work, these papers study traditional financing methods such as debt and equity, with the exception of Chod et al. (2018), Gan et al. (2019), who study financing using blockchain-based systems.

3 Base Model - No Misconduct Risks

In this section, we study a base model of crowdfunding in the absence of misconduct risks. This model will serve as a benchmark for the rest of the analysis: misconduct risks—funds misappropriation and performance opacity—are introduced in Section 4.

Consider an entrepreneur who has invested her savings to develop a functioning prototype of a new product. Let v be a number that summarizes the performance of her prototype, such that more is better (e.g., the duration of a battery, the resolution of a scanner, etc.) and let it be the realization of a random variable V with pdf f over the support $[\underline{v}, \bar{v}]$. For now, we assume that v is common knowledge (we relax this in Section 4). In order to finalize product development (e.g., quality testing, design for manufacturing, etc.) the entrepreneur needs to invest I, which she can attempt to raise either through crowdfunding or bank funding; we describe each funding channel and model the entrepreneur's choice between the two channels further below.

Development yields one of two outcomes. With probability $1 - \delta$, it uncovers unforeseen and irreparable obstacles that lead to the project being terminated and all invested funds being lost. With probability $\delta \in (0, 1)$, development is instead a success, and a product with performance v can be manufactured and sold to customers. Without loss of generality, we assume zero marginal production cost for the final product (for details, see the proof of Lemma 2 in the Online Appendix).

The market comprises a mass $X \cdot (1 + \gamma)$ of infinitesimally small customers. Here X is a Bernoulli r.v. equal to x_h (the *high* market state) with probability $\alpha \in (0, 1)$ and equal to x_l (the *low* market state) otherwise, $x_h > x_l > 0$, and $\gamma > 0$ is an exogenous parameter that regulates the composition of the customer population. Specifically, X is the mass of "online customers" (customers that participate in crowdfunding), and γX is the mass of "offline customers" (customers that participate only post crowdfunding, once the product has been developed). Section 3.2 provides a detailed

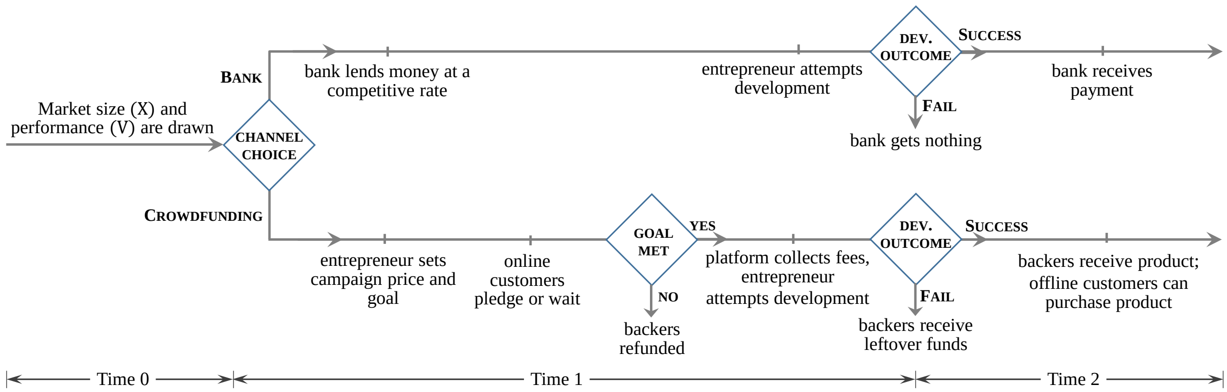

Figure 3.1: Timeline of events in the base model (no misconduct risks)

description of customers and their strategic behavior. Customers' valuation for the product is equal to product performance v. Let $\pi(v|X) = -I + \delta v X(1+\gamma)$ be the profit generated by the project in state X when the entrepreneur can fund the project herself (i.e., upon investing I, with probability δ the product is sold to $X(1+\gamma)$ customers at a price v). To rule out uninteresting cases, we assume that development is not profitable in the low state, but is profitable in the high state.[3] All players are risk neutral.

The timeline of events is depicted in Figure 3.1. At time 0, the market size X and performance V are drawn. Players know the market size probability distribution (i.e., they know α) but do not observe the realized market size (x_h or x_l). All other parameters of the game, including performance v, are common knowledge (this will be relaxed in Section 4). At time 1, the entrepreneur chooses between crowdfunding and bank funding. For simplicity, assume that when indifferent between the two channels, the entrepreneur chooses crowdfunding. Next, we describe the sequence of events separately for each of the two funding channels (Sections 3.1 and 3.2), and then present the full equilibrium that endogenizes the entrepreneur's channel choice (Section 3.3). For extensions to the base model, see Section 6 and the Online Appendix Section A.1.

3.1 Bank Funding (B)

At time 1, the entrepreneur can attempt to raise I from a bank operating in a competitive lending market (the bank breaks even in expectation): see Figure 3.1, top branch. If the bank decides to lend I to the entrepreneur, at time 2 she repays the bank to the best of her ability by using the profit accrued from the sale of the product, that is, she pays the minimum between the profit

[3] In particular, we assume $\pi(v|x_l) \leq 0$, $\pi(v|x_h) > 0 \; \forall v \in (\underline{v}, \bar{v})$, and that $\mathbb{E}_X[\pi(\bar{v}|X)] > 0$ so that bank funding is feasible for some entrepreneurs. The use of a two-state model with a "good" and a "bad" state is standard in the literature (e.g., Chemmanur and Chen (2014), Ueda (2004)) and in our context suffices to capture the risk/reward nature typical of product development.

and $I(1+i)$, where i is the interest charged by the bank (determined endogenously by setting the bank's profit to zero). In equilibrium, the entrepreneur's profit follows from the Modigliani Miller theorem (due to absence of market frictions) and is equal to $\Pi_B(v) = -I + \alpha\delta\mathbb{E}[X](1+\gamma)$, where subscript B indicates the bank funding channel. Bank funding is feasible if and only if v is higher than a threhsold $v_0 \triangleq I[\delta\mathbb{E}[X](1+\gamma)]^{-1}$, obtained by setting $\Pi_B(v) = 0$, since for lower values of v the project does not generate enough revenues to cover its cost.

3.2 Crowdfunding (C)

At time 1, the entrepreneur can alternatively attempt to raise I by launching a crowdfunding campaign (Figure 3.1, bottom branch). We model crowdfunding following the all-or-nothing design employed by most crowdfunding platforms. As customary in the industry, the platform appropriates a fraction β of the funds raised by the entrepreneur.

At time 1, when launching the crowdfunding campaign, the entrepreneur sets the in-campaign price p_C and the funding goal t_C (Online Appendix Lemma 1 specifies the equilibrium outcomes). Online customers (total mass X) observe both and independently choose whether to back the campaign, or defer their purchasing decision to later, after the campaign is over and development uncertainty has been resolved. If the total amount pledged by online customers (henceforth *backers*) is less than the funding goal, the campaign fails: the platform refunds all backers and the product is not developed. Otherwise, the campaign is successful: the platform collects the fee β on the funds raised, the entrepreneur collects the remaining funds and attempts development.

At time 2, the outcome of the project is realized. With probability δ the product is developed successfully: the entrepreneur delivers the product to backers, and sets optimally an offline price $p_C^{off} = v$ (leaving customers with zero surplus), which she offers to all remaining customers (i.e. offline customers, total mass $X\gamma$) plus all online customers who have chosen not to pledge during the campaign. With probability $1-\delta$, development fails and the entrepreneur uses the remaining funds to refund backers.

We show that the pledge price p_C is strictly less than the retail price v. That is, the entrepreneur must offer a discount during the campaign in order to induce online customers to pledge instead of waiting, as they need to be compensated for the risk they bear: risk that development fails and they only receive a partial refund and no product. If the size of the online market is too small to fund a project ($x_h < I(\delta v(1-\beta))^{-1}$), no project can be funded via crowdfunding. Otherwise, crowdfunding is *viable,* i.e., the online market is large enough for the project to be funded via crowdfunding and the expected profit for the entrepreneur is

$$\Pi_C(v) = \alpha\delta\{-\frac{I}{1-(1-\delta)(1-\beta)} + \frac{\delta(1-\beta)}{1-(1-\delta)(1-\beta)}vx_h + vx_h\gamma\}, \tag{3.1}$$

where $\alpha\delta$ outside of the bracket accounts for the fact that the entrepreneur earns a profit only if the market size is high and development is successful, and the three terms in the bracket refer to the investment cost, online sales, and offline sales at the optimal price respectively.

3.3 Choice of Funding Channel: Crowdfunding vs. Bank Funding

Having established the entrepreneur's actions and resulting profits for each funding channel, we now derive her optimal choice between the two. For the comparison, and throughout the rest of the paper, we let $\beta \to 0^+$ to level the playing field and remove any cost advantage of one funding channel over the other (the impact of channel costs is straightforward). The analysis for the general case $\beta > 0$ yields the same qualitative results and can be found in the Online Appendix (Lemma 2). Let $\pi(v|X)$ be the profit when performance is v, conditional on the market state being X.

Lemma 1. *Suppose that crowdfunding is viable, i.e.* $x_h \geq I(\delta v)^{-1}$, $\forall v$*; then, the entrepreneur chooses crowdfunding over bank funding for all performance levels* $v \in [\underline{v}, \bar{v}]$*:*

$$\Pi_C(v) - \Pi_B(v) = \underbrace{(1-\alpha)|\pi(v|x_l)|}_{informational\,advantage} \geq 0. \tag{3.2}$$

All proofs are in the Online Appendix. The dominance of crowdfunding is explained by its *informational advantage*: by raising funds from customers themselves, the entrepreneur can garner direct information about the size of the online market, and indirect information about the size of the offline market. This allows the entrepreneur to pursue development in the profitable market state (x_h) and, more importantly, avoid development in the unprofitable state (x_l). In other words, somewhat paradoxically, the value of crowdfunding lies not so much in its ability to fund, but rather in its ability to prevent funding—prevent the entrepreneur from investing more money in a project that has a negative expected profit.

Henceforth, to avoid trivial cases, we assume that the market size in the high state is large enough to make crowdfunding viable, $x_h \geq I(\delta v)^{-1}$, $\forall v$ and we let the set of possible performance levels (i.e., the support of f) be as large as possible. In other words, we assume that the entrepreneur with the highest performance product, $V = \bar{v}$, breaks-even in the low state, and the entrepreneur with the lowest performance product, $V = \underline{v}$, can barely raise enough funds to develop the product in the high state. Formally, $\delta\underline{v}x_h = I = \delta\bar{v}x_l(1+\gamma)$.

4 Entrepreneurial Misconduct in Crowdfunding

This section revisits the advantage of crowdfunding over bank funding by studying the impact of funds misappropriation and performance opacity, two sources of risk that, albeit present to a different extent in all forms of funding, are particularly acute in crowdfunding. To ease exposition, we thus assume bank funding to be a frictionless channel. To better understand the implications of these misconduct risks, we first study each in isolation (funds misappropriation in Section 4.1 and performance opacity in Section 4.2) before considering their combined effect (Section 4.3). We use superscript $\phi \in \{O, M, OM\}$ to keep track of each case, where M stands for funds misappropriation, O for performance opacity, and OM refers to the presence of both.

The implication of misconduct risk will be measured using two metrics. For a given performance v, define the *crowdfunding profit loss* due to misconduct risk(s) $\phi \in \{O, M, OM\}$ as

$$\Lambda^{\phi}(v) = \Pi_C(v) - \Pi_C^{\phi}(v), \tag{4.1}$$

where the loss is measured relative to the benchmark crowdfunding profit $\Pi_C(v)$ in which neither funds misappropriation nor performance opacity is present (as derived in Section 3.2). A positive profit loss Λ^{ϕ} means that risk ϕ decreases the entrepreneur's profit compared to the benchmark.

Second, define the *efficiency loss* due to misconduct risk(s) $\phi \in \{O, M, OM\}$, as

$$\mathcal{L}^{\phi} = \int_{\underline{v}}^{\bar{v}} \min\left(\Lambda^{\phi}(v), \Pi_C(v) - \Pi_B(v)\right) f(v)\, dv, \tag{4.2}$$

where f is the pdf for performance V. The efficiency loss $\mathcal{L}^{\phi}$ represents the integral of the profit loss due to misconduct risk ϕ across all possible performance levels, accounting for the entrepreneur's choice of funding channel (via the *min* function inside the integral). By aggregating over all possible performance levels and internalizing the entrepreneur's channel choice, the efficiency loss $\mathcal{L}^{\phi}$ effectively captures the interest of multiple stakeholders: the entrepreneur, since it measures the reduction in her expected profit caused by risk(s) ϕ. The platform, since maximizing entrepreneurs' profit means delivering more value to entrepreneurs, and thus being in a position to appropriate more of it (e.g., by charging a higher fee). A central planner (e.g., the government) since consumer surplus in equilibrium is zero, meaning that $\mathcal{L}^{\phi}$ also measures the reduction in total welfare caused by risk(s) ϕ.

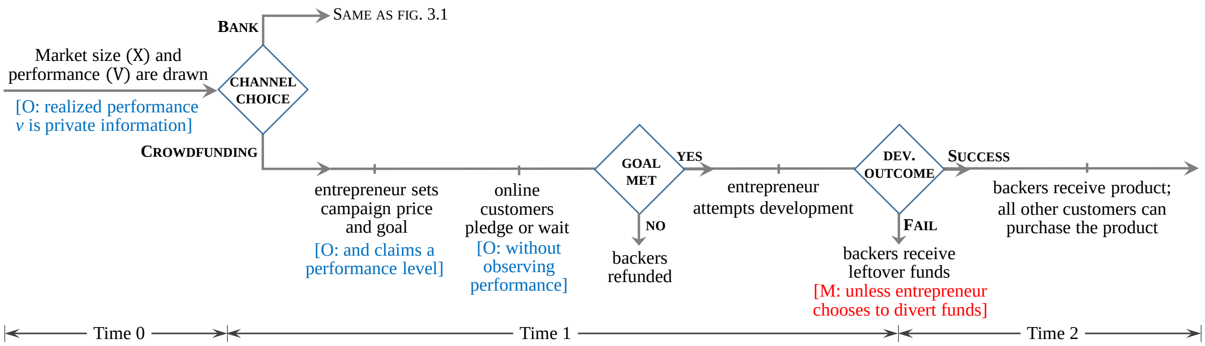

Figure 4.1: Timeline of events for crowdfunding, incorporating changes due to funds misappropriation (M) and performance opacity (O). *Changes with respect to Figure 3.1 are in square brackets to facilitate the comparison.*

4.1 Funds Misappropriation in Crowdfunding (M)

In this section, we expand the base model from Section 3 by allowing an option for the entrepreneur to misappropriate backers' funds without delivering them any product. Generally speaking, there are two moments in which the entrepreneur could decide to take backers' money and run. The first is right after the campaign ends, and the second is after attempting and failing development. We refer to these two cases as pre- and post-development funds misappropriation, respectively. Pre-development funds misappropriation never takes place when the offline market is sufficiently large: this is because, by misappropriating the funds right after the campaign, the entrepreneur gives up the chance to sell the product to the large offline market, making this a suboptimal decision. Post-development funds misappropriation may instead take place even when the offline market is sufficiently large: this is because, after failing development, the entrepreneur has no product to deliver, but, crucially, can still have substantial funds left.[4]

We thus focus our analysis on latter type of funds misappropriation (post-development) given that it persists even when the offline market is large. Figure 4.1 depicts the modified timeline. It incorporates changes due to funds misappropriation (which we examine next) and performance opacity (which we examine in Section 4.2).

Upon failing development, the entrepreneur may decide to misappropriate any leftover funds and incur a penalty cost R. The penalty cost R can be thought of as the product of the odds of being punished, times the costs associated with the penalty. These costs may include, among others, litigation costs, bankruptcy costs, reputation costs in the form of forgone future profits, the opportunity cost of time for the entrepreneur to make excuses and fend off accusations, etc. A higher R

[4] At Indiegogo, the second largest crowdfunding platform, 87% of all campaigns, conditional on reaching the goal, raise strictly more than their goal, exceeding it by 31% on average (Indiegogo 2011).

represents a more mature institutional environment, one in which an entrepreneur who misappropriates backers' money without delivering a product is punished more often or more harshly (e.g. a more solid legal framework, more control on the part of the Federal Trade Commission, etc.).

We use the term *funds misappropriation* to refer to a model that accounts for the possibility that the entrepreneur may misappropriate backers' funds, and the term *running* to refer to the case in which the entrepreneur actually chooses to misappropriate backers' funds. We use superscripts to indicate the assumptions with respect to the crowdfunding environment, e.g., we use Π_C^M to indicate the profit in crowdfunding (C) in the presence of funds misappropriation (M).

Equilibrium outcome and implications

In equilibrium (Online Appendix, Proposition 1) in the presence of funds misappropriation, crowdfunding attracts only entrepreneurs with low enough performance levels (Figure 4.2, panel a). That is, the presence of funds misappropriation drives an unfavorable selection of entrepreneurs into crowdfunding. This is in contrast to Lemma 1 where all entrepreneurs choose crowdfunding. The reason for this is best understood by rewriting profit gains from crowdfunding, $\Pi_C^M(v)-\Pi_B(v)$, as the difference of two terms, $(\Pi_C(v)-\Pi_B(v))-\left(\Pi_C(v)-\Pi_C^M(v)\right)$, obtaining

$$\Pi_C^M(v)-\Pi_B(v)=\underbrace{(1-\alpha)\left|\pi\left(v|x_l\right)\right|}_{informational\,advantage}-\underbrace{\Lambda^M(v)\,.}_{M\,profit\,loss} \tag{4.3}$$

The first term captures the informational advantage of crowdfunding discussed in the previous section. The second term, $\Lambda^M(v)$, captures the profit loss due to funds misappropriation (as defined in equation 4.1). Since the informational advantage decreases in v (see Section 3.3), and the profit loss due to funds misappropriation (weakly) increases in v (see Figure 4.2 b), entrepreneurs with a high enough performance prefer bank funding to crowdfunding. The shape of $\Lambda^M(v)$ is the result of two effects.

A first effect is that, as performance increases, so does backers' willingness to pay, hence more funds can be raised: this means that when performance is high enough ($v > v_{M2}$) the entrepreneur prefers running to refunding backers, and the penalty is incurred, otherwise ($v < v_{M2}$) she refunds backers. A second effect is that the entrepreneur may decide to charge backers a price lower than their willingness to pay, in order to limit the funds raised, as a way to commit not to run if development fails. Such behavior is chosen by the entrepreneur when performance is high enough to make running potentially tempting ($v > v_{M1}$) but low enough to make commitment not overly costly ($v < v_{M2}$).

As expected, funds misappropriation can reduce profit for the entrepreneur. However, it does so

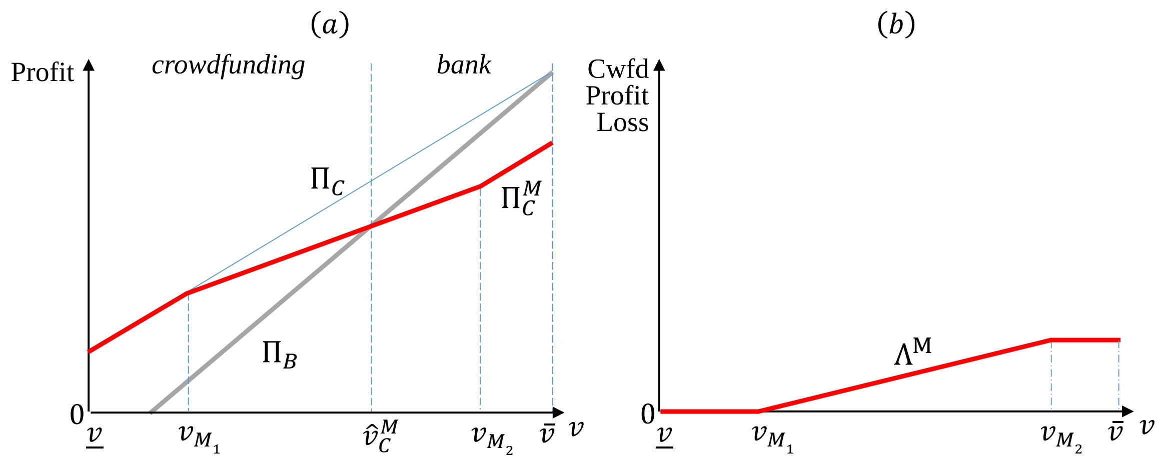

Figure 4.2: Entrepreneur's profit and channel choice (a), and crowdfunding profit loss (b), under funds misappropriation.

only if performance is high enough: profit of low performance entrepreneurs is unaffected because they don't raise enough money to make running worthwhile. As a consequence of the reduction in crowdfunding profit, efficiency loss is also positive.

4.2 Performance Opacity in Crowdfunding (O)

Having understood the adverse effects of funds misappropriation on crowdfunding, we now turn our attention to the impact of performance opacity. Performance opacity is, to different extents, present in all funding channels, since the entrepreneur typically knows more about the product than those who lend money to her. However, this information asymmetry can be reduced when lenders have the possibility to directly examine the product or a functioning prototype, try it, see what it can and cannot do, etc. In a purely online channel like crowdfunding, this is not possible. In the most informative crowdfunding campaigns, backers can at best read a product description and watch a short video one or two minutes long. In this context, misrepresenting product performance is easy. For this reason, we model performance opacity in crowdfunding only, and "normalize" the amount of performance opacity in bank funding to zero. This allows us to capture the difference in performance opacity across the two funding channels under study while avoiding extra notation and complexity.

4.2.1 Preliminary setup and analysis

We model performance opacity by letting product performance v, drawn from the density function f, be *private information to the entrepreneur* (the density f is still common knowledge). In this case, when launching the campaign, in addition to setting the in-campaign price and the funding goal, the entrepreneur makes a performance claim k, which is costless, non-binding, and non-verifiable by customers. Formally, the entrepreneur chooses a claiming strategy $\zeta_v(k) : [\underline{v}, \bar{v}] \times [\underline{v}, \bar{v}] \to [0,1]$ that specifies the probability that, conditional on observing v, she claims performance k (in particular, claims are truthful when $\zeta_v(k) = 1$ if $v = k$ and $\zeta_v(k) = 0$ otherwise). Naturally, the probability that type v claims any performance level must add up to one, $\int_{\underline{v}}^{\bar{v}} \zeta_v(k)\, dk = 1$.

Customers observe k and account for the claiming strategy $\zeta_v(k)$ to form rational expectations regarding the true performance of the product. From here, events unfold as before: if the goal is met and development succeeds, customers receive the product; if the goal is met and development fails, customers are refunded using the funds available; if the goal is not met, customers get a full refund. The resulting model has three distinct sources of risk that capture the uncertainty typical of a crowdfunding campaign: the potential demand for the product is uncertain (market risk), the true performance of the product is, at least for backers, uncertain (performance opacity), and the actual feasibility of the product is uncertain (development risk). Figure 4.1 depicts the modified timeline. It incorporates changes due to performance opacity (O) and also the effects discussed for funds misappropriation (M) (which we disregard for now and revisit in Section 4.3).

It can be shown that performance opacity hides the true performance of the entrepreneur in crowdfunding, even when she can have informal (costless, non-binding) communication with backers (Online Appendix, Lemma 3). This is because the goal of a crowdfunding campaign is to raise the largest sum possible: any claim that were to induce backers to pledge more money would be immediately mimicked by other entrepreneurs, thus removing any possibility that a given claim may signal higher performance and raise more funds than others.[5]

4.2.2 Equilibrium outcome and implications

Due to performance opacity, in equilibrium, customers take into account the entrepreneur's choice of the funding channel $j \in \{C, B\}$ to form an update on the entrepreneur's performance distribution, $f(v|j)$. At the same time, the entrepreneur's choice of the funding channel and pricing decision are optimal given customers' posterior beliefs over v. This leads to the outcome that entrepreneurs choose crowdfunding if and only if performance is lower than a threshold value $\hat{v}_C^O$ (Online Appendix, Proposition 2).

This result is directionally the same as the one observed under funds misappropriation (Section 4.1), but the underlying cause is different. As before, it is instructive to rewrite $\Pi_C^O(v) - \Pi_B(v)$

[5] When some backers are informed about the product's true performance, or when the relation between cost and performance is increasing and known to backers, signaling performance may be possible, at a cost—see Chakraborty and Swinney (2017) for such a model.

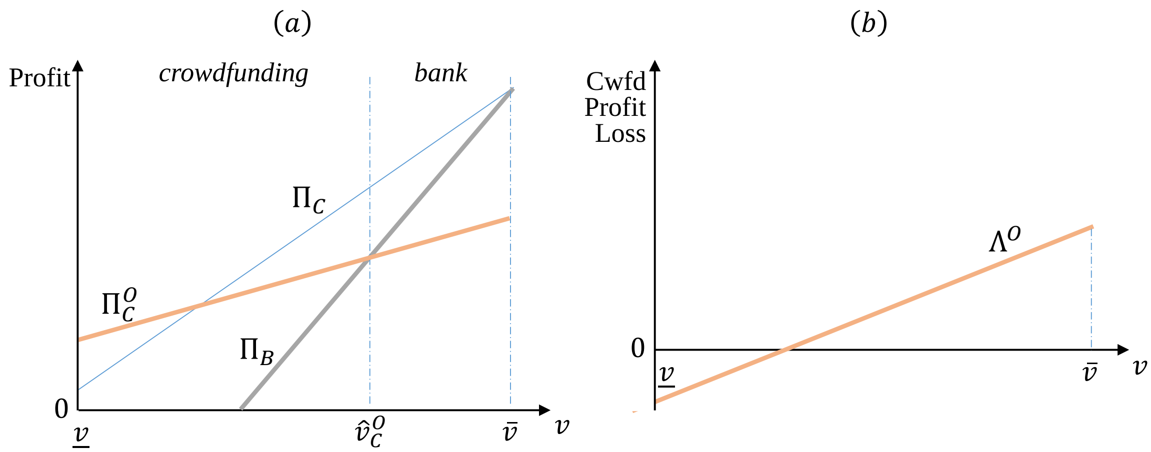

Figure 4.3: Performance opacity: equilibrium profit and channel choice (a), and crowdfunding profit loss (b).

as $(\Pi_C(v) - \Pi_B(v)) - \left(\Pi_C(v) - \Pi_C^O(v)\right)$, so as to decompose the profit gains from crowdfunding as the difference between two terms, obtaining

$$\Pi_C^O(v) - \Pi_B(v) = \underbrace{(1-\alpha)\,|\pi(v|x_l)|}_{informational\,advantage} - \underbrace{\Lambda^O(v)\,.}_{O\,profit\,loss} \tag{4.4}$$

The first term captures the informational advantage of crowdfunding, same as in equation 4.3, and is decreasing in v. The second term, $\Lambda^O(v)$, defined generally in equation 4.1 and specifically in equation A.1, captures the monetary consequences of performance opacity on profit, and is increasing in v. The effect of performance opacity is illustrated in Figure 4.3.

Due to performance opacity, the funds raised by the entrepreneur are a function of average crowdfunding performance, $\mathbb{E}^O[V|C]$, rather than true performance, v, resulting in a "flatter" profit function—compare Π_C^O to Π_C in Figure 4.3 (a). Because of performance opacity, the profit of entrepreneurs with higher-than-average performance is reduced, causing the best among them to prefer bank funding over crowdfunding. Their leaving reduces average performance (hence profit) in crowdfunding, triggering more entrepreneurs to choose bank funding. The resulting spiral of *adverse selection* is similar to what was first studied in Akerlof (1995), but it also differs in that some entrepreneurs continue to prefer crowdfunding. This is because, as more and more entrepreneurs choose bank funding over crowdfunding, the performance of the "top crowdfunder" decreases, making her performance more similar to the other crowdfunders', and performance opacity less harmful, while the informational advantage of crowdfunding increases. Eventually, the hemorrhage of high-performance entrepreneurs comes to a halt. In equilibrium, for the top crowdfunder, the informational advantage provided by crowdfunding barely compensates for the profit loss due to adverse selection. As a result of performance opacity, efficiency loss is positive, although some entrepreneurs with low performance may benefit from it (Figure 4.3 panel b).

4.3 Performance Opacity and Funds Misappropriation in Crowdfunding (OM)

So far we have studied the two sources of misconduct risk, funds misappropriation and performance opacity, in isolation. In this section, we analyze the implications of these risks when jointly present, as is the case in contemporary crowdfunding. In line with what was observed when the two forms of misconduct were present independently, we find that in equilibrium entrepreneurs choose crowdfunding if performance is low enough, $v \leq \hat{v}_C^{OM}$, and choose bank funding otherwise (Online Appendix, Proposition 3). However, the study of the joint presence of funds misappropriation and performance opacity leads to new insights. When jointly present, these two misconduct risks don't simply add up, but rather, they *interact with each other*. In what follows, we focus on the study of such interaction, its nature, and ultimately its impact on efficiency loss—hence, on the entrepreneur's profit and total welfare. To this aim, define the *interaction effect* as the difference between the efficiency loss under funds misappropriation and performance opacity when the two risks interact ($\mathcal{L}^{OM}$) and do not interact ($\mathcal{L}^{O+M}$) with each other. More formally, define the interaction effect as $\mathcal{L}^{OM} - \mathcal{L}^{O+M}$, with

$$\mathcal{L}^{OM} = \int_{\underline{v}}^{\bar{v}} \min\left(\Lambda^{OM}(v), \Pi_C(v) - \Pi_B(v)\right) f(v)\, dv,$$

$$\mathcal{L}^{O+M} = \int_{\underline{v}}^{\bar{v}} \min\left(\Lambda^{M}(v) + \Lambda^{O}(v), \Pi_C(v) - \Pi_B(v)\right) f(v)\, dv,$$

where the *min* operator accounts for entrepreneurs' endogenous channel choice. If $\mathcal{L}^{OM} - \mathcal{L}^{O+M} > 0$, the joint presence of performance opacity and funds misappropriation increases the efficiency loss compared to adding up the losses when each is present in isolation—the interaction effect is positive because the loss is amplified. If $\mathcal{L}^{OM} - \mathcal{L}^{O+M} < 0$, on the other hand, the joint presence of performance opacity and funds misappropriation reduces the efficiency loss compared to adding up the losses when each is present in isolation—the interaction effect is negative because the loss is attenuated. We now investigate the sign of the interaction effect.

Theorem 1. *The interaction effect is positive if the penalty cost is lower than a threshold value $\hat{R}$, and is negative otherwise. Formally,*

$$\mathcal{L}^{OM} - \mathcal{L}^{O+M} \textit{ is } \begin{cases} > 0 & \textit{if} \quad R < \hat{R}, \\ \leq 0 & \textit{if} \quad R \geq \hat{R}. \end{cases} \tag{4.5}$$

Managerial implications

Consider the result of Theorem 1 in light of contemporary crowdfunding. At present, entrepreneurs who successfully raise money in crowdfunding but fail to deliver see hardly any consequence. This maps to a low R scenario in our model, and, hence, to a positive interaction effect. This has several implications. First, it implies that funds misappropriation and performance opacity in crowdfunding are a more serious issue than what could be initially conjectured, due to their harmful *mutually reinforcing* consequences. Second, it implies that if one could remove performance opacity, the benefit would be larger than expected—in terms of entrepreneurs' profit and thus, by extension, in terms of fees that the platform can charge them. This result could therefore spur platforms into action, perhaps by inducing them to perform prototype testing before a campaign is launched. Third, we showed that as R increases, the interaction effect goes from being positive to being negative. This means that any effort on the part of platforms/regulators aimed at deterring running, e.g., tightening current regulation or increasing monitoring, would yield results that are higher than expected on the margin, but lower than expected eventually (i.e., once $R > \hat{R}$) if such efforts were pushed too far.

5 Rethinking Crowdfunding Platform Design

In this section, we examine whether funds misappropriation and performance opacity can be curbed by redesigning crowdfunding platform mechanisms (hereby also referred to as designs or schemes). A natural starting point for our analysis is Strausz (2017), who finds that the optimal mechanism to counter *funds misappropriation* (albeit pre-development, hence of a different kind from ours) is one that implements deferred payments, but he abstracts away from the details of implementation: in his model, the entrepreneur receives some funds at the end of the campaign, and the rest upon delivery of the product, without any information of how payments are actually deferred. Thus, two key questions remain unanswered. 1) Does it matter how deferred payments are implemented? 2) Are deferred payments still optimal in the presence of performance opacity? Our analysis in this section provides answers to both questions.

5.1 Assessing the Effectiveness of Different Deferred Payment Mechanisms

We now present two crowdfunding mechanisms that utilize deferred payments, but differ in the specific mode of implementation. In the Platform Escrow design (PE), when a campaign reaches the goal, the platform transfers to the entrepreneur only funds in the amount equal to the campaign goal, and keeps the rest in escrow.[6] Excess funds (i.e., those raised above the goal) are released to the entrepreneur if the product is developed successfully, and are instead used to refund backers if development fails. By deferring the payment of all the funds raised in excess of the goal and making the payment conditional on development, the PE design has the potential to curb funds misappropriation. In the MA design, a campaign stops accepting pledges as soon as the funding goal has been reached: only a subset of online customers pledge during the campaign, while everyone else waits to purchase the product after it is developed. The MA design implements deferred payments, as the PE design does, but minimizes the number of units sold during the campaign, at a discount (as seen in Section 3.2) thereby maximizing the number of units sold after development (the "aftermarket") at the full retail price. Note that the MA design reduces the funds raised during the campaign and it may appear to work against the incentive of platforms like Kickstarter, which earns a fee on the funds raised. In Section 6.1 we discuss why this is, in fact, not a problem.

We use subscript $d \in \{C, MA, PE\}$ to refer to the different crowdfunding designs, so that $\Pi_d^{\phi}(v)$ refers to the entrepreneur's profit under design d and misconduct risk ϕ when performance is v.[7] Equilibrium outcomes for PE and MA can be found in the Online Appendix (proof of Proposition 1). It should be noted that entrepreneurs are strategic, and take into account the constraints imposed by each mechanism when making decisions. Next, we proceed to evaluate the ability of these two designs to restore the efficiency lost due to entrepreneurial misconduct.

5.1.1 Restoring Efficiency under Funds Misappropriation

Proposition 1. *In the presence of funds misappropriation, under both the PE and MA designs, all entrepreneurs choose crowdfunding over bank funding, and efficiency loss is zero ($\mathcal{L}_{MA}^{M} = \mathcal{L}_{PE}^{M} = 0$).*

When the only form of misconduct is funds misappropriation, both designs successfully deter running by allowing the entrepreneur to collect only the money needed. Unexpectedly, the ability of MA to maximize full price sales does not make it a better design than PE, and in fact, they are equivalent in terms of efficiency loss (and also in terms of profit to the entrepreneur). This result can be understood by noting that the discount offered during a crowdfunding campaign originates from the need to compensate backers for the development risk they bear (if development fails, backers lose their money). By increasing the number of customers who wait for the product, and therefore who do not bear any development risk, the MA design is not reducing such risk, it is just allocating that risk to fewer backers—those who pledge during the campaign. As a consequence,

[6] The crowdfunding platform Pledgemusic.com has been employing escrow for several years now, as a way to deter misconduct. Indiegogo announced its plan to offer escrow as an option to entrepreneurs in the near future (Indiegogo (2018)).

[7] The efficiency loss defined in equation 4.2 is updated to $\mathcal{L}_d^{\phi} = \int_{\underline{v}}^{\bar{v}} \min\left(\Pi_C(v) - \Pi_d^{\phi}(v), \Pi_C(v) - \Pi_B(v)\right) f(v)\, dv$.

backers in the MA design bear more risk, and need to be offered a bigger discount, compared to backers in a PE design (details can be found in the proof of Proposition 1 in the Online Appendix).

As we are going to show next, these findings change quite radically once performance opacity is taken into account.

5.1.2 Restoring Efficiency under Funds Misappropriation and Performance Opacity

We now turn to the question of how effective are the two deferred payment schemes (PE and MA) at restoring efficiency once performance opacity is also taken into account. To facilitate the discussion, we next consider the case when performance opacity is the only form of misconduct. Our results remain unchanged when both funds misappropriation and performance opacity are taken into account, since both PE and MA deter funds misappropriation (see Lemma 4 in the Online Appendix).

Theorem 2. *In the presence of performance opacity:*

1. *The entrepreneur chooses crowdfunding if* $v < \hat{v}_d^O$, $d \in \{PE, MA\}$, *and chooses bank funding otherwise. Further,* $\hat{v}_{PE}^O < \hat{v}_{MA}^O < \bar{v}$;
2. PE *does not improve efficiency as compared to the traditional, all-or-nothing crowdfunding design* C; MA *improves efficiency over* PE *and* C, *but does not fully eliminate inefficiency due to performance opacity; formally,* $\mathcal{L}_C^O = \mathcal{L}_{PE}^O > \mathcal{L}_{MA}^O > 0$.

Neither of the proposed deferred payment designs is optimal (i.e., neither design achieves zero efficiency loss) under performance opacity. Entrepreneurs with a high enough performance have little to gain from the informational advantage of crowdfunding, and have a lot to lose from being bundled with lower-performance entrepreneurs, due to performance opacity, as discussed in Section 4.2. Therefore, the self-selection of high-performance entrepreneurs from crowdfunding to bank funding cannot be avoided, and efficiency loss is strictly positive. The MA design, however, can improve over the PE design thanks to its property of maximizing the aftermarket. By limiting the number of customers who pledge during a campaign at a time when performance is opaque, the MA design increases the number of customers who purchase in the aftermarket, when performance is instead observable. This means that the entrepreneur's profit is more sensitive to true performance in the MA design than in the PE design, and therefore, an entrepreneur with a high performance product finds the MA design more attractive than the PE design. As a result, MA attracts a pool of entrepreneurs that is larger in size, with better performance (on average) relative to PE, making backers willing to pledge a higher price in the former design than in the latter.

These findings highlight three important messages around the use of deferred payment schemes. First, once we account for the presence of both funds misappropriation and performance opacity in crowdfunding, deferred payment schemes are *no longer optimal*. Second, details of implementation are a key element that drives efficiency, and not all deferred payment schemes are created equal: *how* deferred payments are implemented does matter. And third, deferred payment schemes *can* reduce the inefficiency that comes with performance opacity despite the fact that they *cannot* deter entrepreneurs from misreporting performance: in the case of MA, efficiency is improved not by removing performance opacity but by reducing the number of customers that are exposed to misreported claims. In hindsight, it is in fact quite remarkable that deferred payment schemes can help at all in the presence of performance opacity.

5.2 Restoring Efficiency via Deferred Payments and Performance Checks

So far, we have considered mechanisms that operate in the absence of costly interventions, and found MA to be the best performing design. In this section, we expand our analysis by considering a new array of designs that employ *costly* performance checks as a way to restore efficiency—the cost of such checks being factored into efficiency loss—in the presence of both funds misappropriation and performance opacity. Before we proceed, it is important to note that for performance checks to work, performance needs to be objectively measurable: for instance, properties such as weight, size, battery duration and whether a functionality is there or not (e.g., is the product waterproof?) would be verifiable. Thus, performance checks may be a viable choice for some products, but not for others.

Let χ be the cost of a performance check, and let it be strictly positive.[8] At a high level, one can think of four possible ways to embed performance checks into crowdfunding mechanisms, obtained by combining i) whether having the product checked is left as a decision for the entrepreneur, as opposed to being mandatory for all campaigns and ii) whether the check is performed ex-Ante before the campaign is launched (Kickstarter rules mandate that a functioning prototype of the product must exist and be featured in the campaign before this can be launched) or ex-Post after the campaign is over and the development outcome is known. One can further combine each of these four ways of implementing performance checks with either of the two deferred payments schemes studied so far, PE and MA, generating a total of eight possible designs (Figure 5.1). We assume that when the ex-Post check is paired with a PE design, failing the check means that the escrow fund is used to refund backers. In each of these designs, the testing cost χ is incurred by the entrepreneur (for example via higher platform fees with an expected cost increase equal to χ): this ensures that, when checks are optional, they are undertaken only if the benefit to the entrepreneur

[8] We do not specify whether such tests are run by the platform with own resources or by a third party (e.g., a review website the platform decides to partner with) since this is inconsequential for the analysis.

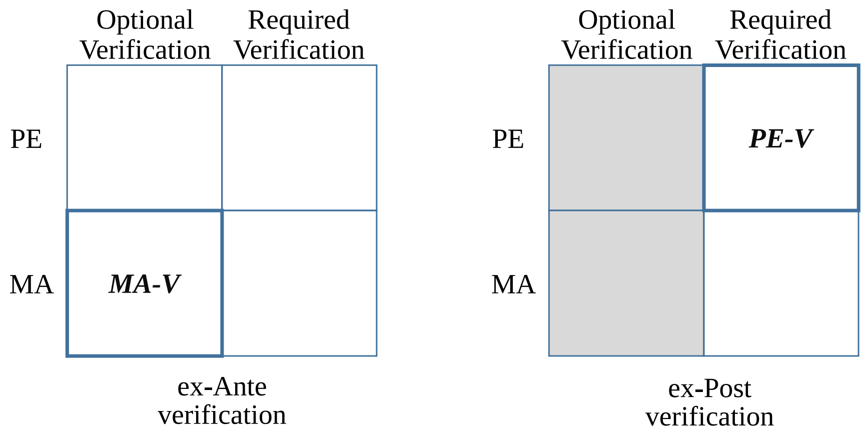

Figure 5.1: Space of designs that employ performance checks
Grayed-out designs: not considered due to equivalency with no-verification designs.

is worth the cost. Two of these eight designs, the ones with ex-Post optional checks (grayed-out in Figure 5.1) never lead to testing in equilibrium, making them equivalent to the designs without testing studied in the previous section: for this reason, we drop them from the analysis. Let $\mathcal{D}_t$ be the set that comprises the six remaining designs that employ testing. We have the following result.

Theorem 3. *The Platform Escrow design with ex-Post Required Verification ($PE-V$) and the Maximum Aftermarket design with ex-Ante Optional Verification ($MA-V$) dominate all other designs that employ performance verification. Formally,* $\min_{d\in\{MA-V,PE-V\}} \mathcal{L}_d^{OM} = \min_{d\in\mathcal{D}_t} \mathcal{L}_d^{OM}$.

Theorem 3 reduces the set of designs that need to be considered from six to just two. Interestingly, these two designs differ with respect to all the three design dimensions evaluated—deferred payments, enforcement and timing of performance checks.

More generally, Theorem 3 implies that *ex-ante checks work best when optimal and paired with the MA design*, while *ex-post checks work best when mandatory and paired with the PE design*. To understand why, it is useful to first observe that performance opacity has two types of effects on entrepreneurs, only one of which is actually harmful. In particular, we can decompose the efficiency loss caused by performance opacity into two effects that have very different implications:

$$\mathcal{L}^O = \underbrace{\int_{\underline{v}}^{\hat{v}_C^O} \left(\Pi_C(v) - \mathbb{E}\left[\Pi_C(v)\,|v < \hat{v}_C^O\right]\right) f(v)\,dv}_{revenue-leveling=0} + \underbrace{\int_{\hat{v}_C^O}^{\bar{v}} \left(\Pi_C(v) - \Pi_B(v)\right) f(v)\,dv.}_{adverse\,selection>0} \tag{5.1}$$

As a *direct* effect, performance opacity makes backers pledge based on expected performance in crowdfunding, rather than on true performance. This *revenue-leveling* effect (first term in the RHS of condition 5.1) is harmless, i.e., efficiency-neutral, in that it merely reallocates revenues and profit across different performance levels. This direct effect, however, induces an *indirect* effect: entrepreneurs with high-enough performance choose bank funding over crowdfunding. This *adverse selection* effect (second term in the RHS of condition 5.1) reduces efficiency because it pushes some high-performance entrepreneurs into choosing bank funding, thus renouncing the informational advantage of crowdfunding. It should also be noted that the (harmless) revenue-leveling effect affects entrepreneurs with relatively low performance products, while the (harmful) adverse-selection effect affects entrepreneurs with relatively high performance products. Distinguishing between the adverse selection and revenue-leveling effects of performance opacity is the key to understand the explanation behind Theorem 3.

Ex-Ante checks work best when optional and paired with the MA design

Ex-Ante checks remove opacity by revealing true performance before the campaign begins. Since performance checks are costly, the most efficient way to employ them would be to remove performance opacity's harmful consequence (adverse selection) but *not* to remove its harmless consequence (revenue-leveling). Further, tests aimed at removing adverse selection should be made only if the gains from doing them outweigh their cost, else should be forgone entirely. Unfortunately, this high-efficiency objective remains elusive due to performance being private information to the entrepreneur. However, as we are about to explain, optional ex-Ante checks perform closer to this ideal objective than mandatory checks do, making them a better design choice.

By testing all campaigns, (ex-Ante) mandatory checks generate inefficiency in two ways. The first source of inefficiency is the wasteful testing cost imposed on low-performance entrepreneurs, since this removes the *revenue-leveling* effect of performance opacity, which is harmless. The second, potential source of inefficiency of mandatory testing is the testing cost imposed on high-performance entrepreneurs. When the cost is high enough, this reduces their profits to a larger extent than performance opacity does, exacerbating *adverse selection* and further reducing efficiency.

These two sources of inefficiency are reduced or eliminated when ex-Ante checks are *optional*. The first source of inefficiency (wasteful testing on low performance entrepreneurs) is reduced because entrepreneurs with a particularly low performance, when given the choice, never choose to be tested, since they benefit from performance opacity (as already discussed, see Figure 4.3, panel b). The second source of inefficiency (exacerbation of adverse selection) is removed entirely, because entrepreneurs choose to get tested only when this improves their profit, ensuring that high-performance entrepreneurs can never be worse off under optional testing. Unfortunately, when deciding on testing, an entrepreneur only considers the cost for herself and not the negative externalities imposed on others (by revealing her higher performance, it forces the other entrepreneurs to charge a lower price), which is why optional testing, while better than mandatory testing, still leads to more testing than optimal.

Finally, ex-Ante optional checks are more efficient when paired with MA than when paired with PE. This is because MA suffers from less severe adverse selection than PE does (Section 5.1.2). Thus, pairing ex-Ante optional tests with MA leads to fewer tests and higher efficiency than pairing them with PE.

Ex-Post checks work best when mandatory and paired with the PE design

If ex-Ante performance checks perform the best when they are optional and are paired to an MA design, as just discussed, the opposite is true for ex-Post performance checks, which perform the best when they are mandatory and are paired with a PE design. Since ex-Post verification happens after the campaign is over, it cannot remove performance opacity by revealing true performance before the campaign starts, as an ex-Ante check would; rather, ex-Post verification can reduce performance opacity only by acting as a punishment mechanism. Thus, for it to be effective it must have two features. First, it must not be a choice of the entrepreneur, meaning that checks must be mandatory. And second, a failure of the check must lead to adverse consequences for the entrepreneur. In the case of PE, the platform can punish the entrepreneur by giving the funds in escrow back to backers, while in the case of MA, the platform has no real way to punish the entrepreneur, since all the funds raised during the campaign are given to the entrepreneur to finance development. Thus, ex-Post verification checks are effective at combating opacity only when mandatory and paired with PE.

The most efficient design

We now compare the performance of the two dominant designs with performance checks, $PE-V$ and $MA-V$.

Theorem 4. *Comparison of $PE-V$ and $MA-V$*

1. *There exist two thresholds, $\underline{\chi}$ and $\bar{\chi}$, with $\underline{\chi} < \bar{\chi}$, such that efficiency loss is lowest under $PE-V$ if the verification cost is low enough, $\chi < \underline{\chi}$, and is lowest under $MA-V$ if the verification cost is high enough, $\chi > \bar{\chi}$.*

2. *With positive testing cost, efficiency loss is positive under both designs.*

Corollary 1. *When the performance density function f is uniform, there exists a threshold $\bar{\bar{\chi}}$ such that efficiency loss is lowest under $PE-V$ if $\chi < \bar{\bar{\chi}}$, and is lowest under $MA-V$ otherwise.*

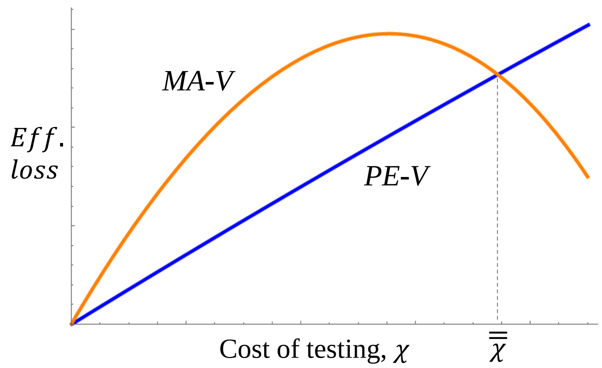

Figure 5.2: Efficiency loss as a function of testing cost χ, when performance density f is uniform. Parameters: $\bar{v} = 100$, $\underline{v} = 50$,$\alpha = 0.4$, $\delta = 0.9$, $I = 9,000$, $x_h = I\left(\delta \underline{v}\right)^{-1}$, $x_l = I\left(\delta \bar{v}\left(1+\gamma\right)\right)^{-1}$, $f \sim U\left[\underline{v},\bar{v}\right]$, any γ.

Part 1 of Theorem 4 shows that the cost of a performance check plays a crucial role in the choice of the best design. This is because both designs execute performance checks under different contingencies and for different performance levels. Specifically, under $PE-V$, the test is performed on those subset of campaigns that have successfully met the goal (a fraction α of all campaigns) and successfully developed the product (a fraction δ of all campaigns that meet their goal). Hence, only a fraction $\alpha\delta$ of all campaigns end up requiring a performance check. In contrast, under $MA-V$ the test is performed before the campaign starts, *but* the entrepreneur may decide to skip the test.

Once these facts are taken into account, we find that the efficiency gap between the two designs under study is non-monotone in the cost of testing, χ (Figure 5.2). In the extreme case of χ equal to zero, both designs are optimal (zero efficiency loss) because they fully deter misconduct at no cost. When χ is very low, $PE-V$ is more efficient: while nearly all entrepreneurs are tested under both designs, $PE-V$ has a cost advantage due to testing only a fraction $\alpha\delta$ of the campaigns. As χ increases, an increasing number of low-performance entrepreneurs choose not to be tested in the $MA-V$ design, thus improving the efficiency of this design: this is because tests on low-performance entrepreneurs are inefficient in that they only reduce the revenue-leveling effect of opacity, which is efficiency-neutral, see equation 5.1. When χ is high enough, $MA-V$ surpasses $PE-V$ in terms of efficiency thanks to the much lower number of (inefficient) tests being performed. Part 2 of Theorem 4 highlights that deferred payments with performance verification, even when best implemented, cannot fully restore efficiency due to the presence of testing costs and due to how these induce suboptimal channel choices of the entrepreneur. When performance is distributed uniformly, the choice between $PE-V$ and $MA-V$ can be summarized with a single threshold decision (Corollary 1).

Figure 5.3 depicts the most efficient design among *all* designs studied, with and without testing,

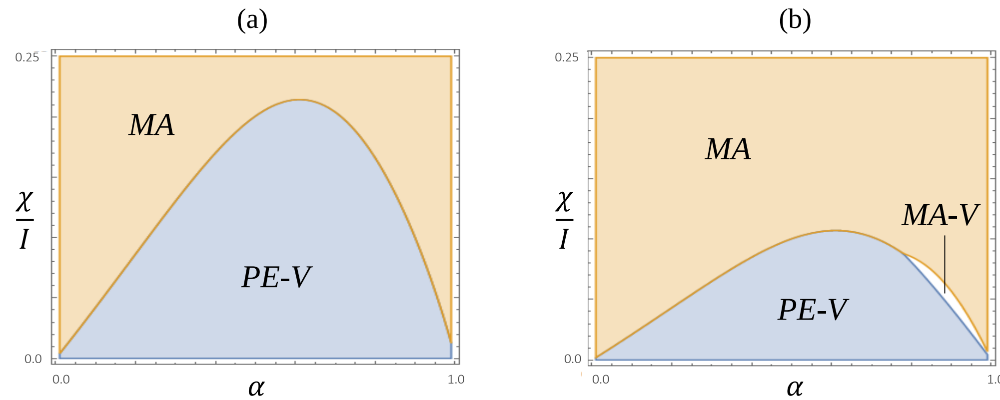

Figure 5.3: Choice of design as a function of high-market probability α and relative cost of performance checks, χ/I, when development probability is 50% (a) and 100% (b). Parameters: $\bar{v} = 100$, $\underline{v} = 30$, any γ; $x_h = I\left(\delta\underline{v}\right)^{-1}$ and $x_l = I\left(\delta\bar{v}\left(1+\gamma\right)\right)^{-1}$ by assumption.

as a function of relative testing cost χ/I and high-market probability α, for the case of intermediate and high development probability (panels a and b respectively) when f is uniform. Intuitively, when the cost of testing is very high, designs with inspection are very wasteful, and the most efficient design is one without inspections—namely MA, the best within that class of designs (Theorem 2). Conversely, when the inspection cost is not too high, designs with inspections are preferred, and in particular $PE-V$ is the most efficient design as long as the cost is low enough. Before we comment on the relative size of the regions, it is useful to discuss the impact of the probability of a high market state, α, on design choice.

Observe that the MA design is more efficient than any design with performance checks when the probability of a high market α is either very high or very low. When α is high, the informational advantage of crowdfunding is small, and most entrepreneurs choose bank funding. In this case performance opacity hurts efficiency very little, because the performance levels of entrepreneurs in crowdfunding are very similar: thus, costly performance checks are not that helpful. When α is low, the informational advantage of crowdfunding is large, and most entrepreneurs choose crowdfunding regardless of performance opacity. In this case costly performance checks are not that helpful because most entrepreneurs would choose crowdfunding anyway. Designs with performance checks ($PE-V$ and $MA-V$) help the most when the odds of a high market are neither too high nor too low, as in this case a good number of entrepreneurs join crowdfunding (opacity is large enough of a problem), but enough of them choose bank funding (there is much to gain by removing opacity and attracting more entrepreneurs to crowdfunding).

Surprisingly, in Figure 5.3, the region in which the $MA-V$ design is the most efficient is very small or non-existent (this finding is consistent throughout the parameter space). The reason is the following. The settings in which $MA-V$ is more efficient than $PE-V$ are characterized by a higher α (the cost advantage of $PE-V$ is lower) and a higher χ (as per Corollary 1). But these settings are also the ones in which testing is not particularly efficient, as just discussed for both χ and α. Thus, whenever $MA-V$ outperforms $PE-V$, it is also frequently the case that MA outperforms $MA-V$. This means that, while in principle $MA-V$ can be the most efficient design out of the three, in practice the best between the two other designs seems to nearly always perform better (this finding is confirmed even when the platform, instead of minimizing inefficiency, seeks to maximize crowdfunding adoption, see Section 6.2). In particular, $PE-V$ works best for large projects (I is large), in which the inspection cost is a small percentage of the budget, and/or for campaigns whose outcome is rather uncertain (α intermediate); in all other cases, MA works best.

5.3 Crowdsourcing Performance Checks

Intuitively, and as apparent from Figure 5.3, designs with inspections perform very well whenever the cost of inspection is very low, as they deter misconduct at a very small cost. The next corollary formalizes this intuition.

Corollary 2. *When the cost of performance checks tends to zero, both $PE-V$ and $MA-V$ are optimal. Formally,* $\lim_{\chi\to 0}\mathcal{L}^{OM}_{PE-V} = \lim_{\chi\to 0}\mathcal{L}^{OM}_{MA-V} = 0$.

While our analysis so far assumed that performance checks are costly, we now investigate whether, under some conditions, it is possible to leverage the power of the crowd to achieve near-zero inspection costs. Specifically, instead of relying on traditional testing (hiring employees or professional websites) the platform could survey backers after they received the product—making this solution feasible with ex-Post testing only—and aggregate their reported performance against the claimed performance. Then, the platform could use the funds in escrow to refund backers if the former is lower than the latter—i.e., if the product under-performed. This approach, which combines $PE-V$ with crowdsourced testing, would be nearly costless for the platform, but is potentially problematic due to incentive reasons: backers have the incentive to always report a lower-than-claimed performance because by doing so they get a partial refund. Some of the potential fixes to this problem, like requiring backers to return the product in order to be eligible for a refund, would also be problematic, since i) returns are costly, and ii) the entrepreneur would have an incentive to deny receiving them. In short, employing a more traditional way of testing is reliable but not cheap, and employing the crowd is cheap but not reliable.

Notably, there is a potential solution that attains the best of both worlds, i.e., it is (almost) costless for the platform, and it garners truthful information directly from backers. This solution consists in adopting both the above solutions, i.e., adopting traditional testing *and* surveying backers, and in using them sequentially. We call it the *sequential testing* approach. Specifically, backers would be surveyed first, and traditional testing would be employed only on those products for which backers' aggregate reported performance scores are below the performance claimed during the campaign. Refunds would be issued from the escrow fund only when testing reveals a performance lower than what was claimed during the campaign. Under the assumption that backers report the true performance whenever they gain nothing from lying, this solution achieves truthful reporting from backers.

Proposition 2. *Suppose that backers report the true performance whenever they gain nothing from lying. Under this assumption, the sequential testing approach induces truthful reporting from backers.*

In the sequential testing approach, backers report true performance, and entrepreneurs, knowing this, always claim true performance, to avoid losing the funds in escrow. Thus, no product needs to be tested in equilibrium. This means that the platform is able to verify the final product performance of a potentially very large number of campaigns at a very low cost (some capacity to perform traditional testing is still needed as a real threat to deter potential misconduct deviations) recovering most of the efficiency lost. While the near-optimal performance of such design should not be taken literally, given that it relies on simplifying assumptions made throughout the model (e.g., performance measurements have no noise), this result highlights the potentially important role that backers could play in combating performance opacity in crowdfunding.

6 Extensions

6.1 Is MA Incentive Compatible For The Platform?

In Theorem 2 we have shown that the MA design dominates PE because it leads to more entrepreneurs choosing crowdfunding over bank funding. This is beneficial for platform profitability, because it attracts more entrepreneurs (with higher-performance products) leading to more funds being raised on the platform. However, in addition to this beneficial *volume effect,* there is another effect that is potentially non-desirable from a platform's perspective, and could impair the adoption of MA. By halting a campaign as soon as the goal is reached, MA is reducing the amount of funds raised during the campaign—*early stopping effect*—and since the platform earns a percentage fee on such funds, halting the campaign when the goal is met reduces revenues for the platform. Preliminary estimates show that these effects are of similar magnitude, with the volume effect being actually about 10% larger, meaning that MA could indeed be economically beneficial for platforms.

Nevertheless, it is of interest to investigate whether the MA design could be modified in order to always improve revenues over the PE design. The solution consists in modifying MA by coupling it with pre-orders. Under this modified design, which we call MAP (Maximum Aftermarket with Pre-orders) once the goal of a campaign has been reached and the campaign is halted, the platform starts accepting Pre-orders for the final product, charging the same fee as it would during the campaign. Importantly, in order to retain the advantage of the MA design, such preorders should be priced at the retail price of the product, and backers have the right to cancel the pre-order after the product is developed and performance becomes known.[9] Essentially, this design preserves the advantages of the MA design, but it allows the platform to earn a fee on all transactions made with the online customer population (as is happens under PE and traditional crowdfunding). Details can be found in the Online Appendix.

Proposition 3. *Consider the case of positive platform fees, $\beta > 0$. Then, the MAP design leads to lower efficiency loss, and in particular higher platform revenues, relative to the PE design. Formally, $\mathcal{L}^{OM}_{MAP} < \mathcal{L}^{OM}_{PE}$.*

6.2 Maximizing Crowdfunding Adoption

In our analysis we have compared different designs with the objective of maximizing efficiency, hence expected entrepreneur's profit and total welfare. In this section, we consider an alternative objective: maximizing crowdfunding adoption—defined as the fraction of entrepreneurs choosing crowdfunding over bank funding. This objective is of interest for a platform that cares about maximizing the number and average product performance of the campaigns launched on the platform.

Proposition 4. *Crowdfunding adoption is highest under $PE-V$ if the cost of testing is low enough, $\chi < \chi_{ad}$, and is highest under MA otherwise.*

The result in Proposition 4 confirms the result in Theorem 2 on the superiority of MA among all designs that do not resort to inspection (PE and C) even when the objective is maximizing crowdfunding adoption. The result by and large also confirms the findings from Theorem 3, but it further reduces the number of designs that need to be considered because it states that, out of all designs with inspection, only one needs to be considered: $PE-V$. Overall these findings—together with the evidence from Figure 5.3 and the result in Proposition 2 on the potentials of crowdsourced testing—suggest that the choice of the best crowdfunding design is one between just two designs: MA and $PE-V$.

[9]The practice of accepting pre-orders after the end of a campaign has been successfully implemented by Indiegogo over the last few years, https://bit.ly/2QEkuhJ.

7 Conclusions

As a Kickstarter user puts it "Some kickstarters are going to be awesome. Some kickstarters are going to be okay. Some kickstarters are going to go bust and never produce anything. Some kickstarters are going to be [obscenity] and take your money" (Schreier 2015). The two misconduct risks considered in our model, performance opacity and funds misappropriation, can capture this full spectrum of outcomes: the entrepreneur may end up delivering a product with higher-than-expected performance ("awesome"), deliver a product with lower-than-expected performance ("ok"), fail development ("never produce anything"), and may even do so without issuing any refund ("take your money").

Our study sheds light on the mechanism through which funds misappropriation and performance opacity reduce crowdfunding efficiency. In particular, our analysis suggests that these forms of misconduct are a bigger problem than we think, due to how they interact with one another, so acting on them is all the more important. Our study also provides recommendations for how to change crowdfunding mechanisms in order to deter misconduct, creating more value for all stakeholders and driving efficiency. After comparing ten different designs under multiple metrics, our analysis provides a remarkably simple recommendation: platforms should use an escrow campaign with ex-post mandatory performance verification when testing is relatively inexpensive, and should use a maximum aftermarket campaign (with pre-orders) otherwise.

While Section 6 and the Online Appendix provide a number of extensions to our main model, other extensions and alternative formulations could be pursued. We model the realization of the offline market size as being a multiple of the online market size (i.e., they are perfectly correlated); all results remain unchanged even if this is true in expectation only. Similarly, all our results continue to hold when the marginal cost of production is greater than zero.

While we model communication from the entrepreneur to backers via performance claims, we do not model communication from backers to the entrepreneurs in the form of feedback on the product design. There is evidence suggesting that backers' feedback may at times prompt the entrepreneur to make improvements to the product. The role of backers' feedback is an interesting and complex question in its own right, and, thus, is outside of the scope of the present paper; we believe that accounting for backers' feedback should not alter the consequences of entrepreneurial misconduct, since low-performing designs are the ones that should benefit the most from backers' feedback, which again points to high performance entrepreneurs being the ones who leave crowdfunding, as in the current model.

Our choice to model the alternative funding option with a bank is meant to provide the entrepreneur with an option other than crowdfunding. There are, of course, other players competing in the corporate financing industry, for instance venture capitalists. Since those other players have more means to ascertain the true performance of a project and to deter running than backers of a crowdfunding campaign, we believe that our analysis captures first-order effects that are shared also by those channels.

Our work is the first to study crowdfunding platform design as a way to curb the inefficiencies that stem from performance opacity and (post-development) funds misappropriation, two sources of risk that are prevalent in crowdfunding platforms. Platforms are starting to take a closer look at their rules, with the intention of finding ways to reduce these risks (Swanner (2014), Indiegogo (2018)). Our findings provide guidance for achieving this goal.

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Rethinking Crowdfunding Platform Design:
Mechanisms to Deter Misconduct and Improve Efficiency
Online Appendix

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A Additional Results

Lemma 1. *In crowdfunding, in equilibrium, the entrepreneur's actions are given by:*

$$\text{offline market (time 2)} \begin{cases} \text{offline price: } p_C^{off} = v. \end{cases}$$

$$\text{crowdfunding (time 1)} \begin{cases} \text{funding goal: } t_C &= I\left(1-\beta\right)^{-1}, \\ \text{online price: } p_C &= \left[\delta v - (1-\delta) I x_h^{-1}\right]\left[1-\left(1-\delta\right)\left(1-\beta\right)\right]^{-1}. \end{cases}$$

The profit is given in equation 3.1.

Lemma 2. *Suppose that platform fees are positive, $\beta > 0$, and that crowdfunding is viable, i.e. $x_h \geq I\left(\delta v\left(1-\beta\right)\right)^{-1}$; then, the entrepreneur chooses crowdfunding over bank funding for all performance levels v if platform's channel costs are not excessively higher than the bank's, i.e., if $\beta \leq \bar{\beta}$, where $\bar{\beta}$ solves $\Pi_C\left(\bar{v}|\bar{\beta}\right) - \Pi_B\left(\bar{v}\right) = 0$.*

Proposition 1. *Under funds misappropriation, entrepreneurs choose crowdfunding if performance is low enough, $v \leq \hat{v}_C^M$, otherwise they choose bank funding. The pledge price set during the campaign, p_C^M, and the profit of the entrepreneur in crowdfunding, $\Pi_C^M\left(v\right)$, are:*

- $p_C^M = v - \left(1-\delta\right)\delta^{-1} I\, x_h^{-1}$, $\quad \Pi_C^M\left(v\right) = \Pi_C\left(v\right)$, $\quad$ *if* $v \leq v_{M1}$
- $p_C^M = (I+R)x_h^{-1}$, $\quad \Pi_C^M\left(v\right) = \alpha\delta\left(R + v x_h \gamma\right)$, $\quad$ *if* $v \in \left(v_{M1}, v_{M2}\right]$
- $p_C^M = \delta v$, $\quad \Pi_C^M\left(v\right) = \Pi_C\left(v\right) - \alpha\left(1-\delta\right)R$, $\quad$ *if* $v > v_{M2}$,

with $v_{M1} = x_h^{-1}\left(R + I\delta^{-1}\right)$ *and* $v_{M2} = \left(\delta x_h\right)^{-1}\left(R+I\right)$.

Crowdfunding profit loss $\Lambda^M\left(v\right)$ is positive when performance is higher than v_{M1}, and efficiency loss $\mathcal{L}^M$ is positive.

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Lemma 3. *In crowdfunding, under performance opacity, the funds raised are independent of true performance v and backers' pledging decisions are made irrespectively of the performance claim k.*

Proposition 2. *Under performance opacity, in equilibrium:*

- ▷ *Entrepreneurs choose crowdfunding if performance is low enough, $v \leq \hat{v}_C^O$, and choose bank funding otherwise. The pledge price during the campaign is $p_C^O = \mathbb{E}^O [V|C] - (1-\delta)\,\delta^{-1} I\, x_h^{-1}$, and the crowdfunding profit is $\Pi_C^O(v) = \alpha \left\{-I + \delta \mathbb{E}^O [V|C]\, x_h + \delta v x_h \gamma\right\}$, with $\mathbb{E}^O[V|C] = (F(\hat{v}_C^O))^{-1} \int_{\underline{v}}^{\hat{v}_C^O} v f(v)\, dv$.*
- ▷ *Crowdfunding profit loss $\Lambda^O(v)$ is given by*

$$\Lambda^O(v) = \alpha\delta x_h \left[v - \mathbb{E}^O[V|C]\right]. \tag{A.1}$$

It is strictly increasing in v, and we have $\Lambda^O(\underline{v}) < 0 < \Lambda^O\left(\hat{v}_C^O\right)$. Efficiency loss is positive, that is, $\mathcal{L}^O > 0$.

Proposition 3. *Under the joint presence of funds misappropriation and performance opacity, in equilibrium:*

- ▷ *Entrepreneurs choose crowdfunding if performance is low enough, $v \leq \hat{v}_C^{OM}$, and choose bank funding otherwise. Upon failing development, the entrepreneur runs with probability*

$$\eta(R) = \max\{0, \min\{1, R\,(1-\delta)(\delta F(\hat{v}_C^{OM})^{-1} \int_{\underline{v}}^{\hat{v}_C^{OM}} v f(v)\, dv \cdot x_h - I - \delta R)\}\}. \tag{A.2}$$

- ▷ *Efficiency loss is positive, i.e., $\mathcal{L}^{OM} > 0$.*

Lemma 4. *The equilibrium outcome for MA and PE under performance opacity is the same, with or without funds misappropriation.*

A.1 Model extensions

A.1.1 Market Size as an Increasing Function of Performance Level

In this extension, we consider the case in which a higher-performance product leads not only to higher customers' willingness to pay, as in the main model, but also to a larger expected market size. We operationalize this by letting the probability of the high market size α be an increasing function of performance, $\alpha = \alpha(v)$, $\partial_v \alpha(v) > 0$.

Proposition 4. *When the probability of a high market state, α, is increasing in performance v, our main results are unchanged. In particular, Theorems 1, 2, 3, and 4 continue to hold.*

Under this extension, nearly all results are unchanged because all relevant analysis is about players' behavior *conditional* on the crowdfunding campaign being successful (the market is high) else money does not change hands. This means that the probability of the high market does not directly effect the analysis, except for affecting backers' beliefs on performance v conditional on the campaign being successful—but this has minimal impact on our analysis since it mostly considers a general density f.

A.1.2 Development Probability as a Function of Performance Level

In this extension, we consider the case in which the probability to successfully develop the product is a function of product performance, $\delta = \delta(v)$. In general, this function could be increasing or decreasing. On the one hand, the function $\delta(v)$ could be decreasing to the extent that higher-performance products are more complex and thus more likely to hit unforeseen roadblocks in the development process. On the other hand, the function $\delta(v)$ could be increasing if entrepreneurs have different competence levels, and if entrepreneurs who are more competent choose to develop products with higher performance. Consider the following assumptions:

Assumption 1. *$v\,\delta(v)$ increases in v.*

When this assumption holds, a higher-performance product is more profitable, in expectation, than a lower-performance product. While not needed so far, this is a natural assumption for our model, where v is meant to capture vertical differentiation among entrepreneurs/products (the higher v, the better).

Assumption 2. *$\delta(v)$ is concave in v.*

This assumption states that complexity and unforeseen problems increase more than linearly in performance ($\delta\,(v)$ has a decreasing slope) which seems plausible in many cases. With the help of the above assumptions, we now extend results from the main model.

Proposition 5. *When development probability is a function of performance, $\delta = \delta(v)$:*

- ▷ *Theorem 1 directly applies under assumptions 1 and 2;*
- ▷ *Theorems 2, 3 and 4 directly apply under assumption 1.*

Assumption 1 implies that a higher performance level leads to a higher expected profit for the entrepreneur, hence the informational advantage of crowdfunding (Lemma 1) decreases in performance v: this is sufficient to have single crossing of the entrepreneur's profit under the two channels under examination, crowdfunding and bank funding, which is in turn sufficient for Theorems 2, 3 and 4 to hold. Assumption 2 is a technical requirement sufficient for the equilibrium under funds misappropriation to exhibit a two-threshold structure (Section 4.1) which, together with assumption 1, is in turn sufficient for Theorem 1 to hold.

B Proofs

Proof of Lemma 1. For all performance levels we have that

$$\Pi_C(v) - \Pi_B(v) \quad = \quad \alpha\left[-I + \delta v x_h (1+\gamma)\right] - \left[-I + \delta v \mathbb{E}[X](1+\gamma)\right] \quad > 0.$$

□

Proof of Theorem 1. Define R_1 as the solution to $\eta(R) = 1$ and R_0 as the solution to $\eta(R) = 0$, which yields $R_1 = \delta \mathbb{E}\left[V | V < \hat{v}_C^{OM_3}\right] x_h - I$ and $R_0 = R_1/\delta$ (note that $R_1 \leq R_0$). The proof consists in showing that $\mathcal{L}^{OM} - \mathcal{L}^{O+M} > 0$ when $R < R_1$, that $\mathcal{L}^{OM} - \mathcal{L}^{O+M} \leq 0$ when $R > R_0$, and that $\mathcal{L}^{OM} - \mathcal{L}^{O+M} = 0$ once for $R \in [R_1, R_0]$. We now discuss the three cases.

1. $R < R_1$. The result holds because $\Lambda^{OM}(v) = \alpha\left\{\delta x_h v - x_h \left[\delta F\left(\hat{v}_C^{OM}\right)^{-1} \int_{\underline{v}}^{\hat{v}_C^{OM}} v f(v)\, dv\right] + (1-\delta) R\right\} > \Lambda^O(v) + \Lambda^M(v)$, where the inequality holds if and only if $\hat{v}_C^O > \hat{v}_C^{OM}$. Suppose that, instead, $\hat{v}_C^O \leq \hat{v}_C^{OM}$; then we run into a contradiction because $\Pi_B\left(\hat{v}_C^{OM}\right) \geq \Pi_C^O\left(\hat{v}_C^{OM}\right) > \Pi_C^{OM}\left(\hat{v}_C^{OM}\right) = \Pi_B\left(\hat{v}_C^{OM}\right)$, where the first inequality follows from $\Pi_B(v) - \Pi_C^O(v)$ being strictly increasing in v, from $\Pi_C^O\left(\hat{v}_C^O\right) = \Pi_B\left(\hat{v}_C^O\right)$, and from $\hat{v}_C^O < \hat{v}_C^{OM}$; the last equality follows from the equilibrium condition of OM; and the second inequality holds because $\Pi_C^O\left(\hat{v}_C^{OM}\right) > \Pi_C^{OM}\left(\hat{v}_C^{OM}\right)$.
2. $R > R_0$. We have $\Pi_C^{OM}(v) = \Pi_C^O(v)$. The result holds because $\Lambda^{OM}(v) \leq \Pi_C(v) - \Pi_C^{OM}(v) + \left(\Pi_C(v) - \Pi_C^M(v)\right) = \Lambda^O(v) + \Lambda^M(v)$.
3. $R \in [R_1, R_0]$. It remains to show that, once $\mathcal{L}^{OM}(R) - \mathcal{L}^{O+M}(R)$ becomes negative for some $\breve{R} \in (R_1, R_0]$, it remains negative for every $R \in \left[\breve{R}, R_0\right]$. This can be shown by applying two sufficient conditions to two subcases. Specifically, condition that $\frac{d}{dR}\left(\mathcal{L}^{OM} - \mathcal{L}^{O+M}\right)$ is zero for at most one R in $[R_1, R_0]$ to the subcase $v_{M2} > \hat{v}_C^{O+M}$ and $\hat{v}_C^{O+M} > \hat{v}_C^{OM}$; and condition that $\mathcal{L}^{OM}(R) - \mathcal{L}^{O+M}(R)$ must be non-increasing in $[R_1, R_0]$ to the remaining subcase.

□

Proof of Proposition 1. Following the same reasoning as done in the absence of misconduct risks (page 11) it can be shown that, under the MA and PE designs, in equilibrium, the entrepreneur chooses a goal equal to I. We now discuss pricing separately for each design. Under MA, online customers back the project iff $-p_{MA}^M + \delta v = 0$, hence the entrepreneur sets $p_{MA}^M = \delta v$. In the high state, the entrepreneur collects money from $I/(\delta v)$ backers, then the campaign stops. If development fails, profit is zero. If development succeeds, the entrepreneur sells the product at a price v to $x_h \gamma + x_h - I/(\delta v)$ customers. The profit is then $\Pi_{MA}^M(v) = \alpha\delta\left[v\left(x_h(1+\gamma) - I/(\delta v)\right)\right] = \alpha\left[-I + \delta v x_h (1+\gamma)\right] = \Pi_C(v)$. Under PE, online customers back the project iff $-p_{PE}^M + \delta v + (1-\delta)\left(p_{PE}^M - I/x_h\right) = 0$, hence the entrepreneur sets $p_{PE}^M = v - \frac{1-\delta}{\delta} \cdot \frac{I}{x_h}$. In the high state, if development fails, the entrepreneur breaks even. If development succeds, she gets the funds in escrow, equal to $\left(v - \frac{1-\delta}{\delta} \cdot \frac{I}{x_h}\right) x_h - I$, and sells to $x_h \gamma$ offline customers at a price v. The total profit is $\Pi_{PE}^{M}(v) = \alpha\delta\left[\left(v - \frac{1-\delta}{\delta}\cdot\frac{I}{x_h}\right)x_h - I + vx_h\gamma\right] = \alpha\left[-I + \delta v x_h(1+\gamma)\right] = \Pi_C(v)$. It follows that, in both designs, all types choose crowdfunding over bank funding, hence there is no efficiency loss. □

Proof of Theorem 2. In equilibrium, the entrepreneur will prefer crowdfunding if and only if performance is low enough, because $\frac{d}{dv}\Pi_B(v) > \frac{d}{dv}\Pi_d^O(v)$, $d \in \{PE, MA\}$, due to the fact that backers, in equilibrium, are insensitive to true performance. Under MA, let $\hat{v}_{MA}^O$ be the highest performance within crowdfunding. Backers are willing to pledge if and only if $-p + (1-\alpha)p + \alpha\delta\mathbb{E}\left[V|V \le \hat{v}_{MA}^O\right] \ge 0$. The highest price that backers are willing to pay is, therefore, $p_{MA}^O = \delta\mathbb{E}\left[V|V \le \hat{v}_{MA}^O\right]$, and the profit for the entrepreneur is $\Pi_{MA}^O(v) = \alpha\left[-I\frac{v}{\mathbb{E}\left[V|V\le\hat{v}_{MA}^O\right]} + \delta v x_h(1+\gamma)\right]$, where $\hat{v}_{MA}^O$ solves $\Pi_{MA}^O\left(\hat{v}_{MA}^O\right) = \Pi_B\left(\hat{v}_{MA}^O\right)$. Under PE, let $\hat{v}_{PE}^O$ be the highest performance within crowdfunding. Backers are willing to pledge if and only if $-p + (1-\alpha)p + \alpha\delta\mathbb{E}\left[V|V \le \hat{v}_{PE}^O\right] + \alpha(1-\delta)\left[p - \frac{I}{x_h}\right] \ge 0$. The highest price that backers are willing to pay is, therefore, $p_{PE}^O = \mathbb{E}\left[V|V \le \hat{v}_{PE}^O\right] - \frac{(1-\delta)I}{\delta x_h}$, and the profit for the entrepreneur is $\Pi_{PE}^O(v) = \alpha\left[-I + \delta\mathbb{E}\left[V|V \le \hat{v}_{PE}^O\right]x_h + \delta v x_h\gamma\right]$, where $\hat{v}_{PE}^O$ solves $\Pi_{PE}^O\left(\hat{v}_{PE}^O\right) = \Pi_B\left(\hat{v}_{PE}^O\right)$. We now show the result in the first point, that $\hat{v}_{PE}^O < \hat{v}_{MA}^O$. Define $\psi(v) = \mathbb{E}[V|V \le v]/v$, which depends only on $f(\cdot)$ and v, and not on the campaign design chosen. Then $\Pi_B\left(\hat{v}_{MA}^O\right) > \alpha\left[-I + \delta\psi\left(\hat{v}_{MA}^O\right)\hat{v}_{MA}^O x_h\right] + \alpha\delta\hat{v}_{MA}^O x_h\gamma = \Pi_{PE}^O\left(\hat{v}_{MA}^O\right)$. Since $\Pi_B\left(\hat{v}_{MA}^O\right) > \Pi_{PE}^O\left(\hat{v}_{MA}^O\right)$ and $\frac{d}{dv}\left[\Pi_B(v) - \Pi_{PE}^O(v)\right] > 0$, it must be that $\Pi_B(v)$ and $\Pi_{PE}^O(v)$ cross for $v < \hat{v}_{MA}^O$, which implies $\hat{v}_{PE}^O < \hat{v}_{MA}^O$. We now prove the result at the second point. First, from the expression for $\Pi_{PE}^O(v)$, it is straightforward to conclude that $\Pi_{PE}^O(v) = \Pi_C^O(v)\,\forall v$, which implies $\mathcal{L}_{PE}^O = \mathcal{L}_C^O$. Next, we leverage the result from the first point to show that

$$\mathcal{L}_{PE}^O - \mathcal{L}_{MA}^O \; > \; \alpha\int_{\underline{v}}^{\hat{v}_{PE}^O}\left[-I\left(\frac{v}{\mathbb{E}\left[V|V\le\hat{v}_{MA}^O\right]} - 1\right) + \delta v x_h - \delta\mathbb{E}\left[V|V \le \hat{v}_{PE}^O\right]x_h\right]f(v)\,dv \; > 0.$$

It remains to show that $\mathcal{L}_{MA}^O > 0$. This is easily seen by the fact that $\Pi_B(\bar{v}) > \Pi_{MA}^O(\bar{v})$ and therefore $\hat{v}_{MA}^O < \bar{v}$, hence total welfare is necessarily lower due to development when $X = x_l$ for some $v < \bar{v}$.

□

Proof of Theorem 3. This proof comprises of five steps. The name of the designs reflect the timing (ex-Ante or ex-Post) and enforcement rule (Required or Optional) of performance Verification contingencies.

Step 1: equilibrium outcome of $PE - OAV$

Let $\bar{\mathcal{I}}$ be the set of entrepreneurs who choose not to be tested in crowdfunding. The benefit of inspection for the entrepreneur is a function of $v - \int_{\bar{\mathcal{I}}}\tau f(\tau)\,dv$, hence increases in performance v, while the cost of inspection is fixed. It follows that in equilibrium, in crowdfunding, the entrepreneur chooses to be tested iff performance is higher than a threshold $\breve{v}_{PE-OAV}^{OM}$. Let $\breve{v}_{PE-OAV}^{OM}$ be the type who is indifferent between paying for inspection and not paying; then it is the $\breve{v}$ that solves:

$$-\chi + \alpha\delta\left[\left(\breve{v} - \frac{1-\delta}{\delta}\frac{I}{x_h}\right)x_h - I + \breve{v}x_h\gamma\right] = \alpha\delta\left[\left(\mathbb{E}^O[V|v<\breve{v}] - \frac{(1-\delta)}{\delta}\frac{I}{x_h}\right)x_h - I + \breve{v}x_h\gamma\right], \qquad \text{(B.1)}$$

hence $\check{v}^{OM}_{PE-OAV}$ solves $\alpha\delta x_h\left(\check{v}-\mathbb{E}\left[V|v<\check{v}\right]\right)=\chi$. In case of multiple solutions to this equation, the one with the highest $\check{v}^{OM}_{PE-OAV}$ (least opaque) Pareto dominate all others, since having performance tested within crowdfunding reduces efficiency (it has negative externalities on all other types in crowdfunding). Let $\hat{v}^{O}_{C}$ be the indifferent type between crowdfunding and bank funding under performance opacity. If $\check{v}^{OM}_{PE-OAV}>\hat{v}^{O}_{C}$, then no type pays for the test. The test cost $\bar{\chi}$ above which nobody pays for the test is given by $\bar{\chi}=\alpha\delta x_h\left(\hat{v}^{O}_{C}-\mathbb{E}\left[V|v<\hat{v}^{O}_{C}\right]\right)$. If $\chi>\bar{\chi}$ then the marginal type is the same as in PE. Otherwise, the marginal performance entrepreneur $\hat{v}^{OM}_{PE-OAV}$ is the solution to $-\chi+\alpha\delta\left[\left(\hat{v}^{OM}_{PE-OAV}-\frac{1-\delta}{\delta}\frac{I}{x_h}\right)x_h-I+\hat{v}^{OM}_{PE-OAV}x_h\gamma\right]$ $=\Pi_B\left(\hat{v}^{OM}_{PE-OAV}\right)$. The entrepreneur chooses crowdfunding if and only if $v\leq\hat{v}^{OM}_{PE-OAV}$. Profit is then

$$\Pi^{OM}_{PE-OAV}(v)=\begin{cases}-\chi+\Pi_C(v) & if\ v>\check{v}^{OM}_{PE-OAV}\\ \alpha\left[-I+\delta\mathbb{E}\left[V|v<\check{v}^{OM}_{PE-OAV}\right]x_h+\delta\check{v}^{OM}_{PE-OAV}x_h\gamma\right] & ow.\end{cases}$$

Step 2: equilibrium outcome of $MA-V$

Before the campaign is launched, the entrepreneur has the option to have the product inspected at a cost χ. The outcome of the inspection becomes public information. It is easy to show that if an entrepreneur with performance v is better off paying the inspection cost, every other type is also better off. In equilibrium, high-enough types pay for inspection in crowdfunding, while the other types do not, their performance still remaining opaque. Let $\hat{v}_{MA-V}$ be the highest type in crowdfunding. An equilibrium in which nobody checks her product exists if and only if the marginal entrepreneur under MA would prefer not to be checked when given a choice. This means $-\chi+\alpha\left[-I+\delta\hat{v}^{OM}_{MA}x_h(1+\gamma)\right]\leq\alpha\delta\left[\hat{v}^{OM}_{MA}\left(x_h-\frac{I}{\delta\mathbb{E}\left[V|v<\hat{v}^{OM}_{MA}\right]}\right)+\hat{v}^{OM}_{MA}x_h\gamma\right]$, or $\chi\geq\bar{\chi}_{MA-V}$. If this holds, then the marginal type is the same as in MA. Otherwise, the marginal performance entrepreneur $\hat{v}^{OM}_{MA-V}$ is the solution to $\Pi^{OM}_{MA-V}(v)=\Pi_B(v)$, or $\hat{v}^{OM}_{MA-V}=\frac{\bar{v}[(1-\alpha)I-\chi]}{I(1-\alpha)}$. Let $\check{v}^{OM}_{MA-V}$ be the lowest type in crowdfunding to choose inspection, which solves (simplifying) $I\left(\frac{\check{v}^{OM}_{MA-V}}{\mathbb{E}\left[V|v<\check{v}^{OM}_{MA-V}\right]}-1\right)=\frac{\chi}{\alpha}$. Profit is then $-\chi+\Pi_C(v)$ if $v>\check{v}^{OM}_{MA-V}$ and $\alpha\left[-I\frac{v}{\mathbb{E}\left[V|v<\check{v}^{OM}_{PE-OAV}\right]}+\delta v x_h(1+\gamma)\right]$ otherwise.

Step 3: $MA-V$ dominates $PE-OAV$

Consider that any entrepreneur, *conditional on choosing to be tested*, earns the same profit under $MA-V$ and under $PE-OAV$. Now take entrepreneur $\check{v}^{OM}_{PE-OAV}$. This entrepreneur pays χ to be tested, but is indifferent between being tested or not, by definition. The same entrepreneur, under $MA-V$, decides not to be tested because the difference in payoff for type $\check{v}^{OM}_{PE-OAV}$ between not being tested under $MA-V$ and not being tested under $PE-OAV$ is

$$\alpha\delta\left(\check{v}^{OM}_{PE-OAV}-\mathbb{E}\left[V|v<\check{v}^{OM}_{PE-OAV}\right]\right)\left\{x_h-\frac{I}{\delta\mathbb{E}\left[V|v<\check{v}^{OM}_{PE-OAV}\right]}\right\}>0.$$

Hence, $\check{v}^{OM}_{PE-OAV}<\check{v}^{OM}_{MA-V}$. The result follows because

$$\int_{\underline{v}}^{\hat{v}_{MA-V}} \Pi_{MA-V}^{OM}(v) f(v)\, dv - \int_{\underline{v}}^{\hat{v}_{PE-OAV}^{OM}} \Pi_{PE-OAV}^{OM}(v) f(v)\, dv \quad = \quad \int_{\check{v}_{PE-OAV}^{OM}}^{\check{v}_{MA-V}^{OM}} \chi f(v)\, dv > 0.$$

Step 4: equilibrium outcome of $PE-V$

No type has incentive to lie about performance, since by lying she forgoes all profit. Let $\hat{v}_{PE-V}$ be the highest type in crowdfunding, $\hat{v}_{PE-V}^{OM} = \frac{\bar{v}(I(1-\alpha)-\alpha\delta\chi)}{I(1-\alpha)}$. The profit of type v from choosing crowdfunding is $\Pi_{PE-V}^{OM}(v) = \alpha\delta\left[\left(v - \frac{1-\delta}{\delta}\frac{I}{x_h}\right)x_h - I - \chi + v x_h \gamma\right]$ or, rearranging, $\Pi_{PE-V}^{OM}(v) = \Pi_C(v) - \alpha\delta\chi$.

Step 5: $MA-RAV$, $PE-RAV$, and $MA-RPV$ are dominated

$MA-V$ dominates $MA-RAV$ because in the latter testing is done on all entrepreneus, adding inspection costs without any effect on efficiency, since these tests remove the revenue-balancing effect of performance opacity, which is efficiency neutral (see equation 5.1 in the paper). Formally, $\mathcal{L}_{MA-RAV}^{OM} = \mathcal{L}_{MA-V}^{OM} + \chi\int_{\underline{v}}^{\check{v}_{MA-V}^{OM}} dF(v)$. $MA-V$ also dominates $PE-RAV$ since the latter is outcome-equivalent to $MA-RAV$. Finally, $PE-V$ dominates $MA-RPV$ because inspection costs are the same under both designs, but in the latter opacity is still present since the platform does not have any funds to threaten entrepreneurs who misreport performance. □

Proof of Theorem 4. Let $\Delta\Pi(\chi) \triangleq \int_{\underline{v}}^{\bar{v}}\big(\max\big(\Pi_{PE-V}^{OM}(v|\chi), \Pi_B(v)\big) - \max\big(\Pi_{MA-V}^{OM}(v|\chi), \Pi_B(v)\big)\big) f(v)\, dv$. Then, efficiency loss is lower for $PE-V$ if and only if $\Delta\Pi(\chi) > 0$. The proof of part 1 consists of three steps. Steps 1 and 2 cover the case $\chi < \underline{\chi}$. Steps 1 and 3 cover the case $\chi > \bar{\chi}$. The proof of part 2 is trivial.

Step 1:

We show that $\Delta\Pi(0) = 0$: this follows by noting that, when $\chi = 0$, the marginal entrepreneur under both designs earns the same profit, hence $\hat{v}_{PE-V}^{OM} = \hat{v}_{MA-V}^{OM}$.

Step 2:

Note that $lim_{\chi\to 0^+}\left[\frac{d}{d\chi}\Delta\Pi(\chi)\right] = (1-\alpha\delta)\int_{\underline{v}}^{\bar{v}} f(v)\, dv + (1-\alpha\delta)\frac{\bar{v}}{I(1-\alpha)}|(1-\alpha)\pi(\bar{v}|x_l)|f(\bar{v})$, which is strictly positive since $\alpha\delta < 1$ by assumption.

Step 3:

We show that $\lim_{\chi\to+\infty}\Delta\Pi(\chi) < 0$. Let $\hat{\chi}$be large enough that $\Pi_{PE-V}^{OM}(\underline{v}|\chi = \hat{\chi}) \le 0$. Then, $PE-V$ always performs worse than bank funding, while $MA-V$ performs at least as well as MA, implying that $\Delta\Pi(\chi) < 0$ for any $\chi \ge \hat{\chi}$.

□

Proof of Corollary 1. Given Theorem 4, in order to prove $\underline{\chi} = \bar{\chi}$ it suffices to show that $\frac{d^2}{d\chi^2}\Delta\Pi < 0$. When f is uniform, $\breve{v}^{OM}_{MA-V} = \underline{v}\max\left(1, \frac{\alpha I+\chi}{\alpha I-\chi}\right)$. Consider the case $\breve{v} > \underline{v}$, the other is analogous. Let $f(v) = b$; then

$$\begin{aligned}\frac{d^2}{d\chi^2}\Delta\Pi &= 2b\left[\left(-\frac{\bar{v}}{I(1-\alpha)}\right) - \frac{\underline{v}}{\alpha I-\chi}\left(1+\frac{\alpha I+\chi}{\alpha I-\chi}\right) + \alpha\delta\left(\alpha\delta\frac{\bar{v}}{I(1-\alpha)}\right)\right] + \\ &+ (1-\alpha)\,\delta x_l\,(1+\gamma)\left(-\alpha\delta\frac{\bar{v}}{I(1-\alpha)}\right)^2 b - (1-\alpha)\,\delta x_l\,(1+\gamma)\left(-\frac{\bar{v}}{I(1-\alpha)}\right)^2 b + \\ &-\chi\left(\frac{2\underline{v}}{(\alpha I-\chi)^2}\left(1+\frac{\alpha I+\chi}{\alpha I-\chi}\right)\right)b < 0.\end{aligned}$$

□

Proof of Corollary 2. It follows since $\Pi^{OM}_{MA-V}(v) \to \Pi_C(v)$ and $\Pi^{OM}_{PE-V}(v) \to \Pi_C(v)$ as $\chi \to 0^+$.

□

Proof of Proposition 2. Since agents are infinitesimal, their individual vote cannot change the overall outcome, hence they all prefer to tell the truth. This concludes the proof. It is, however, interesting to see that the result continues to hold even if agents were discrete (as in the real world). We are going to do so by focusing on the incentive to lie of an individual backer. We focus on the case in which aggregate performance is the average reported performance, but other operators like the median would equally work.

Note that backers have lexicographic preferences over the possible outcomes, that is, firstly, they prefer to get a refund relative to not getting a refund, and secondly, they prefer to tell the truth relative to lying. We now show that a backer can never gain from lying. We only need to consider pure strategies since an equilibrium in mixed strategies cannot exist due to lexicographic preferences. We discuss two cases.

Case 1. Suppose that the entrepreneur did not overclaim performance. Then a backer, regardless of her individual reported performance, will not receive a refund (and despite the fact that her reported performance does affect the aggregate reported performance). There are two sub-cases to consider. If the average reported performance is no higher than what claimed, the process ends and she gets no refund; if the average reported performance is higher than what claimed, the subsequent traditional testing reveals the true performance, and she gets no refund. Therefore, a backer has nothing to gain from lying in this case.

Case 2. Suppose that the entrepreneur did overclaim performance. If every backer tells the truth, every backer gets a refund, so this is an equilibrium, and this outcome Pareto Dominates every other outcome for backers, since *all* backers tell the truth and get a refund. By definition of a backer's utility, no other outcome can improve over this. While not needed for the proof, we can nonetheless show that there does not exist a subgame perfect equilibrium to this branch of the game in which backers lie, not even a Pareto dominated one. The reason is simple: telling the truth is always preferred to lying for a backer, *unless* she is pivotal and by lying she can trigger the refund. But when the entrepreneur did overclaim performance, lying can never trigger the refund, so everyone is better off not lying.

Therefore, in equilibrium, the sequential approach measures true product performance.

□

Proof of Proposition 3. The proof consists in showing that if the platform applies the same fee β used under C to both pledges and pre-orders collected under MAP, then the platform earns a strictly higher profit in MAP than it does under C (or PE, since they are outcome-equivalent under performance opacity). The time sequence of a MAP campaign under performance opacity (funds misappropriation is fully deterred by deferred payments, as shown in Proposition 1):

1. Market size is realized
2. The entrepreneur chooses campaign price p^O_{MAP}, goal t^O_{MAP}, retail price p^{off}_{MAP}, and pre-order discount ζ, with $\zeta \geq 0$ (note: for notational simplicity we assume the entrepreneur has commitment power for the retail price, but for the proof she only truly needs to choose ζ)
3. Backers decide whether to pledge or not. If the goal is not met, the campaign ends. Else
   (a) Pledges are accepted for a total of $I\left(1-\beta\right)^{-1}$, and I is given to the entrepreneur to finance development.
   (b) The other online customers can pre-order the product at a price $\left(1-\zeta\right)p^{off}_{MAP}$.
4. Development outcome:
   (a) success: product is delivered to all backers who either pledged on the campaign or pre-ordered the item. The platform earns $\rho\left(1-\zeta\right)p^{off}_{MAP}$ on each pre-order, the rest goes to the entrepreneur. The product is sold to offline customers.
   (b) failure: pre-orders are cancelled, no money is taken by the platform or the entrepreneur on pre-orders.

Equilibrium outcome. The optimal goal is $t^O_{MAP} = I\left(1-\beta\right)^{-1}$. For the purpose of this proof, we can focus on the case in which the market is x_h since when the market is in the low state no transaction happens in any crowdfunding design, including MAP and C.

The expected surplus of an online customer for each available action (conditional on the market size being x_h) is

$$\begin{aligned} \text{pledging on the campaign} \quad & -p^O_{MAP} + \delta\mathbb{E}^O\left[V|C\right] \\ \text{postponing} \quad & \mathbb{E}^O\left[\delta\left[-p^{off}_{MAP}\left(V\right)+V\right]|C\right] \\ \text{pre-ordering} \quad & \mathbb{E}^O\left[\delta\left[-\left(1-\zeta\right)p^{off}_{MAP}\left(V\right)+V\right]|C\right]. \end{aligned}$$

The firm sets prices to extract all surplus from the customers. Assuming that when indifferent, customers prefers pre-orders to waiting, this means $p^O_{MAP} = \delta\mathbb{E}^O\left[V|C\right]$, $p^{off}_{MAP} = v$, $\left(1-\zeta\right)p^{off}_{MAP} = v$, implying that $\zeta = 0$, that is, preorders are processed at the retail price. Let x_{h1} be the mass of customers who pledge on the campaign. From $x_{h1}p^O_{MAP} = I\left(1-\beta\right)^{-1}$ we derive $x_{h1} = \frac{I}{(1-\beta)p^O_{MAP}}$. The entrepreneur profit under MAP is $\Pi^O_{MAP}\left(v\right) = \delta\left[x_h v\left(1-\rho\right) - \frac{I}{\delta}\cdot\frac{v}{\mathbb{E}^O[V|C]}\cdot\frac{1-\rho}{1-\beta}\right] + \delta v x_h \gamma$.

In C, when platform fees β are positive, the price is given by $p_C^O = \frac{\delta \mathbb{E}^O[V|C]-(1-\delta)I\, x_h^{-1}}{1-(1-\delta)(1-\beta)}$. The profit for the entrepreneur under C is then

$$\begin{aligned}\Pi_C^O(v) &= \delta\left\{\left[p_C^O x_h(1-\beta) - I + v x_h \gamma\right]\right\} \\ &= \delta\left\{\tfrac{\delta \mathbb{E}^O[V|C]}{1-(1-\delta)(1-\beta)} x_h(1-\beta) - \tfrac{I}{1-(1-\delta)(1-\beta)} + v x_h \gamma\right\}.\end{aligned}$$

If under MAP the firm sets $\rho = \beta$, then we have $\Pi_{MAP}^O(v) = \delta\left[x_h \mathbb{E}^O[V|C](1-\beta) - \frac{I}{\delta}\right] + \delta x_h \gamma v$. We can then rewrite $\Pi_C^O(v)$ as (conditional on the market being in the high state)

$$\Pi_C^O(v) = \frac{\delta^2}{1-(1-\delta)(1-\beta)}\left[x_h \mathbb{E}^O[V|C](1-\beta) - \frac{I}{\delta}\right] + \delta v x_h \gamma.$$

Define $\lambda(\beta,\delta) = \frac{\delta}{1-(1-\delta)(1-\beta)}$ where $\lambda(\beta,\delta) < 1$, and suppose that the preorder fee under MAP is the same as backers' fee, $\rho = \beta$, which is the same as in C. Let $\hat{v}_C^O$ be the performance of the highest-performance entrepreneur in crowdfunding under C. For her, the profit gap between MAP and C is given by

$$\begin{aligned}\Pi_{MAP}^O(\hat{v}_C^O) - \Pi_C^O(\hat{v}_C^O) &= \delta\left\{x_h \hat{v}_C^O(1-\beta) - \tfrac{I}{\delta}\tfrac{\hat{v}_C^O}{\mathbb{E}^O[V|C]} - \lambda(\beta,\delta) x_h \mathbb{E}^O[V|C](1-\beta) + \lambda(\beta,\delta)\tfrac{I}{\delta}\right\} && > 0 \text{ iff} \\ & x_h(1-\beta)\left(\hat{v}_C^O - \lambda(\beta,\delta)\mathbb{E}^O[V|C]\right) - \tfrac{I}{\delta}\left(\tfrac{\hat{v}_C^O}{\mathbb{E}^O[V|C]} - \lambda(\beta,\delta)\right) && > 0 \text{ iff} \\ & x_h(1-\beta)\left(\hat{v}_C^O - \lambda(\beta,\delta)\mathbb{E}^O[V|C]\right) - \tfrac{I}{\delta \mathbb{E}^O[V|C]}\left(\hat{v}_C^O - \lambda(\beta,\delta)\mathbb{E}^O[V|C]\right) && > 0 \text{ iff} \\ & \left(\hat{v}_C^O - \lambda(\beta,\delta)\mathbb{E}^O[V|C]\right)\left[x_h(1-\beta) - \tfrac{I}{\delta \mathbb{E}^O[V|C]}\right] && > 0 \text{ iff} \\ & x_h(1-\beta) - \tfrac{I}{\delta \mathbb{E}^O[V|C]} && > 0 \text{ iff} \\ & \delta x_h \mathbb{E}^O[V|C](1-\beta) - I && > 0.\end{aligned}$$

It can be readily checked that this condition holds if and only if $p_C^O x_h(1-\beta) > I$: as long as at least some preorders are made, $\Pi_{MAP}^O(\hat{v}_C^O) - \Pi_C^O(\hat{v}_C^O) > 0$, hence adoption is higher under MAP than under C, and the platform's profit is also higher since the fees earned on the funds collected are the same across the two designs.

□

Proof of Proposition 4. The proof of Theorem 3, Step 5, holds the same way for adoption, leaving us the task to compare $PE-V$, $MA-V$, $PE-OAV$, and MA.

Step 1: $MA-V$ dominates $PE-OAV$.

We consider four sub-cases. If under both designs the marginal entrepreneurs chooses to be tested, then $\hat{v}_{MA-V}^{OM} = \hat{v}_{PE-OAV}^{OM}$. If under both designs the marginal entrepreneur chooses not to be tested, then nobody is tested and $\hat{v}_{MA-V}^{OM} = \hat{v}_{MA}^{OM} > \hat{v}_{PE}^{OM} = \hat{v}_{PE-OAV}^{OM}$. Let's define $\dot{v}$ as the marginal entrepreneur who is indifferent between testing and not testing, and is the solution to $\Pi_C(v) - \chi = \Pi_B(v)$. Note that $\Pi_C(v) - \chi - \Pi_B(v)$ is decreasing in v, hence a marginal entrepreneur who prefers (not) testing must be lower (higher) than $\dot{v}$. If the marginal entrepreneur chooses to be tested under $PE-OAV$ but not under $MA-V$, then it must be that $\hat{v}^{OM}_{PE-OAV} < \dot{v} < \hat{v}^{OM}_{MA-V}$. Finally, the case in which the marginal entrepreneur chooses to be tested under $MA - V$ but not under $PE - OAV$ is not possible, because for this to be true, it must be true that, without testing, the marginal entrepreneur under $MA - V$ (hence under MA) is lower than under $PE - OAV$ (hence PE), which we know to be false from the proofs of Theorem 2 and Lemma 4 (i.e., we know that $\hat{v}^{OM}_{MA} > \hat{v}^{OM}_{PE}$).

Step 2: $MA - V$ is dominated.

If under $MA - V$ the marginal entrepreneur chooses not to be tested, then $\max\left(\hat{v}^{OM}_{PE-V}, \hat{v}^{OM}_{MA}\right) \geq \hat{v}^{OM}_{MA} = \hat{v}^{OM}_{MA-V}$. Otherwise, we have $\hat{v}^{OM}_{PE-V} = \frac{\bar{v}(I(1-\alpha)-\alpha\delta\chi)}{I(1-\alpha)} > \frac{\bar{v}[(1-\alpha)I-\chi]}{I(1-\alpha)} = \hat{v}^{OM}_{MA-V}$.

Step 3:

Since $\hat{v}^{OM}_{MA}$ is not impacted by χ and $\hat{v}^{OM}_{PE-V}$ is decreasing in χ, the result follows. □

B.1 Other results

Proof of Lemma 1. Suppose that crowdfunding is viable, $x_h \geq I\left(\delta v\left(1-\beta\right)\right)^{-1}$. In equilibrium, the subgame-perfect offline price is $p_C^{off} = v$. The campaign price p_C solves

$$-p_C + (1-\alpha)\, p_C + \alpha\left[\delta v + (1-\delta)\big(p_C\,(1-\beta) - I x_h^{-1}\big)\right] = 0.$$

Any goal within the interval $[I\,(1-\beta)^{-1}, \, p_C x_h]$ is an equilibrium. These multiple equilibria differ only in the funding goal set by the entrepreneur. This is a rather innocuous issue since all such equilibria are outcome- and payoff-equivalent for all players. In order to simplify the exposition, we refine the set of equilibria by casting an arbitrarily small probability over the market sizes in the interval (x_l, x_h). Specifically, for any game Γ, define its ϵ-perturbation Γ_ϵ in which $g(\cdot)$ is replaced by $g_\epsilon(\cdot)$, given by

$$g_\epsilon(x) = \begin{cases} 1-\alpha-\epsilon\frac{(x_h-x_l)}{2} & if\, x = x_l \\ \alpha-\epsilon\frac{(x_h-x_l)}{2} & if\, x = x_h \\ \epsilon & if\, x \in (x_l, x_h) \end{cases}, \tag{B.2}$$

for $\epsilon > 0$. A strategy profile σ is an equilibrium in Γ if and only if there exists a strategy profile σ_ϵ that i) is an equilibrium in the ϵ-perturbation Γ_ϵ, and ii) is such that $\lim_{\epsilon\to 0^+}\sigma_\epsilon = \sigma$. This technical assumption allows us to single out the funding goal that is robust to the possibility that an outcome other than $\{x_l, x_h\}$ is realized, albeit with a very small probability. Under $g_\epsilon(x)$ it is immediate to see that any goal other than $I\,(1-\beta)^{-1}$ cannot be an equilibrium. The profit is obtained by substituting p_C into $\Pi_C(v) = \alpha\left\{\delta\left[p_C x_h\,(1-\beta) + \gamma v x_h - I\right]\right\}$. The viability condition $x_h > I\left(\delta v\,(1-\beta)\right)^{-1}$ is derived from $p_C x_h \geq I\,(1-\beta)^{-1}$ with simple algebra. The case when crowdfunding is not viable is trivial.

□

Proof of Lemma 2. The difference $\Pi_C(v|\beta) - \Pi_B(v)$, given by

$$\underbrace{(1-\alpha)\,|\pi(v|x_l)|}_{informational\,advantage} - \underbrace{\left\{\alpha\beta\left(\beta(1-\delta)+\delta\right)^{-1}\left[\delta^2 v x_h - (1-\delta)\,I\right]\right\}}_{platform\,fee} + \underbrace{Ir}_{bank\,fee},$$

decreases in β and decreases in v. Define $\bar{\beta}$ as the solution to $\Pi_C\left(\bar{v}|\bar{\beta}\right) - \Pi_B(\bar{v}) = 0$. It then follows that $\Pi_C(v|\beta) - \Pi_B(v) \geq 0\,\forall v, \forall\beta \leq \bar{\beta}$. Note that, with a positive marginal cost c, the entrepreneur would set the goal to $(I + x_h c)(1-\beta)^{-1}$, with no change in the proof. This substitution trivially extends the results in all other proofs to the case of positive marginal costs, and is omitted for brevity.

□

Proof of Proposition 1. The outcome is found using backward induction. Assume that at time 2, upon raising $p_C^M \cdot x_h$ and investing I, the entrepreneur fails development. In this case, running is the best response for the entrepreneur iff $p_C^M x_h - I > R$, that is, iff $p_C^M > \bar{p}$, with $\bar{p} = (R+I)\,x_h^{-1}$. Otherwise, the entrepreneur is better off using any leftover funds to (partially) refund backers. If backers anticipate that the entrepreneur will run upon failing development, they are willing to pledge at most $p_{run} = \delta v$, since with probability $1-\delta$ the product will not be delivered. If they anticipate a refund, they are willing to pledge as much as $p_{ref} = v - (1-\delta)\,I\,(\delta x_h)^{-1}$, with $p_{run} < p_{ref} < v$. In equilibrium, the entrepreneur charges the highest price that strategic customers are willing to pledge, conditional on them correctly inferring her running strategy. The result follows.

□

Proof of Lemma 3. For this result it is convenient to make explicit use of $\beta > 0$ and of the $\epsilon-$perturbed market size density function g_ϵ, then let $\beta \to 0^+$ and $\epsilon \to 0^+$, same as for the equilibrium analysis of crowdfunding in the absence of misconduct risks (page 11). The proof is structured as follows. Initially, we prove our result without allowing the entrepreneur to make any performance claim. In particular, we first show that a separating equilibrium in which all types can signal their true type to backers (fully separating equilibrium) always exist, and in such equilibrium, all types raise the same funds in crowdfunding. We then confirm this result when considering separating equilibria in which types can signal to belong to a subset of types (partially separating equilibria). It then follows that in any equilibrium, all types raise the same funds. Finally, we show that there is a unique pooling equilibrium outcome, and this Pareto dominates any separating equilibrium. Once we allow performance claims, we show that these are ignored by backers.

Fully separating equilibrium

Consider two types within $[\underline{v}, \bar{v}]$, where type θ has valuation v_θ, $\theta \in \{L, H\}$, $v_H > v_L$. Focusing on two types is enough to narrow down the possibility for a fully separating equilibrium. It is a standard result in signaling games that in a separating equilibrium, the low type chooses the optimal full information bundle. The goal is then $t_L = I(1-\beta)^{-1}$, and the price is $p_L = \left[\delta v_L - (1-\delta)\, I\mathbb{E}\left[X|X \geq t_L/p_L\right]^{-1}\right] \left[1-(1-\beta)(1-\delta)\right]$. This equation admits a unique solution for $\epsilon \to 0^+$ since in this case $\mathbb{E}\left[X|X \geq t_L/p_L\right] \to x_h$. Let $\Pi_Y^Z(p,t)$ be the expected profit of type Y when the campaign parameters are (p,t) and customers believe her to be of type Z. In a separating equilibrium, the low type chooses the full-information bundle (p_L, t_L), the high type chooses a bundle (p_H, t_H), off-equilibrium path beliefs are robust to the intuitive criterion, i.e., are set to H for all campaigns in the set $S_H = \left\{(p_{dev}, t_{dev}) : \Pi_L^L(p_L, t_L) \leq \Pi_L^H(p_{dev}, t_{dev})\right\}$ and are set to L otherwise, and it must be true that neither type wants to deviate, which boils down to $(p_H, t_H) = \arg\max_{(p,t)\in S_H}\left[\Pi_H^H(p,t)\right]$ and $\Pi_H^H(p_H, t_H) \leq \Pi_H^L(p_L, t_L)$.

The set S_H includes any bundle with $p < p_L$ and any t (any price lower than p_L reduces profit for any t), any bundle with $p = p_L$ and $t \neq t_L$ (any goal other than t_L cannot increase profit for $p = p_L$), any bundle with $p > p_L$ and $t > x_h p$ (when $p > p_L$, as $\epsilon \to 0$, the only goal that makes profit lower than $\Pi_L^L(p_L, t_L)$ is one that cannot be reached, $t > x_h p$, since in all other cases the higher prices makes for a higher profit). Among these bundles, the one that leads to the highest profit for type H is such that $p = p_L$ and $t < t_L$. This can be seen noting that any bundle with $p > p_L$ would lead to zero profit. Also, for any t, increasing p would increase profit, and for any p, choosing a goal $t > t_L$ would decrease profit relative to any $t < t_L$, as long as backers are willing to pledge p. Backers are willing to pledge on a bundle that satisfies $p = p_L$ and $t < t_L$ if $Pr\{p_L X \geq t_L\}[-(1-\delta)[p_L\beta + I/\mathbb{E}\left[X|X \geq t_L/p_L\right]] + \delta(v_H - p_L)] - Pr\{p_L X \in [t_t, t_L)\}\, p_L(1-\beta) \geq 0$ and one can always find a $t \in [0, t_L)$ that is large enough to make the inequality hold. Hence, this separating equilibrium always exists. Leveraging the above result, and considering now all types, the same arguments can be made by having L be the lowest type $\underline{v}$ and H *any* higher type. It is then straightforward to show that a fully separating equilibrium always exists, one in which all types offer the same price and in which the goal chosen is decreasing in the performance of the product. In particular, all types set $p_{sep} = \left[\delta \underline{v} - (1-\delta)\, I\mathbb{E}\left[X|X \geq t_L/p_L\right]^{-1}\right] \left[1-(1-\beta)(1-\delta)\right]^{-1}$, the optimal price for the lowest type. Type v can set goal $t_{sep}(v) = I(1-\beta)^{-1} - (v - \underline{v})\,\psi$, with $\psi > 0$. Since no type has incentive to deviate (they raise the same funds in all posted campaigns) this is an equilibrium as long as backers are willing to pledge p_{sep} for any type: one can always find ψ low enough to satisfy this.

Partially separating equilibrium

Consider an equilibrium in which there are $N > 0$ sets P_n of types v, $n = 1, ..., N$, such that each type within set P_n chooses the same price p_{sep}^n and goal t_{sep}^n. Without loss of generality, we shall order these sets by increasing average set performance, so that $\mathbb{E}\left[V|V \in P_n\right] \leq \mathbb{E}\left[V|V \in P_{n+1}\right]\ \forall n \in [1, N-1]$. We do not impose any constrains on these sets. This means that we cover the case in which P_n are partitions of the support of f, akin to **?**, but also more general cases in which the sets P_n are non-convex. Using the same arguments as above, any two type sets cannot be choosing different prices, otherwise types in one pool would be better off deviating to the other. Therefore, all type sets choose the same price. Analogously, one can rule out that a type set containing higher types can choose a higher threshold. Therefore, any partially separating equilibrium must feature $p^i_{sep} = p^j_{sep}$ and $t^i_{sep} < t^j_{sep}$ for any $i, j \in \{1, .., N\}$such that $i < j$.

Pooling equilibrium

In a pooling equilibrium all types choose a threshold $t_{pool} = I\,(1-\beta)^{-1}$ and a pledge price

$$p_{pool} = \left[\delta \mathbb{E}\,[V] - (1-\delta)\,\frac{I}{x_h}\right][1-(1-\beta)\,(1-\delta)]\,.$$

There are many off-equilibrium path beliefs consistent with this case. For example, everyone who deviates is thought to be the lowest type $\underline{v}$, and therefore obtains a weakly lower threshold and a strictly lower price, offering no incentive to deviate. Note that all pooling equilibria differ only in out-of-equilibrium beliefs and are, therefore, outcome and payoff equivalent. In fact, any other choice of price and threshold would make the lowest type $\underline{v}$ better off deviating to p_{pool} and t_{pool}.

Compared to the fully separating equilibrium, the pooling equilibrium results in the same payoff for $\underline{v}$ and in a strictly higher payoff for all other types, due to higher price and optimal threshold, and therefore the pooling equilibrium Pareto dominates the fully separating equilibrium. This is also true if we compare the pooling equilibrium with any partially separating equilibrium, in particular, the price in a pooling equilibrium is higher compared to the price in a partially separating equilbrium, p^n_{sep}. Note that p^n_{sep} must represent the lowest willingness to pay of backers among all type sets P_n, since backers must be willing to pay this amount. Because the pool with the lowest willingness to pay has a willingness to pay that is weakly lower than $\mathbb{E}\,[V]$ by construction, it must be that $p_{pool} \geq p^n_{sep}$. A necessary condition for $p_{pool} = p^n_{sep}\,\forall n$ to hold is therefore that all type sets P_n have the same expected performance (this already rules out the case of P_n being partitions of the support of f). Suppose that this is the case. Then, in order to make signaling possible, the n type sets must set different thresholds, which means that $n-1$ of them will be suboptimal thresholds. Posting a suboptimal threshold reduces backers' willingness to pay relative to the pooling equilibrium (backers incur an additional cost whenever the amount raised is in $[t_n, I\,(1-\beta)^{-1})$, a cost that they would not incur in the pooling equilibrium) hence backers are no longer willing to pledge p_{pool} for $n-1$ out of the n type sets. Hence it must be that $p_{pool} > p^n_{sep}$ and the result follows.

Cheap talk

We now consider the possibility that an entrepreneur with performance ψ can make a performance claim k_ψ in addition to choosing the price and the goal, and check whether it is possible for some types to charge a higher price than others. Let (p_ψ, t_ψ, k_ψ) be the campaign of an entrepreneur with performance ψ, where for simplicity we assume that $\psi \in \{\psi_1, \psi_2\}$. Denote bakers' willingness to pay when they observe (p_2, t_2, k_2) with w_2, and when they observe (p_1, t_1, k_1) with w_1. For this to be an equilibrium, it must be that $p_2 = w_2$, $p_1 = w_1$, otherwise either type is better off increasing the price. Assume $p_2 > p_1$ ($p_2 < p_1$ is analogous).

Then, with the exclusion of the case $I = t_1 < t_2$, type ψ_1 is always better off mimicking type ψ_2, due to type ψ_2 raising more funds due to charging a higher price, and/or choosing a goal that allows to collect funds in a larger set of profitable market states. In the case $I = t_1 < t_2$, either player is better off mimicking the other. Therefore, enabling performance claims does not allow any type of entrepreneur to charge a higher price than any other type. The case $p_1 = p_2$ is straightforward. We therefore conclude that all entrepreneurs raise the same funds, and that performance claims are ignored by backers.

□

Proof of Proposition 2. In a pooling equilibrium, backers' willingness to pay is given by solving $\alpha p_C^O + \alpha(1-\delta)\left(\frac{p_C^O x_h - I}{x_h}\right) + \alpha\delta\mathbb{E}^O[V|C] = 0$, which yields $p_O = \mathbb{E}^O[V|C] - \frac{1-\delta}{\delta} \cdot \frac{I}{x_h}$, where $\mathbb{E}^O[V|C]$ is the expected performance given that the entrepreneur chose bank funding over crowdfunding. The profit of an entrepreneur in crowdfunding is $\Pi_C^O(v) = \alpha\delta\{[p_O x_h - I + v x_h \gamma]\}$. It follows that $\frac{d}{dv}\Pi_B(v) = \delta\mathbb{E}[X](1+\gamma) > \alpha\delta x_h \gamma = \frac{d}{dv}\Pi_C^O(v)$, which implies that, in equilibrium, the entrepreneur joins crowdfunding if and only if performance is lower than a threshold value—define this value as $\hat{v}_C^O$. The entrepreneur with valuation $\hat{v}_C^O$ must be indifferent between the two channels, therefore it solves $\Pi_B(\hat{v}_C^O) = \Pi_C^O(\hat{v}_C^O)$, which yields $\hat{v}_C^O = \left[(1-\alpha)I + \alpha\delta x_h \mathbb{E}\left[V|V \leq \hat{v}_C^O\right]\right]\left[\delta(\mathbb{E}[X](1+\gamma) - \gamma\alpha x_h)\right]^{-1}$. This proves the first point in the proposition. The second point follows from the definition of $\Lambda^O(v)$, and from $\underline{v} < \mathbb{E}\left[V|V \leq \hat{v}_C^O\right] < \hat{v}_C^O$. For the third point, note that $\mathbb{E}\left[V|V \leq \hat{v}_C^O\right] < \bar{v}$ implies $p_O < p_C(\bar{v})$, which together with $\Pi_B(\bar{v}) = \Pi_C(\bar{v})$ imply $\Pi_B(\bar{v}) > \Pi_C^O(\bar{v})$, hence $\hat{v}_C^O < \bar{v}$. Then

$$\mathcal{L}^O = \int_{\underline{v}}^{\hat{v}_C^O}\left(\Pi_C(v) - \Pi_C^O(v)\right) f(v)\,dv + \int_{\hat{v}_C^O}^{\bar{v}}\left(\Pi_C(v) - \Pi_B(v)\right) f(v)\,dv > 0$$

□

Proof of Proposition 3. We now present the equilibrium outcome distinguishing three cases, indexed with superscript $OM_{1..3}$, that focus on the sign of the quantity $p_C^{OM} x_h - I - R$. We then merge these cases into a unifying formulation.

Case 1 (OM_1): $p_C^{OM_1} x_h - I - R > 0$. Clearly $\Pi_C^{OM_1}(v) \triangleq \alpha\left\{-I + p_C^{OM_1} x_h - (1-\delta)R + \delta v x_h \gamma\right\} > \alpha\{R - (1-\delta)R + \delta v x_h \gamma\} > 0\,\forall v$, hence the lowest type makes a profit in crowdfunding. Online customers' wtp, hence $p_C^{OM_1}$, is then given by $\delta\frac{1}{F\left(\hat{v}_C^{OM_1}\right)}\int_{\underline{v}}^{\hat{v}_C^{OM_1}} v f(v)\,dv$. Define $\hat{\Pi}_C^{OM_1}(v|y)$ as the profit of type v in crowdfunding under OM_1 conditional on the highest type in crowdfunding being y, or $\hat{\Pi}_C^{OM_1}(v|y) = \alpha\left\{-I + \delta\frac{1}{F(y)}\int_{\underline{v}}^{y}\tau f(\tau)\,d\tau \cdot x_h + \delta v x_h \gamma - (1-\delta)R\right\}$. Then $\hat{v}_C^{OM_1}$ solves $\hat{\Pi}_C^{OM_1}\left(\hat{v}_C^{OM_1}|\hat{v}_C^{OM_1}\right) = \Pi_B\left(\hat{v}_C^{OM_1}\right)$.

Case 2 (OM_2): $p_C^{OM_2} x_h - I - R < 0$. Since no type runs, we have $p_C^{OM_2} = \mathbb{E}\left[V|V < \hat{v}_C^{OM_2}\right] - \frac{1-\delta}{\delta} \cdot \frac{I}{x_h}$, same as p_C^O. The lowest type makes a profit in crowdfunding, same as in O. The profit for a type v is $\Pi_C^{OM_2}(v) = \alpha\left\{+\delta\left[p_C^{OM_2} x_h - I + v x_h \gamma\right]\right\} = \alpha\left\{-I + \delta\mathbb{E}\left[V|V < \hat{v}_C^{OM_2}\right] x_h + \delta v x_h \gamma\right\}$. Define $\hat{\Pi}_C^{OM_2}(v|y)$ as the profit of type v in crowdfunding under OM_2 conditional on the highest type in crowdfunding being y, or $\hat{\Pi}_C^{OM_2}(v|y) = \alpha\{-I + \delta\mathbb{E}[V|V < y] x_h + \delta v x_h \gamma\}$, then $\hat{v}_C^{OM_2}$ is the valuation that solves $\hat{\Pi}_C^{OM_2}\left(\hat{v}_C^{OM_2}|\hat{v}_C^{OM_2}\right) = \Pi_B\left(\hat{v}_C^{OM_2}\right)$.

Case 3 (OM_3): $p_C^{OM_3} x_h - I - R = 0$. In this case running and refunding yield the same payoff, and the price is given by $p_C^{OM_3} = \frac{I+R}{x_h}$. Let η be the probability that an entrepreneur runs when development fails. The profit is then

$$\begin{aligned}\Pi_C^{OM_3}(v) &= \alpha \left\{ \delta v x_h \gamma + \eta \left[p_C^{OM} x_h - I - (1-\delta) R \right] + (1-\eta) \left[\delta \left(p_C^{OM} x_h - I \right) \right] \right\} \\ &= \alpha \left\{ \delta v x_h \gamma + \delta R \right\}.\end{aligned}$$

The highest type in crowdfunding must solve $\Pi_C^{OM_3}\left(\hat{v}_C^{OM_3}\right) = \Pi_B\left(\hat{v}_C^{OM_3}\right)$, and this yields

$$\hat{v}_C^{OM_3} = \frac{I + \alpha\delta R}{\delta \left[\mathbb{E}[X](1+\gamma) - \alpha x_h \gamma \right]}. \tag{B.3}$$

The price $p_C^{OM_3}$ solves $-p_C^{OM_3} + \delta \mathbb{E}\left[V|v < \hat{v}_C^{OM_3}\right] + (1-\delta)(1-\eta)\left[\frac{\left(p_C^{OM_3} x_h - I\right)}{x_h}\right] = 0$. Solving for η we obtain $\eta(R) = \frac{\delta \mathbb{E}\left[V|V<\hat{v}_C^{OM_3}\right] x_h - I - \delta R}{R(1-\delta)}$. Since $\hat{v}_C^{OM_3}$ is unique, so is η.

□

Proof of Lemma 4. The use of MA and PE fully deters funds misappropriation because the entrepreneur, upon failing development, has no leftover funds to run away with. The rest of the proof is identical to the proof for Theorem 2.

□

Proof of Proposition 4. It can be readily checked that all the proofs in the paper continue to hold when α is an increasing function of v. We briefly touch on the foundational results. All results are available upon request.

Lemma 1

The informational advantage of crowdfunding, $-(1-\alpha(v))\left[-I + \delta v x_l (1+\gamma)\right]$, decreases in v.

Proposition 1

For the proof it is relevant what happens after the campaign is a success (else money does not change hands). The fact that α is a function of v does not affect the proof in the least.

Lemma 3 and Proposition 2

All profit expressions in the proofs are conditional on the campaign being a success (else money does not change hands). The fact that α is a function of v only affects backers' posterior distribution of performance conditional on a campaign being successful. Since the proofs use a general density f, they continue to hold by simply replacing $f(\cdot)$ with its updated posterior $f(\cdot|X = x_h)$.

Proposition 3 and Theorem 1

The equilbrium under OM follows from the ones under O and M, so it stays the same. The proof of the theorem stems from the shape of $\frac{d}{dR}\left[\mathcal{L}^{OM}-\mathcal{L}^{O+M}\right]$, so the fact that α is a function of v does not change the proof in the least.

Section 5

All the proofs build on results from Section 4. The only change in the proofs is in backers' update of $f(\cdot)$ as discussed above. The only proof that needs updating is that of Theorem 4, where we have

$$\begin{aligned}\Delta\Pi(\chi) &= \left[-\alpha I\left(1-\phi\left(\check{v}^{OM}_{MA-V}\right)\right)\right]F\left(\check{v}^{OM}_{MA-V}\right)+\int_{\hat{v}^{OM}_{MA-V}}^{\hat{v}^{OM}_{PE-V}}\left\{\alpha\left[-I+\delta v x_h(1+\gamma)\right]-\Pi_B(v)\right\}f(v)\,dv\\ &\quad+\chi\int_{\check{v}^{OM}_{MA-V}}^{\hat{v}^{OM}_{MA-V}}f(v)\,dv-\chi\alpha\delta\int_{\underline{v}}^{\hat{v}^{OM}_{PE-V}}f(v)\,dv,\end{aligned}$$

with $\phi(k)=\frac{\mathbb{E}[V|v<k]}{\mathbb{E}[V|v<k,X=x_h]}=F(k)^{-1}\int_{\underline{v}}^{k}vf(v)\,dv\left[\int_{\underline{v}}^{k}v\alpha(v)f(v)\left(\int_{\underline{v}}^{k}\alpha(z)f(z)\,dz\right)^{-1}dv\right]^{-1}$.

It is easy to check that $\Delta\Pi(0)=0$ and $\frac{d}{d\chi}\Delta\Pi(\chi)|_{\chi=0}>0$ still hold, so results are confirmed.

□

Proof of Proposition 5. It can be readily checked that all the proofs in the paper continue to hold when $v\delta(v)$ is increasing, save for Proposition 1, where $\delta(v)$ concave is a sufficient condition for it to hold. We briefly touch on the foundational results, and focus on Proposition 1 due to its additional requirement. All results are available upon request.

Lemma 1

The informational advantage of crowdfunding, $-(1-\alpha)\left[-I+\delta(v)vx_l(1+\gamma)\right]$, decreases in v.

Proposition 1

We solve the game using backward induction. Assume that at time 2, upon raising $p_C^M\cdot x_h$ and investing I, the entrepreneur fails development. In this case, running is the best response for the entrepreneur iff $p_C^M x_h-I>R$, that is, iff $p_C^M>\bar{p}$, with $\bar{p}=(R+I)x_h^{-1}$. Otherwise, the entrepreneur is better off using any leftover funds to (partially) refund backers. If backers anticipate that the entrepreneur will run upon failing development, they are willing to pledge at most $p_{run}=\delta(v)v$, since with probability $1-\delta(v)$ the product will not be delivered. If they anticipate a refund, on the other hand, they are willing to pledge as much as $p_{ref}=v-(1-\delta(v))I(\delta(v)x_h)^{-1}$, which is higher than p_{run} but less than v, since when development fails the entrepreneur refunds them using leftover funds. In equilibrium, the entrepreneur charges the highest price that strategic customers are willing to pledge, conditional on them correctly inferring her running strategy. We now prove that, if $\delta(v)v$ increases in v, and if $\delta(v)$ is weakly concave, then there are three possible cases to consider. From the equation that define p_{run} and p_{ref} (page 1) it follows that $p_{ref}\geq p_{run}$. If $\delta(v)v$ increases in v then p_{run} increases in v. Finally, if $\delta(v)$ is weakly concave then p_{ref} is weakly concave, since $\frac{d}{dv}p_{ref} = \delta'' \cdot I \left(x_h \delta^2\right)^{-1}$. Consider the richer case of $p_{run}(\underline{\mathrm{v}}) < \bar{p} < p_{run}(\bar{v})$ (the others are easier to check). All we need to show is that $p_{ref}(v)$ is equal to $\bar{p}(v)$ at most once. Since $p_{ref} \geq p_{run}$ we know that $p_{ref}(\bar{v}) > \bar{p}$. If $p_{ref}(\underline{v}) > \bar{p}$ then $p_{ref} > \bar{p}$ for all v. If instead $p_{ref}(\underline{v}) < \bar{p}$, define v_1 as $p_{run}(v_{run}) = \bar{p}$, and suppose that p_{ref} crosses $\bar{p}$ twice, and let v_2 be the highest performance for which $p_{ref}(v_2) = \bar{p}$. Then it must be that $v_2 < v_{run}$; but then, due to the concavity of p_{ref}, this means that p_{ref} is decreasing for every $v > v_2$. Then $p_{ref}(v_{run}) < \bar{p} = p_{run}(v_{run})$, which contradicts $p_{ref} \geq p_{run}$. It follows that there exist two thresholds v_{M1} and v_{M2} that define three cases. For $v < v_{M1}$ we have that $p_{run} < p_{ref} \leq \bar{p}$, for $v > v_{M2}$ we have that $\bar{p} < p_{run} < p_{ref}$, and for intermediate v's we have $p_{run} \leq \bar{p} < p_{ref}$. These are the same cases as in the base model, so the equilibrium outcome is the same.

Lemma 3

For the pooling equilibrium, the proof is the same, except that in this case the price is given by $p_{pool} = \left[\mathbb{E}\left[\delta(V)V\right] - (1-\delta)\frac{I}{x_h}\right]\left[1-(1-\beta)(1-\delta)\right]^{-1}$. As before, the pooling equilibrium Pareto dominates the separating equilibrium if and only if the lowest type earns more in the pooling equilibrium, which now holds iff $\delta(\underline{v})\underline{v} \leq \mathbb{E}\left[\delta(V)V\right]$. A sufficient condition is that $\delta(v)v$ be non-decreasing. The rest of the proof is otherwise identical.

Proposition 2

When $\delta(v)$ is decreasing, funds raised in crowdfunding are higher for low-performance entrepreneurs, leading again to higher-performance types preferring bank funding. High-performance entrepreneurs can still raise enough to meet the goal because expected value $(v\delta(v))$ increases in v. Formally, $I = x_h \underline{v}\,\delta(\underline{v}) < x_h F\left(\hat{v}^O\right)^{-1} \int_{\underline{v}}^{\hat{v}_C^O} \left[v - (1-\delta(v))\,\delta(v)^{-1}\, I\, x_h^{-1}\right] dF = x_h p_C^O$.

Proposition 3 and Theorem 1

The equilbrium under OM follows from the ones under O and M, so it stays the same. The proof of the theorem stems from the shape of $\frac{d}{dR}\left[\mathcal{L}^{OM} - \mathcal{L}^{O+M}\right]$, so the fact that δ is a function of v does not change the proof in the least.

Section 5

All the proofs build on results from Section 4, in particular on O. The only change in the proofs is that δ is moved within the integral sign, or the expectation sign, with no effect on the main results (theorems, propositions, lemmas).

□