CROWDFUNDING OR BANK FINANCING: INNOVATION WITH THE THREAT OF DOWNSTREAM IMITATION AND MARKET UNCERTAINTY

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Crowdfunding or Bank Financing: Innovation with the Threat of Downstream Imitation and Market Uncertainty

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Abstract

We consider a startup seeking external financing such as crowdfunding and bank financing. Public information disclosure may incur downstream imitation under crowdfunding, and demand uncertainty creates an additional burden on profitability under bank financing. We study how the startup can mitigate downstream imitation via information disclosure and what is the optimal funding choice in the presence of downstream imitation and demand uncertainty. Reward-based crowdfunding has experienced dramatic growth in recent years. However, crowdfunding is a double-edged sword: on the one hand, releasing more information can induce more contributors to pledge and increase the chance of surviving in the campaign; on the other hand, more public information lowers the barrier to entry and attracts opportunistic entrepreneurs. We explore how a startup might mitigate this threat via information disclosure and discuss the benefits of two financing strategies. We employ a game-theoretical model where the startup can either choose the bank financing strategy and start the business activity without demand information or elect the crowdfunding strategy in the presence of downstream imitation. We find that the startup may accommodate imitation in the presence of a small or large crowdfunding market. The information disclosure can be used as a weapon to mitigate downstream imitation, i.e., the startup may strategically hide crowdfunding information to weaken or expel the imitator. We show that the startup should choose bank financing if the commercial risk is low and crowdfunding otherwise. That is, the complementary relationship between the risk of downstream imitation and commercial risk appeals for bank fi-

nancing. We show how startups can strategically reveal product information on the public crowdfunding platform, thus guiding startups for deterring potential downstream imitation. We also show that the commercial risk of projects affects startups' funding choice, which in turn is of interest to crowdfunding platforms aiming at high-quality projects.

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Chapter 1

Introduction

In recent years, *reward-based crowdfunding*, in which an entrepreneur promises backers a reward (e.g., a completed product) in exchange for funding, has experienced dramatic growth. For example, Kickstarter, one of the most famous crowdfunding platforms, reported that the money pledged has increased from $2.5 million in 2009 to $777.8 million in 2020 (Kickstarter 2020). While big brands may embrace crowdfunding for marketing purposes (Robles 2017), most crowdfunding project owners are startups. To raise funds through reward-based crowdfunding, a startup needs to run a campaign on a public crowdfunding platform (Belleflamme et al. 2014), e.g., Kickstarter, IndieGogo, JD Finance. By setting a reward price as well as a funding goal, the startup attracts potential backers through the publicized prototype and the promise of a completed product as a reward.[1] The startup receives all the funds as long as the funding goal is reached; otherwise, this project is typically scrapped. Such a financing strategy has brought 20,000 innovative projects or ideas to market annually in recent ten years (Kickstarter 2020).

Unfortunately, star products in the campaign are also frequent targets of downstream

[1]The most common type of reward-based campaign is called *all-or-nothing*, in which the creator needs to set a target funding goal.

imitation, i.e., opportunistic entrepreneurs may utilize public information from fruitful crowdfunding projects and counterfeit these successful products. For example, a 24-year-old entrepreneur in Canada launched his product – The Cozy Bag, based on the successful project named KAISR on Indiegogo (Guzman 2017). The copycat tends to compete with the original startup at a lower price in the downstream retail market (Bercovici 2019), e.g., the project named Fidget Cube on Kickstarter offers a reward price at \$20. At the same time, its counterfeiting products are sold at \$4 and \$1.5 on Amazon and Taobao, respectively (Lee 2017). The motivation behind downstream imitation is clear: free-riding on the innovative ideas associated with consumers' attention. This copycat issue does cost the crowdfunding market millions of dollars (Burgess 2016). On the one hand, existing promising products incur costs in the presence of downstream imitation. On the other hand, copycats hurt the whole crowdfunding market since potential startups may worry about possible stigma and turn to other financing strategies (Carman 2020).

Since downstream imitation is a severe and real threat to startups that aims to run a campaign on the public crowdfunding platform. Specifically, crowdfunding is a double-edged sword: releasing more information, such as disclosing more features or functionalities of the product, can induce more contributors to pledge and increase the chance of surviving in the campaign, while more public information also lowers the barrier to entry (Cowden and Young 2020). Thus, it is increasingly important to understand how downstream imitation impacts startups' information disclosure and how startups can effectively combat imitation with pricing and information decisions. However, to our knowledge, no prior study addresses these critical issues. In particular, it is unclear how firms make pricing decisions in a crowdfunding campaign in the presence of downstream imitation; what economic implications strategic disclosure of information will have on the operation of the crowdfunding platform; and how these results rely on market conditions such as imitation efficiency and crowdfunding market size. In this paper, we investigate these essential questions in a sequential game.

In addition to the choice of soliciting financial contributions via a crowdfunding campaign, startups have other options, such as traditional bank financing strategy (NSBA 2017)[2]. Under bank financing, startups can sell products to the market without the risk of information leakage, which mitigates potential downstream imitation. To be specific, the adoption of bank financing makes it possible for startups to monopolize the market at the early stage and strengthen brand awareness in this niche. However, startups may be at a disadvantage when the prospect of innovative projects or ideas cannot be probed in advance. Thus, banks charge an interest rate to offset the risk from market uncertainty, and startups need to pay additional costs eventually.

Both crowdfunding and bank financing strategies provide startups with financing benefits, while the latter creates an additional burden on profitability due to demand uncertainty. Since for new products, the demand is usually hard to predict, and the variance could be significant. By contrast, the rise of reward-based crowdfunding has made it possible for startups to pre-sell and probe the market in advance (Agrawal et al. 2014, Strausz 2017). Specifically, crowdfunding outcomes serve as a credible public signal of products' prospects (Babich et al. 2021). If the result of a crowdfunding campaign signals that the actual demand is in the low state, then the startup is free to stop the development before incurring costs. Thus, in the absence of potential downstream imitation, the crowdfunding strategy can perform well and much better than the traditional bank financing strategy. However, the issue of downstream imitation cannot be neglected when running a crowdfunding campaign, and this brings up an interesting question: Which type of financing strategies performs better if potential downstream imitation is taken into account?

Motivated by the above discussion, the primary objective of this paper is to investigate the following research questions in the presence of downstream imitation.

[2]The percentages of adoption for the surveyed firms are: large bank loan (15%), community bank loan (14%), venture capital/angel investors (3%), and crowdfunding (1%).

(1) What is the equilibrium outcome if the startup chooses the crowdfunding strategy, and how is it affected by the market conditions, e.g., crowdfunding market size and downstream imitation efficiency?

(2) How do the two financing strategies compare to each other in terms of their impacts on the startup's profits and consumer surplus in the presence of market uncertainty?

To answer these questions, we build a game-theoretical model where the startup can either choose the bank financing strategy and start the business activity without demand information, or elect the crowdfunding strategy in the presence of downstream imitation. Among the results, we highlight our main findings below.

First, monopoly or duopoly may occur with distinct drivers if the startup opts for crowdfunding strategy. When the barrier to entry is high, the startup monopolizes both the crowdfunding and the retail market without the need to hide information. By contrast, when the barrier to entry is low, an intermediate crowdfunding market makes it profitable for the startup to expel the imitator via concealing information. However, the startup chooses to accommodate imitation if the crowdfunding market is small or large. In the case of a small crowdfunding market, the funding goal cannot be reached if the startup tries to expel the imitator via concealing information. In the case of a large crowdfunding market, the profits earned in the crowdfunding market exceed the losses in the retail market regardless of the efficiency of the competitor.

Second, the startup may fully or partially disclose the product information under crowdfunding. Specifically, when the crowdfunding market is intermediate, partial information disclosure is adopted to expel the imitator and guarantee the monopoly power. On the other hand, the startup may strategically hide crowdfunding information to weaken the imitator and mitigate downstream imitation when the imitation efficiency is high. The startup may not be able to choose the optimal strategy of information disclosure if the crowdfunding market is too small due to financial constraints. Thus, our results show that both full and partial information strategies are possible in the equilibrium.

Third, a more efficient imitator creates an incentive for the startup to hide more crowdfunding information in monopoly or duopoly case, respectively. However, the optimal information strategy is non-monotonic in the imitation efficiency. This is because the startup chooses the beneficial oligopoly case, and monotonicity does not hold when the case transfers from monopoly to duopoly or duopoly to monopoly. On the other hand, the optimal information strategy is non-monotonic in the size of the crowdfunding market. The idea behind this behavior is that a smaller crowdfunding market creates an incentive for the startup to hide more information with the goal of mitigating downstream imitation. However, the startup fails to choose the optimal information strategy due to financial constraints if the crowdfunding market is too small.

Finally, the startup should choose bank financing if the commercial risk is low and crowdfunding otherwise. To be specific, the complementary relationship between the risk of downstream imitation and commercial risk appeals for bank financing. Our results show that there exists a threshold regarding the commercial success rate, and this threshold weakly decreases in downstream imitation. Moreover, the crowdfunding strategy always brings at least the same surplus to consumers as bank financing does. Thus, the crowdfunding strategy achieves a weakly win-win in the crowdfunding region.

This paper is organized as follows. Section 2 provides a brief review of the relevant literature. In Section 3, we formulate the model and present the case of traditional bank financing. Section 4 analyzes the properties of the optimal information disclosure strategy under crowdfunding, which allows us to compare the optimal expected profit under crowdfunding to that under bank financing and characterize the conditions under which the crowdfunding strategy is beneficial in Section 5. Finally, we provide conclusions and directions for future research in Section 6. All proofs are relegated to the appendices.

Chapter 2

Literature Review

Our paper is generally connected with two academic fields known as crowdfunding and information leakage. Specifically, we focus on literature regarding campaign design and operations under crowdfunding and information leakage issues among supply chain.

Crowdfunding campaign design. There is a sizable literature in economics and business that focuses on crowdfunding campaign design (see Strausz 2017, Fatehi and Wagner 2019, Ellman and Hurkens 2019). Hu et al. (2015) study the optimal product line design and pricing decisions in a crowdfunding mechanism. Chang (2016) examines whether the fixed or flexible funding mechanism should be adopted under crowdfunding and show that fixed funding campaigns perform better. Kumar et al. (2020) investigate the role of crowdfunding contracts as a price-discrimination mechanism and show that tighter financing constraints may decrease the degree of price discrimination. Observing a cascade effect on the campaign, Du et al. (2017) propose three contingent stimulus policies to save lagging projects. Belavina et al. (2020) also propose two mechanisms based on deferred payments, different timing, and enforcement rules to mitigate two kinds of risks: funds misappropriation and performance opacity. These papers show that appropriate crowdfunding mechanisms are key ingredients for success. Apparently, the threat of potential downstream imitation is absent in those works. Hence, by considering potential downstream imitation, we manage to derive more insights in this paper.

Crowdfunding operations. Launching a successful campaign and maximizing the profit given certain conditions (e.g., risk of failure, funding goal, and market size) in the long run is another critical topic in the crowdfunding community (see Alaei et al. 2016, Chemla and Tinn 2020, Chakraborty and Swinney 2021). Roma et al. (2018) focus on the information value of crowdfunding and answer the question of whether an entrepreneur should launch a crowdfunding campaign before gaining access to venture capital and how to set the parameters of a crowdfunding campaign. Babich et al. (2021) show that launching a crowdfunding campaign can help to overcome the agency problem but may harm the firm and venture capital investors. Zhang et al. (2017) consider revenue management under crowdfunding. In particular, crowdfunding involves economic interactions and observational learning, making it distinct from other business activities. Xu et al. (2018) and Cong and Xiao (2021) discuss the operation of crowdfunding campaigns in the presence of information aggregation. Xu and Zhang (2018) summarize the firm's optimal reward choice in the presence of network externality. Apart from these papers, we investigate a startup's crowdfunding strategy in the presence of potential downstream imitation, and uncover the strategic role of information disclosure as a weapon to defer and/or weaken the ensuing retail competition. In addition, we further compare with traditional bank financing to study the startup's optimal funding choices and the associated welfare implications.

Information leakage. Our paper also contributes to the emerging literature on the issue of information leakage in the business area (see Purohit 1994, Gao and Su 2016, Pun and DeYong 2017). Sun et al. (2010) propose the *barrier-erecting strategy* and the *market-grabbing strategy* to deter the imitator's entry in the presence of technology transfer. Yi et al. (2020) investigate the impact of counterfeiting from the perspective of the global supply chain and answer the question of how supply chain members combat counterfeiting. The majority of the previous research on the issue of counterfeiting assumes there is knowledge transfer; however, information leakage may occur in the presence of sequential decision. The extant studies on advance-selling show that selling with information disclosure at a predetermined time of the season leads to information leakage (see Li and Zhang 2013, Chu and Zhang 2015, Li 2016). In this paper, we model a startup that can strategically hide crowdfunding information to deter potential entry and provide important and practical insights on using information disclosure as a weapon in many business settings.

To sum up, our primary contribution to the literature is as follows. We are among the first to consider the impact of downstream imitation on the information disclosure strategy under crowdfunding and the optimal funding choice. This advances the relevant literature and captures many of the real-life situations and therefore has a considerable practical value. Moreover, by introducing the information disclosure to startups' crowdfunding operations, our model links the crowdfunding information disclosure to their crowdfunding and retail pricing decisions, which has essential managerial implications but is largely overlooked in the literature that studies crowdfunding operations.

Chapter 3

Model setup

In this section, we describe a game between a startup and a potential imitator. We first introduce each player's objective function and their decisions in Section 3.1 and consumers' demand function in Section 3.2. Then we formalize the sequence of events in Section 3.3. Finally we present the case of traditional bank financing as the benchmark model and its results in Section 3.4. The notations used in this paper are summarized on Appendix A.1.

3.1 Firms

We consider one startup having an innovative idea, and the quality q of its product is determined exogenously by this idea. To put this idea into practice and cover the fixed setup cost C_s, the startup needs to resort to external financing. Traditional bank financing strategy used to be the first choice when firms require external financing. Given the funding target C_s, the bank evaluates the market risk and decides the interest rate to charge. After securing the loan, the startup sells its products to the whole market at price p_b. Alternatively, the startup may consider the innovative crowdfunding strategy, which receives increasing attention recently and is more friendly to startups. If the startup chooses crowdfunding, it needs to decide the information disclosure level λ besides the reward price p_c on the crowdfunding platform. After a successful campaign, the startup continues to sell its products to the retail market at retail price p_r. The startup thus needs to make decision on whether to raise funding via a crowdfunding campaign or to borrow money from the bank.

However, disclosing product's information in a public crowdfunding platform may attract potential imitators. As the crowdfunding platforms gain in popularity, an increasing number of speculators try to capitalize on the success of promising products. These potential imitators keep scanning the crowdfunding platform and try to produce counterfeiting products from what the startup discloses. To capture this downstream threat in our model, we introduce a potential imitator in the retail period. This imitator would not enter the market until it receives the signal of a successful campaign. After observing the innovative product with quality λq on the crowdfunding platform, the imitator with efficiency $\delta \leq 1$ can only replicate part of the original product. That is, the quality of counterfeiting product is $\delta\lambda q$, and the startup and the imitator compete on their quality respectively in the retail market.

Similar to the startup, the imitator enters the market only when its profit can cover the fixed costs C_i. In the main model, where δ is exogenously given, we restrict that $\delta \in (0, \frac{4}{7})$ to exclude the uninteresting case where an imitator with stronger efficiency in imitation harms itself.

3.2 Consumers

The whole market can be divided into two parts: the crowdfunding market with a fraction $\frac{\alpha}{\alpha+1}$ and the retail market with a fraction $\frac{1}{\alpha+1}$. We call α the crowdfunding market proportion, and a large (small) α indicates that the ratio of crowdfunding market potential over retail market potential is high (low). All consumers share the same utility function $u = \theta q - p$, where θ is consumers' preference for quality and is assumed to be uniformly distributed over $[0, 1]$, q and p represent the product quality and price they observe respectively. In our model, the perceived quality depends not only on the stage but also on the startup's information disclosure. To be specific, during the crowdfunding stage, consumers make purchasing decisions based on what the startup displays on the crowdfunding platform, and the perceived quality in this stage is λq. After a successful campaign, consumers observe that the startup delivers promised products to backers in the crowdfunding stage, and the updated perceived quality is q. And if the imitator enters the retail market, consumers can observe its product quality $\delta\lambda q$ directly.

Since the product is innovative, the startup is uncertain about the market response. To capture the market uncertainty, we assume that the whole market is composed of population of infinitesimally small consumers with total mass $(\alpha + 1)X$. Here X follows a Bernoulli distribution[1]:

$$X = \begin{cases} X_H, & \text{with probability } \beta \\ X_L, & \text{with probability } 1 - \beta \end{cases},$$

where $\beta \in (0, 1)$ and $X_H > X_L \geq 0$. Specifically, the crowdfunding market size is αX and the retail market size is X. To rule out uninteresting cases, we assume that there is zero demand in the low state, that is, $X_L = 0$. In the case of bank financing, the startup sells the product to the whole market with total mass $(\alpha + 1)X$. This setting ensures fair comparison by incorporating all consumers in the retail market under bank financing.

[1]Many literature use a two-state model to capture the risk associated with innovative products (e.g., Ueda 2004, Roma et al. 2018, Belavina et al. 2020)

3.3 Sequence of Events

There are three stages in our model, with detailed game sequences given below.

Stage 1 (*The choice of financing*) The startup chooses to raise funds via the crowdfunding campaign or the bank.

Stage 2 (*Financing*)

- In the case of bank financing, the bank decides the interest rate r_b to charge.
- In the case of crowdfunding, the startup decides the reward price p_c and the information disclosure level λ to the crowdfunding market.

Stage 3 (*Selling*)

- In the case of bank financing, the startup sells the product to the whole market at price p_b before the demand realization.
- In the case of crowdfunding, the startup stops the project if the campaign fails. Otherwise, the imitator decides whether or not to enter the market and compete with the startup for the retail market at price p_i and p_s respectively.

3.4 Bank Financing Strategy

Startups rely on traditional bank financing strategy for fund-raising. This kind of financing strategy, though bringing additional costs to the startup, does prevent information leakage before the selling period. In this section, we study the startup's optimal pricing decision under bank financing as performance benchmark. Specifically, we first characterize the bank's interest rate decision, and then derive the startup's optimal pricing and profit.

When the bank makes the interest rate decision, it is often assumed that the bank loans are competitively priced (e.g., Kouvelis and Zhao 2018, Kouvelis et al. 2019, Kouvelis and Xu 2021). Consistent with the literature of supply chain finance, we assume that the risk-free interest rate is zero for expositional brevity. We denote that $\eta > 0$ as the interest rate premium charged by the bank. Because of the market uncertainty, there are two possible outcomes of issuing the loan: (1) the market is in low state, and the bank can only get the startup's sales revenue, i.e., both the bank and the startup receive zero profit, and (2) the market is in high state, and the bank can recover the investment as expected. Thus, the bank offers the interest rate r_b in which the bank is indifferent between issuing the loan to the startup and earning the interest rate premium η, i.e.,

$$C_s(1+\eta) = \mathbb{E}_X[\min\{(\alpha+1)p_b(1-\frac{p_b}{q})X, C_s(1+r_b)\}].$$

On the basis of this risk pricing mechanism, we derive the interest rate r_b the bank would charge and the optimal pricing strategy and profit when bank financing strategy is feasible.

Proposition 1. *Bank financing strategy is feasible when $\beta > \frac{4C_s(1+\eta)}{(\alpha+1)qX_H}$. In this case, the bank issues the loan with the interest rate r_b^* to the startup, i.e., $r_b^* = \frac{1+\eta}{\beta} - 1$, the optimal price and associated expected profit are:*

$$p_b^* = \frac{q}{2} \quad and \quad \mathbb{E}_X[\Pi_s^B]^* = qX_H\frac{(\alpha+1)\beta}{4} - C_s(1+\eta).$$

Proposition 1 first characterizes the condition when the bank financing strategy is feasible. The commercial success rate β should be large enough to ensure that the bank can break even and the startup find it profitable in high state. Thus, the bank financing strategy is feasible only when the commercial success rate is large enough, i.e., $\beta > \frac{4C_s(1+\eta)}{(\alpha+1)qX_H}$. The optimal interest rate r_b^* decreases in the commercial success rate β, since less risk premium is required when the market is more likely to be the high state. Proposition 1 also states that the optimal price under bank financing is independent of the commercial success rate β. By contrast, the startup's equilibrium profit increases in the commercial success rate. To ensure fair comparisons between bank financing and crowdfunding strategy, we assume that the interest rate premium η charged by the bank is zero in the subsequent analysis.

Chapter 4

Crowdfunding Strategy

This section analyzes the optimal information disclosure and pricing strategy under crowdfunding. Note that under crowdfunding strategy, in contrast to selling to the whole market under bank financing, the startup first focuses on the crowdfunding market and subsequently promotes successful products to the retail market. Hence, we describe a two-period game to capture this essential characteristic of crowdfunding strategy. The solution concept we adopt is the subgame-perfect Nash equilibrium, which is derived via backward induction. To be specific, we first solve the subgame of retail stage in Section 4.1 and then go backwards to the crowdfunding stage in Section 4.2. Moreover, we conduct sensitivity analysis with respect to the crowdfunding market proportion α and the imitation efficiency δ in Section 4.3.

4.1 Retail Stage

In the retail stage, we focus only on the case of high state, that is, $X = X_H$. Since when the market size is $X_L = 0$, the crowdfunding strategy helps the startup to end an unpromising product. There are two possible equilibriums in this stage: (1) there is no entry and the startup monopolizes the retail market, and (2) the imitator and the startup competes for their own market share. Specifically, the next lemma provides us a view on the optimal pricing strategies in the retail stage.

Lemma 1. *Given $\lambda \in (0,1]$, the optimal retail pricing strategy and associated profit are:*

(i) When $\frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2} \leq C_i$ holds, the imitator does not enter the market (i.e. monopoly case), and the equilibrium outcome is:

$$p_s^* = \frac{q}{2}, \quad \Pi_{sr}^* = \frac{qX_H}{4};$$

(ii) When $\frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2} > C_i$ holds, the imitator enters the market (i.e. duopoly case), and the equilibrium outcome is:

$$p_i^* = \frac{\delta\lambda q(\delta\lambda - 1)}{\delta\lambda - 4}, \quad \Pi_i^* = \frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda - 4)^2},$$

$$p_s^* = \frac{2q(\delta\lambda - 1)}{\delta\lambda - 4}, \quad \Pi_{sr}^* = \frac{4q(1-\delta\lambda)X_H}{(\delta\lambda - 4)^2}.$$

The above lemma shows that the startup's retail pricing and profit depends on the information disclosure decision and the imitation efficiency. When $\frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2} \leq C_i$, part (i) indicates that there is no entry because of the high barrier to entry. The startup sells its product to half of the retail market at a monopoly price. Part (ii) reveals the equilibrium prices and profits of the duopoly case. We can see that the crowdfunding information disclosure and the imitator's efficiency act as a negative driving force on the startup's profit, i.e., a stronger opponent harms the startup's profit to a larger extent. However, the imitator's profit increases in δ when $\delta\lambda \leq \frac{4}{7}$ and decreases otherwise. Higher efficiency, in other words, hurts the imitator. This is because δ is exogenously determined, and to rule out uninteresting cases, we assume that $\delta \in (0, \frac{4}{7}]$ hereafter.

Lemma 1 further provides insights that the startup can use the crowdfunding information disclosure λ as a weapon to weaken or expel the imitator. We define an imitation efficiency threshold δ_i below which the imitator would not enter the market, i.e., $\Pi_i^*(\delta_i) = C_i$. When $\delta > \delta_i$, the startup can hide crowdfunding information to convince the imitator that this product is not so profitable. We denote $\lambda_{ci} := \frac{\delta_i}{\delta}$ as the threshold of information disclosure, and any decision above λ_{ci} incurs downstream imitation.

4.2 Crowdfunding Stage

In the crowdfunding stage, the startup needs to decide the reward price p_c and the level of information disclosure λ. Since the decision of reward price does not influence all subsequent decisions, the optimal reward price can be rewritten as $p_c^* = \frac{q\lambda}{2}$. For convenience of exposition, we define k_s as $\frac{C_s}{qX_H}$ and k_i as $\frac{C_i}{qX_H}$ in the later analysis. The following proposition shows the equilibrium results under crowdfunding.

Proposition 2. *When crowdfunding strategy is feasible ($\alpha > 4k_s$), there are five possible equilibrium cases under crowdfunding. Table 4.1 summarizes the results for each equilibrium cases.*

Table 4.1: Equilibrium Cases

Case	λ^*	p_c^*	p_s^*	p_i^*	$\mathbb{E}_X[\Pi_s]^*$	$\mathbb{E}_X[\Pi_i]^*$
CMF	1	$\frac{q}{2}$	$\frac{q}{2}$	-	$(\frac{1}{4} + \frac{1}{4}\alpha - k_s)\beta q X_H$	-
CMP	λ_{ci}	$\frac{q\lambda_{ci}}{2}$	$\frac{q}{2}$	-	$(\frac{1}{4} + \frac{1}{4}\lambda_{ci}\alpha - k_s)\beta q X_H$	-
CDF	1	$\frac{q}{2}$	$\frac{2(1-\delta)}{4-\delta}q$	$\frac{(\delta-1)\delta}{\delta-4}q$	$(\frac{1}{4}\alpha + \frac{4(1-\delta)}{(\delta-4)^2} - k_s)\beta q X_H$	$(\frac{(1-\delta)\delta}{(\delta-4)^2} - k_i)\beta q X_H$
CDP1	$\frac{4k_s}{\alpha}$	$\frac{2qk_s}{\alpha}$	$\frac{\alpha-4\delta k_s}{2(\alpha-\delta k_s)}q$	$\frac{\delta k_s(\alpha-4\delta k_s)}{\alpha(\alpha-\delta k_s)}q$	$\frac{\alpha(\alpha-4\delta k_s)}{4(\alpha-\delta k_s)^2}\beta q X_H$	$(\frac{\delta k_s(\alpha-4\delta k_s)}{4(\alpha-\delta k_s)^2} - k_i)\beta q X_H$
CDP2	λ_s	$\frac{q\lambda_s}{2}$	$\frac{2(1-\delta\lambda_s)}{4-\delta\lambda_s}q$	$\frac{\delta\lambda_s(\delta\lambda_s-1)}{\delta\lambda_s-4}q$	$(\frac{\lambda_s}{4}\alpha + \frac{4(1-\delta\lambda_s)}{(\delta\lambda_s-4)^2} - k_s)\beta q X_H$	$(\frac{\delta\lambda_s(1-\delta\lambda_s)}{(\delta\lambda_s-4)^2} - k_i)\beta q X_H$

Note: Here "-" means the imitator does not enter the retail market.

Proposition 2 shows that each equilibrium case is characterized by different types of the startup and the imitator, corresponding to different combinations of α and δ.

Specifically, in case "CMF", which represents the monopoly case with full information disclosure under crowdfunding, there is a high barrier to entry and the imitator does not enter the market. When the barrier to entry is low, the threat of downstream imitation is credible and the optimal information disclosure strategy depends on the imitator's efficiency. In case "CMP", the imitation is inefficient, and the costs of expelling the imitator is low, thus the startup conceals critical product information to deter entry. However, when the imitation is efficient, the startup may strategically display product information in the presence of downstream imitation (e.g., case "CDF", case "CDP1" or case "CDP2"). There are two different reasons for such a concealment of information. First, the startup can not display too little information due to the crowdfunding financial constraint. For example, in case "CDP1", the startup has to set $\lambda^* = \frac{4k_s}{\alpha}$ to ensure the success of campaign, even though the optimal λ is much lower than the one it chooses. The second reason why the startup hides the crowdfunding information is purely strategic – to weaken the imitator. For example, in case "CDP2", the startup uses the information disclosure as a weapon to mitigate the risk of downstream imitation.

The level of information disclosure clearly demonstrates the key trade-off: the immediate financing needs and the downstream imitation threats. More specifically, disclosing more information in the crowdfunding stage can help the startup to raise money, but it may also attract a more competitive imitator. By contrast, hiding crowdfunding information can mitigate the risk of downstream imitation, but the startup may fail to reach the funding goal. To summarize, the level of information disclosure (i.e., full or partial) and the nature of retail competition (i.e., monopoly or duopoly) actually reflect this trade-off. The following proposition provides us a comprehensive view on the nature of these equilibrium cases.

Proposition 3. *Suppose the crowdfunding strategy is feasible ($\alpha > 4k_s$).*

(i) If $\delta \leq \delta_i$ or ($\delta_i < \delta \leq \frac{4}{7}$ and $\frac{4k_s}{\delta_i}\delta \leq \alpha \leq \overline{\alpha}_M$), the startup monopolizes the market, otherwise the imitator will enter the market.

(ii) If $\delta > \hat{\delta}$ *or* ($\delta_i < \delta \leq \hat{\delta}$ *and* $\frac{4k_s}{\delta_i}\delta < \alpha < \frac{\delta^2(\delta+8)}{(\delta-4)^2(\delta-\delta_i)}$*), the startup hides some quality information to weaken or exclude the imitator, i.e.,* $\lambda^* < 1$*; otherwise, the startup discloses full quality information, i.e.,* $\lambda^* = 1$*.*

Part (i) of Proposition 3 presents the conditions for downstream competition. The relationship between the crowdfunding market proportion and the imitation efficiency is illustrated by Figure 4.1, where the startup monopolizes the retail market only when the barrier to entry is high (i.e., $\delta > \delta_i$), or the crowdfunding market proportion is intermediate (i.e., $\underline{\alpha}_M < \alpha < \overline{\alpha}_M$). When the threat of downstream imitator is credible, the startup faces the choice between monopoly and duopoly. If the crowdfunding market is small compared to the imitation efficiency (i.e., $\alpha \leq \underline{\alpha}_M$), then the startup's first priority is to ensure the success of campaign rather than the monopoly power. By contrast, if the crowdfunding market is relatively large (i.e., $\alpha \geq \overline{\alpha}_M$), it is unprofitable for the startup to deter the entry by sacrificing the crowdfunding market. This is because, when the crowdfunding market is large enough, the monopoly profit ensured by hiding crowdfunding information can not cover the loss in the crowdfunding market. Only when the crowdfunding market proportion is intermediate would the startup prefer the monopoly power.

One of the main contributions of this paper is to characterize the conditions under which the startup fully or partially reveals the product information. Part (ii) of Proposition 3 further reveals interesting insights regarding the crowdfunding information disclosure. If the threat of downstream imitation is strong, the startup always chooses to undermine or expel the imitator by hiding crowdfunding information. However, even though the threat is insignificant, this proposition shows that the startup may partially disclose the information. This is because the costs of expelling a weak imitator is modest, and this provides an incentive for the startup to monopolize the market. Figure 4.1 depicts the impact of downstream imitation on the information disclosure as stated in Proposition 3.

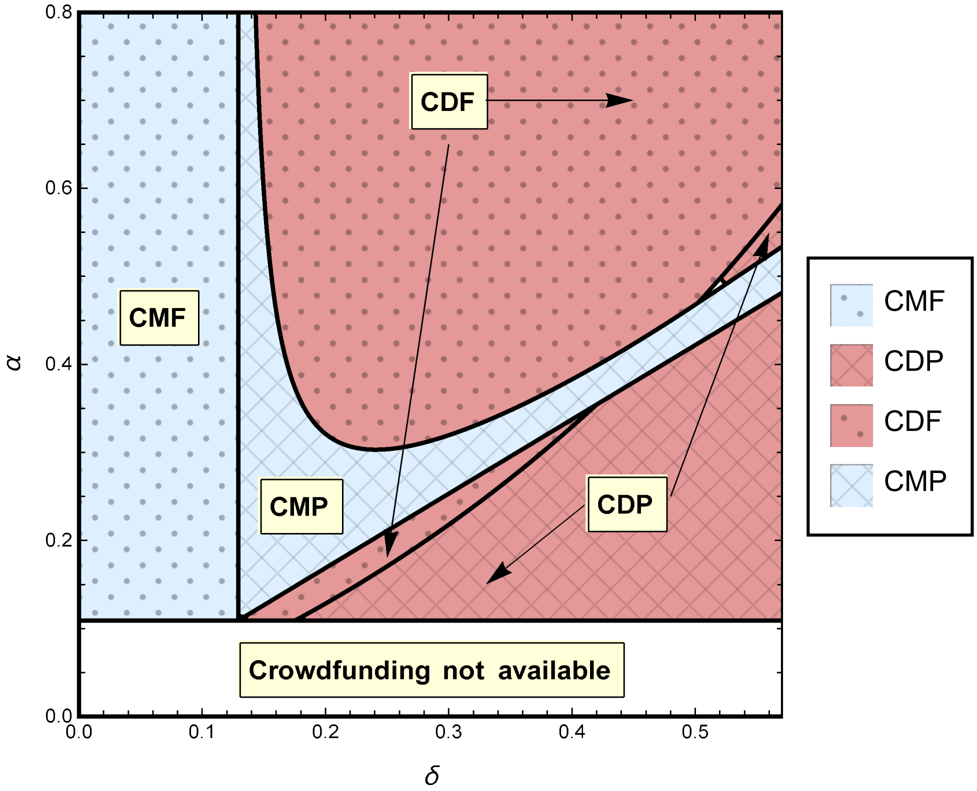


Figure 4.1: Equilibrium cases ($\delta_i = 0.129, k_s = 0.027$)

4.3 Sensitivity Analysis

In this subsection, we conduct a sensitivity analysis on the strategy of information disclosure and profits, seeking to investigate the role crowdfunding market proportion and imitation efficiency play in this duopoly game. For example, the startup may leverage on crowdfunding information disclosure to affect the imitator's product quality, which in turn affects its retail profit. The crowdfunding and retail prices, although important to the profit too, can be stated in terms of the level of information disclosure and follow similar patterns as λ^* shows. Thus, we focus on the analysis of λ^* for simplicity. We start with the proposition below.

Proposition 4. *When crowdfunding strategy is feasible ($\alpha > 4k_s$),*

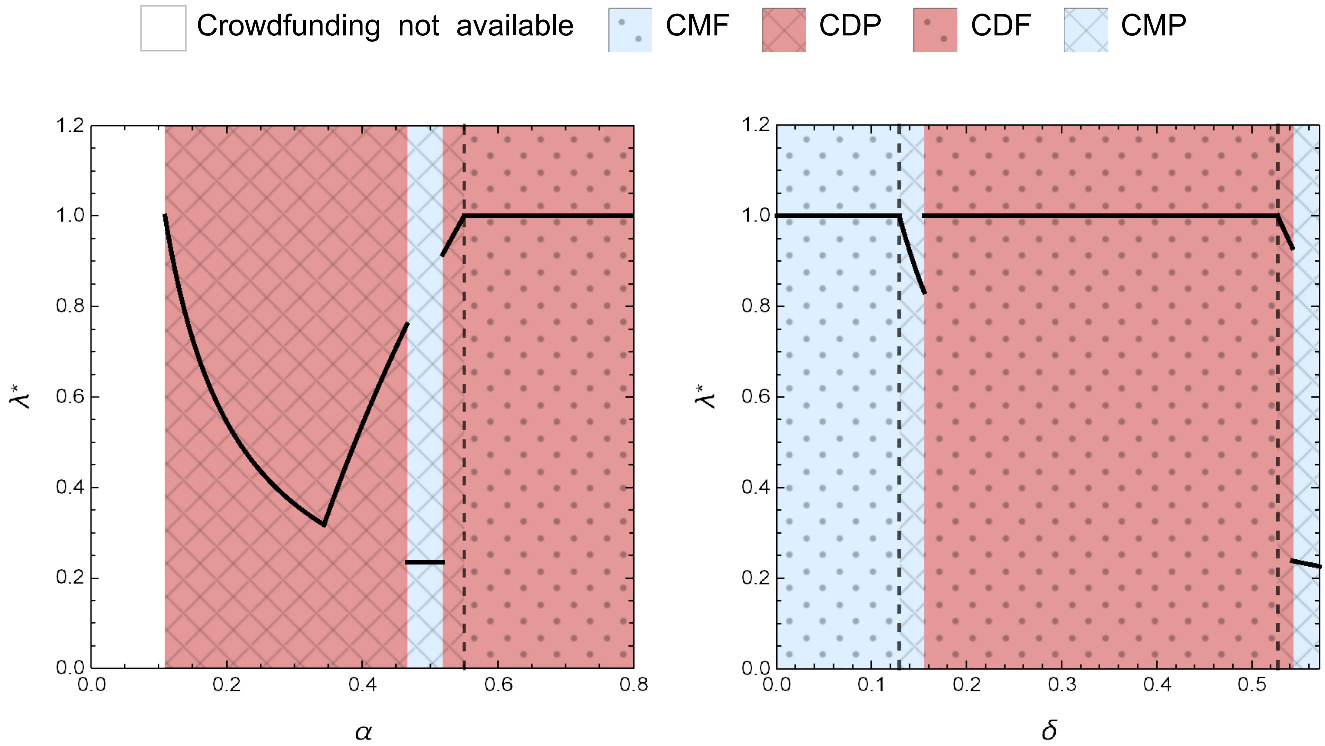
(i) In case "CMF" and "CMP", the level of information disclosure λ^* is constant

in α and weakly decreases in δ (i.e. $\frac{\partial \lambda^*}{\partial \delta} \leq 0$);

(ii) In case "CDF" and "CDP", the level of information disclosure λ^* is non-monotonic in α and weakly decreases in δ (i.e. $\frac{\partial \lambda^*}{\partial \delta} \leq 0$).

The foremost result shown in Proposition 4, given by part (i) and (ii) respectively, is that in the presence of a more efficient imitator, the startup hides more crowdfunding information. The rationale behind this behavior is that the highest level of information disclosure to expel the imitator (i.e., λ_{ci}) decreases in the imitator's efficiency in counterfeiting the product. That is, as λ increases, the startup has to hide more crowdfunding information and incur greater losses in crowdfunding market, with the goal of monopolizing the retail market. Part (ii) next reveals a similar impact of imitation efficiency on the optimal level of information disclosure when accommodating imitation, since it is preferable for the startup to weaken a threatening imitator and soften the retail competition.

On the contrary, the size of crowdfunding market does not affect the decision of information disclosure in an intuitive way, i.e., λ^* may decrease or increase in α. This is because when the crowdfunding market is small, the startup gives a higher priority to ensure the success of campaign, otherwise the business activity cannot continue. This financial constraint becomes relaxed as α increases, thus relieves the startup from the effort involved in hiding crowdfunding information. When the size of crowdfunding market is intermediate, the financial constraint is inactive under the optimal information decision, and the startup is more inclined to attract more customers by higher information disclosure in crowdfunding market as α increases. An intermediate crowdfunding market may also create incentive for the startup to choose λ_{ci} to expel the imitator, and this decision is constant and does not depend on α. Proposiiton 4 elaborates how the optimal level of information disclosure is affected by the market conditions in each cases respectively, however, does not capture why the startup changes the information strategy under different conditions. The next corollary then presents the overall sensitivity analysis regarding to the optimal level of information disclosure and explains the idea behind these equilibrium shifts.



(a) Effect of α on λ^*

(b) Effect of δ on λ^*

Figure 4.2: $\delta_i = 0.129, k_s = 0.027$

Corollary 1. *When crowdfunding strategy is feasible ($\alpha > 4k_s$), the level of information disclosure λ^* is non-monotonic in both α and δ.*

On the basis of proposiiton 4, corollary 1 further shows the comparative statics with respect to the changes of market conditions, that is, how does the equilibria shift when α or δ increases. One example of crowdfunding equilibrium shifts is demonstrated in Figure 4.2. When the crowdfunding market size increases, λ^* always follows a "Duopoly"→"Monopoly"→"Duopoly" sequence,[1] e.g. "CDP"→"CMP"→"CDP"→"CDF" in Figure 4.2 (a). These equlibria shifts always exhibit a upward jump discontinuity

[1]This sequence can be proved based on Proposition 2.

in the transition of “Monopoly”→“Duopoly”. The rationale behind this behavior is that a large crowdfunding market reduces the incentive to monopolize the retail market, and makes it more profitable to accommodate the imitator, i.e. balance two markets with information decision λ_s or give highest priority to the crowdfunding market with information decision $\lambda^* = 1$. On the contrary, when the crowdfunding market is small, the startup cannot use the information disclosure as a weapon and has to accommodate the imitator, with the goal of a successful crowdfunding campaign, even though it is more profitable to expel the imitator with information decision λ_{ci}. The transition from “Duopoly” to “Monopoly” thus may be continuous if the startup chooses the duopoly case because of the financial constraint, or exhibit a downward jump discontinuity from λ_s to λ_{ci} if the startup chooses the duopoly case with the goal of balancing profits from two markets.

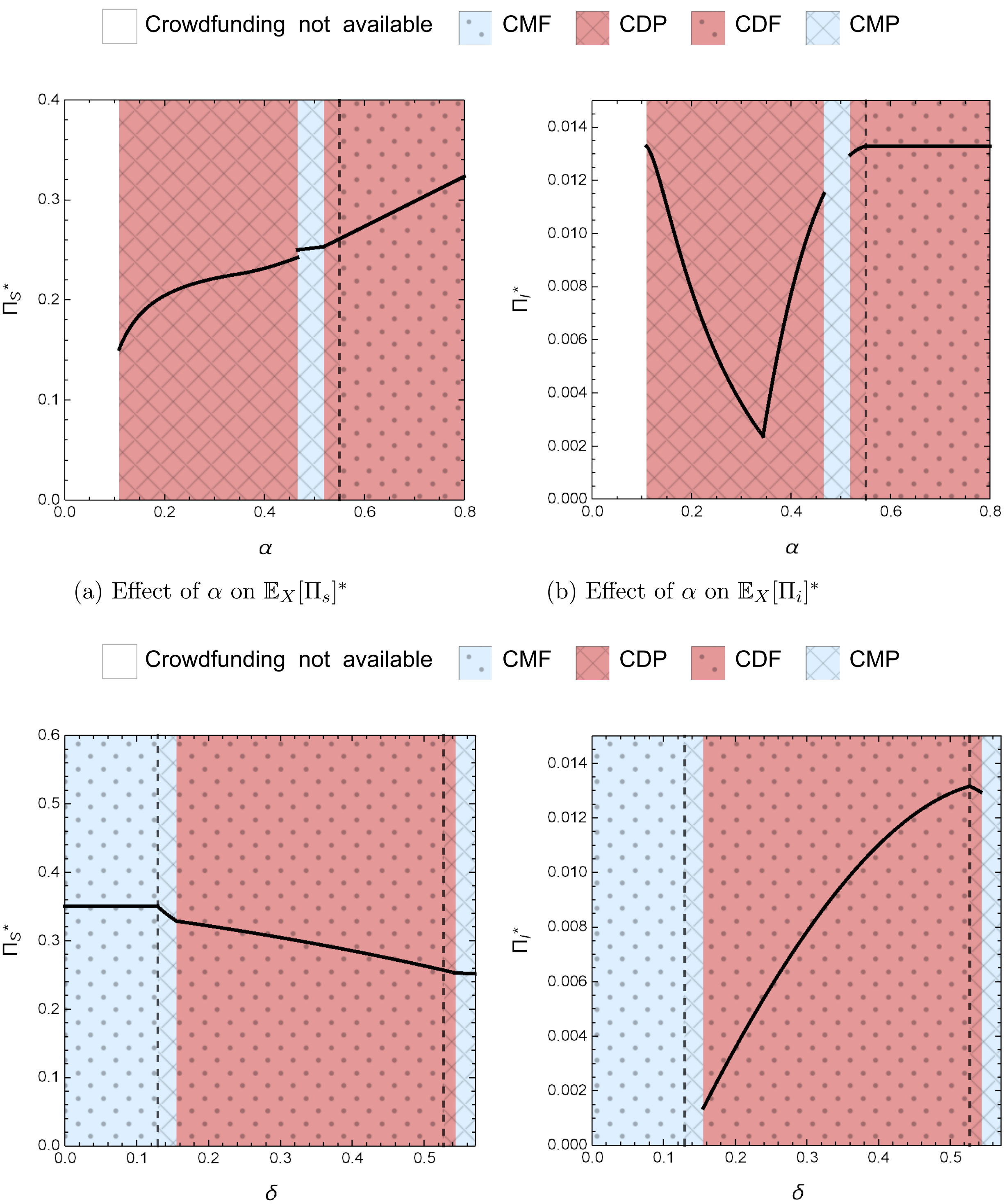
On the other hand, when the downstream imitation efficiency increases, λ^* follows a “Monopoly”→“Duopoly”→“Monopoly” or “Monopoly”→“Duopoly” sequence,[2] e.g. “CMF”→“CMP”→“CDF”→“CDP”→“CMP” in Figure 4.2 (b). Interestingly, an efficient or inefficient imitator may strengthen the incentive for the startup to hide crowdfunding information, with the goal of weakening or expelling the imitator, while the startup may accommodate the imitator with intermediate efficiency. The idea behind this behavior is that the costs to expel an inefficient imitator is negligible and an efficient imitator poses a serious threat to the startup who publicizes the whole information. When the financial constraint is inactive, the optimal level of information disclosure λ^* actually exhibits a upward jump discontinuity in the transition from “Monopoly” to “Duopoly” and a downward jump discontinuity in the transition from “Duopoly” to “Monopoly”. Since the startup can freely choose the information disclosure strategy without the constraint of funding goal. These transitions actually reveal the trade-off in the allocation of profits from the crowdfunding and the retail market, as shown by the following proposition.

[2] This sequence can be proved based on Proposition 2.

Proposition 5. *When crowdfunding strategy is feasible ($\alpha > 4k_s$), the startup's profit $\mathbb{E}_X[\Pi_s]^*$ always weakly increases in α (i.e. $\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} \geq 0$) and weakly decreases in δ (i.e. $\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} \leq 0$), while the imitator's profit $\mathbb{E}_X[\Pi_i]^*$ is non-monotonic in α and δ.*

Proposition 5 summarizes the impact of crowdfunding market and downstream imitation on profits and, Figure 4.3 illustrates an example of equilibrium profit curves for the startup and the imitator, respectively. To be specific, the crowdfunding market size α and the downstream imitation efficiency δ affects the startup's profit in an intuitive way, i.e., larger α or smaller δ will result in higher profit. This observation can be explained in the following way. On the one hand, regardless of different cases of information disclosure and oligopoly, a larger crowdfunding market or a weaker imitator benefits the startup. On the other hand, the monotonicity of crowdfunding market and downstream imitation hold across different cases because the startup benefits from the first-mover advantage by which it can elect dominant cases. For example, case "CMP" dominates case "CDP" when α increases in Figure 4.3a, and case "CDF" dominates case "CMP" when δ increases in Figure 4.3c. This further helps explain why the optimal level of information disclosure is not continuous in the previous proposition, since the dominant cases vary under different market conditions.

On the contrary, the effect of α and δ on the imitator's profit is non-monotonic. The effect of α on Π_i^* is illustrated by Figure 4.3b, where larger crowdfunding market hurts the imitator if crowdfunding target constraint is binding and benefits the imitator otherwise. In this case, a large crowdfunding market relaxes the startup's financial constraint, and endows the startup with a level of flexibility in decision-making, i.e. the startup hides more crowdfunding information and weakens the imitator. By contrast, when the crowdfunding financial constraint is not binding, the startup gives more priority to the crowdfunding market and displays more crowdfunding information as α increases. For example, in Figure 4.3b, the imitator's profit first decreases and then increases in case "CDP". Interestingly, high efficiency in imitation does not always benefit the imitator, since the startup may strategically disclose crowdfunding information to weaken the imitator or deter the entry. For example, in Figure 4.3d, the imitator's profit increases in case "CDF" but decreases in case "CDF" as δ increases.



(a) Effect of α on $\mathbb{E}_X[\Pi_s]^*$

(b) Effect of α on $\mathbb{E}_X[\Pi_i]^*$

(c) Effect of δ on $\mathbb{E}_X[\Pi_s]^*$

(d) Effect of δ on $\mathbb{E}_X[\Pi_i]^*$

Figure 4.3: Effect of Crowdfunding Market Size and Imitation Efficiency on Startup's and Imitator's Profit

Chapter 5

Optimal Funding Choice

In this section, we shift our focus to the optimal funding choice between bank financing and crowdfunding strategies. Specifically, we first investigate the impact of commercial success rate and imitation efficiency on the optimal funding choice, and discuss the strengths and weaknesses of both financing strategies. Then we discuss how commercial success rate and imitation efficiency affect the startup's optimal profit. Finally, we present the impact of optimal funding choice on consumer surplus. The detailed comparisons between bank financing and crowdfunding strategies are given in the next proposition.

Proposition 6. *When crowdfunding and bank financing strategy are both feasible (i.e. $\alpha > 4k_s$ and $\beta > \frac{4k_s(1+\eta)}{(\alpha+1)}$), if $\beta > \hat{\beta}$ and $\delta > \delta_i$, it is optimal for the startup to choose the bank financing strategy; otherwise, the startup should choose the crowdfunding strategy*[1].

Proposition 6 summarizes the startup's optimal funding choice under different situations. When there is no downstream imitation due to a high barrier to entry, i.e., $\delta < \delta_i$, crowdfunding is preferred over bank financing regardless of the commercial risk. This is because, in the absence of downstream imitation, crowdfunding strategy

[1] The optimal crowdfunding strategy has been given in Proposition 2.

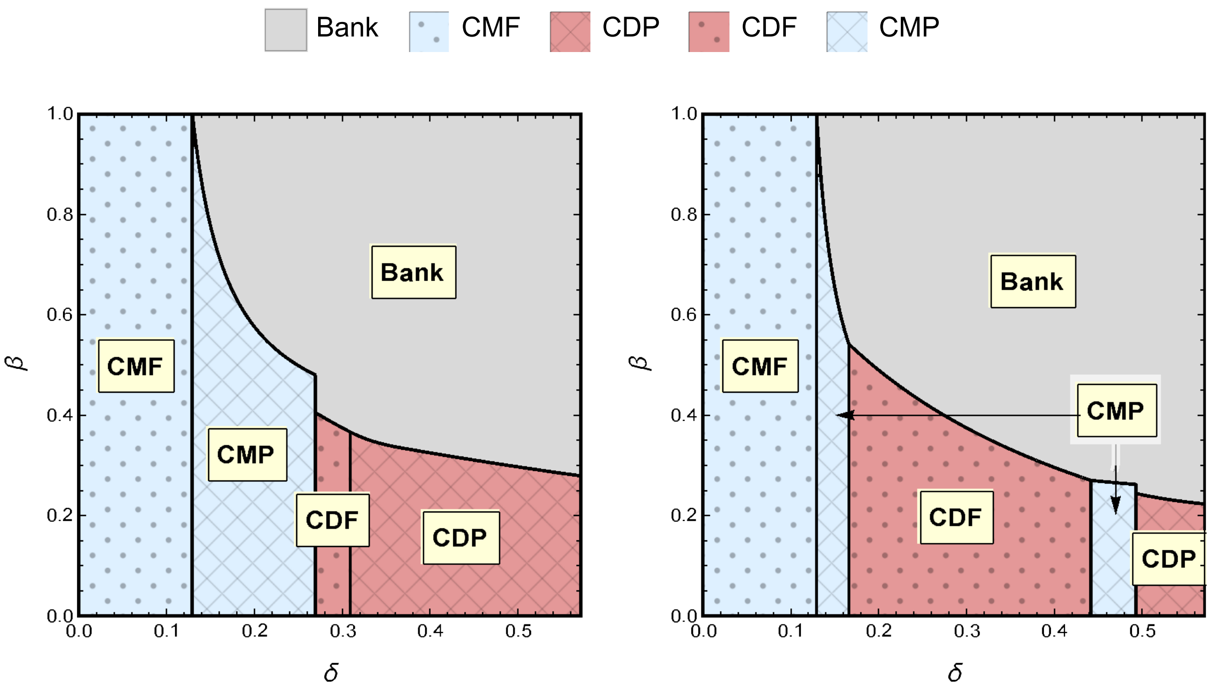
helps the startup mitigate the commercial risk and avoid unnecessary investment by probing the market demand without any additional costs. In the presence of downstream imitation, the startup may choose bank financing if the commercial risk is low (i.e. $\beta > \hat{\beta}$) and crowdfunding otherwise. Such observation provides a key managerial insight: When the startup raises money for the product with high commercial risk, e.g. innovative or niche products, since the real demand is uncertain, it is preferable to launch a crowdfunding campaign and collect information on demand. By contrast, when consumers are familiar with the type of product and the commercial risk is thus low, the bank financing strategy favors the startup by reducing the potential downstream competition.

The downstream imitation also creates an incentive for the startup to choose the bank financing. However, when the project is at a high risk of failure, i.e. small β, the startup opts for the crowdfunding strategy regardless of the magnitude of downstream threat. The rationale behind this is that the bank charges high interest for market uncertainty, and this amplifies the risk-averse function of crowdfunding strategy. In this case, the optimal crowdfunding strategy has been shown in Proposition 2 and varies on different commercial success rates and downstream imitation efficiencies. For example, in Figure 5.1 (a), the optimal crowdfunding strategy follows "CMF"→"CMP"→"CDF"→"CDP" sequence as δ increases, while in Figure 5.1 (b), the optimal crowdfunding strategy follows "CMF"→"CMP"→"CDF"→"CMP"→"CDP" as δ increases. This risk-averse function of crowdfunding strategy diminishes when the project is anticipated to achieve success with large probability, and thus a promising prototype encourages the startup to choose bank financing in the presence of strong downstream imitation.

We further discuss the threshold of commercial success rate in which the startup is indifferent between bank financing and crowdfunding strategies and its relationship with the magnitude of downstream imitation in the next corollary.

Corollary 2. *The threshold $\hat{\beta}$, where the startup is indifferent between bank financing* *and crowdfunding, decreases in δ.*

As the imitation efficiency increases, the startup becomes more conservative and chooses bank financing even though the commercial risk is not low, regardless of the crowdfunding market proportion α. This is because the risk of downstream imitation complements the commercial risk, induces the startup to choose traditional bank financing to mitigate these risks. It is noteworthy that such case with a high risk of downstream imitation but low commercial risk are common in reality; for example, the KAISR original air lounge, which exceeded its Indiegogo goal in just 12 hours, faced competition from the counterfeit product named Cozy Bag quickly. Since this innovative idea regarding to product design has been fully disclosed in a public platform, and the barrier to entry is low in this niche market.



(a) Small α (b) Large α

Figure 5.1: Optimal Funding Choice in δ, β

Note: $\delta_i = 0.129, k_s = 0.027$ in (a)-(b); $\alpha = 0.416$ in (a); $\alpha = 0.227$ in (b).

Next, we investigate how would the market conditions affect the startup's profit under optimal funding choice and answer our second research question. Under certain conditions on the startup's fixed costs, the following corollary shows the results of the sensitivity analysis regarding the relevant parameters.

Corollary 3. *When crowdfunding and bank financing strategy are both feasible (i.e.* $\alpha > 4k_s$ *and* $\beta > \frac{4k_s(1+\eta)}{(\alpha+1)}$*), the startup's optimal profit weakly decreases in* δ *and weakly increases in* β*.*

Again, the commercial success rate β and the downstream imitation efficiency δ affects the startup's optimal profit in an intuitive way, i.e., larger β or smaller δ will result in higher profit. These results can be explained by the following fact: First, as shown by Proposition 5, more promising product or higher barriers to counterfeit benefits the startup under optimal crowdfunding strategy. Second, as shown by Proposition 1, the startup would earn less when there is higher failure risk of its project and the downstream imitation does not directly affect the profit under optimal bank financing strategy. Finally, the monotonicity holds across different financing strategies since the startup can elect dominant strategies.

To conclude this section, we summarize and compare the impacts of different financing strategies on consumer surplus in the next proposition.

Proposition 7. *When crowdfunding and bank financing strategy are both feasible (i.e.* $\alpha > 4k_s$ *and* $\beta > \frac{4k_s(1+\eta)}{(\alpha+1)}$*), the crowdfunding strategy always weakly benefits consumers and achieves weakly win-win in crowdfunding region (i.e. Customers are indifferent between crowdfunding strategy and bank financing strategy in case CMF).*

Proposition 7 summarizes the impact of implementing crowdfunding or bank financing strategy on consumer surplus. To be specific, crowdfunding strategy always brings more or equal surplus to consumers more than bank financing strategy does, and thus achieves weakly win-win in crowdfunding region, e.g. case "CMF", "CMP", "CDF" and "CDP" in Figure 5.1 (a). This weakly win-win outcome can be explained in the following way. On the one hand, the startup may strategically hide product's information under crowdfunding strategy, and this behavior lowers the crowdfunding price and increases the surplus for consumers in the crowdfunding market. On the other hand, due to the downstream competition, the startup lowers the retail price and more consumers can afford such purchasing in the retail market. Particularly, in case "CMF", crowdfunding strategy provides the same consumer surplus as bank financing strategy does, since the startup fully discloses crowdfunding information and charges the same price as using the bank financing strategy in the absence of downstream imitation. Moreover, consumers may find that their anticipated utility are not always better under crowdfunding strategy than that under bank financing strategy, but their received utility under crowdfunding strategy are always greater.

Chapter 6

Conclusion

This paper investigates a duopoly game where the startup depends on outside financing to cover fixed costs. The startup can either choose to run a crowdfunding campaign to solicit financial contributions in the presence of downstream imitation, or elect to borrow money from a bank and incur additional interest. We first analyze the optimal information disclosure strategy and pricing decisions under crowdfunding, and then compare these results to that under bank financing. In this paper, we focuses on the optimal funding choice and incorporate two new features into the setting. First, there exists potential downstream imitation under crowdfunding. Second, the startup can hide crowdfunding information strategically during the campaign. Together, the two features considered in our model introduce new and interesting results and insights when seeking outside financing.

We report several main results from this paper. First, the startup accommodates imitation only when the crowdfunding market is not intermediate, and the imitator is not so efficient. To be specific, a large crowdfunding market encourages the startup to disclose more information, while a small crowdfunding market suppresses the incentive to use information disclosure as a weapon due to financial constraint. We find that when the crowdfunding market is intermediate, the startup may strategically hide crowdfunding information to weaken or expel the imitator. The idea behind this decision is that the threat of downstream imitation can be mitigated via strategic information disclosure. Second, our results show that the crowdfunding strategy performs well, and in many cases much better than the bank financing strategy if the commercial risk is not low. The complementary relationship between the risk of downstream imitation and the commercial risk creates an incentive for the startup to opt for the bank financing strategy. Furthermore, the crowdfunding strategy always weakly benefits consumers since consumers may receive products with higher quality than that anticipated in the presence of downstream imitation. Thus, the crowdfunding strategy achieves weakly win-win as long as the commercial risk is not too low.

We conclude by pointing out the caveats of our model and suggesting some directions for future research. First, consumers make take-it-or-leave-it decisions in our model. If, however, strategic consumers may postpone purchasing decisions to the next period, which is possible in reality (Pun and DeYong 2017), then the analysis and result will be changed. Second, to capture the uncertainty of demand for crowdfunding projects, we assume the actual demand may be high or low, and the demand in the low state is normalized as zero. However, a general demand function will accommodate more realistic settings, although incorporating it requires more computational efforts. Third, the setting of information disclosure in our model is using to capture the information and quality gap between the startup and the imitator. However, information disclosure also plays an important role in mitigating quality uncertainty. Finally, the combination of bank financing and crowdfunding may perform better than either bank financing or crowdfunding strategy. For example, in some cases, the startup can split the fixed costs and set a lower funding goal to monopolize the market.

Appendix A

A.1 Model Notations

Table A.1: Summary of Model Notations

Parameters	
α	crowdfunding market share, the market share for the retail is normalized as 1
β	commercial success rate
X	market size of the retail market, $X = \begin{cases} X_H & \text{with probability } \beta \\ 0 & \text{with probability } 1-\beta \end{cases}$
q	the quality of the startup's product
θ	consumers' preference for quality, $\theta \sim U[0,1]$
δ	imitator's efficiency in imitation, $\delta \in (0,1)$
η	interest rate premium under bank financing
Π_j^i	j's profit when using i strategy, where $i \in \{B, CM, CD\}$ indicates bank financing strategy, crowdfunding strategy in monopoly case and in duopoly case, $j \in \{i, s, sc, sr\}$ indicates imitator's profit, startup's total profit in both markets, startup's profit in crowdfunding market and in retail market
r_b	interest rate charged by the bank
k_s	crowdfunding target coefficient, and the target is $C_s = k_s\beta q X_H$
k_i	Imitator's entry cost coefficient, and the entry cost is $C_i = k_i\beta q X_H$

Decisions	
λ	Crowdfunding Strategy: the level of quality disclosure decided by the startup, $\lambda \in [0,1]$
p_c	Crowdfunding Strategy: the reward price decided by the startup in the campaign
p_s	Crowdfunding Strategy: the retail price decided by the startup in the retail period
p_i	Crowdfunding Strategy: the retail price decided by the imitator in the retail period
p_b	Bank Financing Strategy: the retail price decided by the startup

Derived	
δ_i	$\delta_i = \frac{-\sqrt{1-48k_i}+8k_i+1}{2(k_i+1)} (\frac{\delta_i\lambda(1-\delta_i\lambda)}{(\delta_i\lambda-4)^2}\Big\|_{\lambda=1} = k_i)$ and is a one-to one map from $0 \leq k_i \leq \frac{1}{48}$ to $\delta_i \in [0, \frac{4}{7}]$, we use it to capture imitator's fixed cost in later sections, only when $\delta > \delta_i$ will the imitator be willing to enter the market
λ_{ci}	$\lambda_{ci} = \frac{\delta_i}{\delta}$, the upper bound λ for the startup to exclude the imitator
λ_s	maximum point for Π_s^{CD}, can be derived by the 1st order condition $\frac{\alpha}{4} + \frac{4\delta(\delta\lambda_s+2)}{(\delta\lambda_s-4)^3} = 0$, and λ_s increases in α and decreases in δ
$\hat{\delta}$	The lower δ bound for the region where $\lambda_s < 1$, and $\hat{\delta}$ is the unique root to $\alpha = \frac{16\delta(\delta+2)}{(4-\delta)^3}$.
δ_s	The unique root to $\frac{\alpha}{4} + \frac{4\delta(\delta\lambda_s+2)}{(\delta\lambda_s-4)^3} = 0$.
$\overline{\alpha}_M$	The upper bound for monopoly case, when $\delta_i < \delta \leq \delta_s$, $\overline{\alpha}_M = \frac{\delta^2(\delta+8)}{(\delta-4)^2(\delta-\delta_i)}$, and when $\delta_s < \delta \leq \frac{4}{7}$, $\overline{\alpha}_M$ is the unique root to $\Pi_s^{CM}(\lambda_{\text{ci}}) = \Pi_s^{CD}(\lambda_s)$.
$\hat{\beta}$	The lower bound β for bank financing in equilibrium, $\hat{\beta} = \begin{cases} \frac{4(\delta-4)^2k_s}{\delta(\delta+8)+4(\delta-4)^2k_s} & \text{Case CDF} \\ \frac{4\delta k_s}{\alpha(\delta-\delta_i)+4\delta k_s} & \text{Case CMP} \\ \frac{4k_s(\alpha-\delta k_s)^2}{\alpha^3+(\alpha+1)\delta^2k_s^2-2(\alpha-1)\alpha\delta k_s} & \text{Case CDP1} \\ \frac{4k_s}{\alpha+4k_s+\alpha(-\lambda_s)+\frac{16(\delta\lambda_s-1)}{(\delta\lambda_s-4)^2}+1} & \text{Case CDP2} \end{cases}$

Note: Here $\vee$ denote the maximum operator (i.e.,$x \vee y = \max(x, y)$), $\wedge$ denote the minimum operator (i.e.,$x \wedge y = \min(x, y)$).

A.2 Proof of Statements

Proof of Proposition 1 We prove this proposition via backward induction. Suppose bank financing strategy is feasible and the bank charges the interest rate r_b, the startup chooses the price p_b to optimize the profit, that is,

$$\max_{p_b} \mathbb{E}_X[\Pi_s^B] = \mathbb{E}_X\left[\left((\alpha+1)p_b(1-\frac{p_b}{q})X - C_s(1+r_b)\right)^+\right] .$$

Regardless of the interest rate r_b charged, suppose it is profitable for the startup in high state, then the first-order condition yields the optimal price and associate profit

$$p_b^* = \frac{q}{2} \quad \text{and} \quad \mathbb{E}_X[\Pi_s^B]^* = \beta(qX_H\frac{(\alpha+1)}{4} - C_s(1+r_b)).$$

And it is profitable for the startup in high state only when $\mathbb{E}_X[\Pi_s^B]^* > 0$, i.e., $qX_H\frac{(\alpha+1)}{4} - C_s(1+r_b) > 0$. Anticipating the startup's optimal pricing decision, the bank decides whether to offer the loan and charges the interest rate r_b according to the competitive credit pricing equation, i.e.,

$$\begin{aligned} C_s(1+\eta) &= \mathbb{E}_X[\min\{(\alpha+1)p_b^*(1-\frac{p_b^*}{q})X, C_s(1+r_b)\}] \\ &= \beta\min\{qX_H\frac{(\alpha+1)}{4}, C_s(1+r_b)\} \\ &= \beta C_s(1+r_b). \end{aligned}$$

Thus, the optimal interest rate charged is $r_b^* = \frac{1+\eta}{\beta} - 1$, and bank financing strategy is feasible when $\mathbb{E}_X[\Pi_s^B]^* > 0$, i.e., $\beta > \frac{4C_s(1+\eta)}{(\alpha+1)qX_H}$. □

Proof of Lemma 1 The retail market can be the monopoly case or the duopoly case depending on whether the imitator enters the market. And the imitator enters the market only when the retail profit is greater than the costs.

Duopoly case. The startup and the imitator simultaneously choose p_s and p_i respectively to maximize their own profits, that is,

$$\begin{cases} \max\limits_{p_s} \quad \Pi_{sr}^{CD} = p_s(1-\theta_{si})X_H \\ \max\limits_{p_i} \quad \Pi_i = p_i(\theta_{si} - \dfrac{p_i}{\lambda\delta q})X_H \\ \text{s.t.} \quad p_i(\theta_{si} - \dfrac{p_i}{\lambda\delta q})X_H \geq C_i \end{cases} \tag{A.1}$$

Here θ_{si} denotes the preference for quality at which consumers are indifferent between purchasing from the startup and purchasing from the imitator, i.e., $\delta\lambda q\theta_{\mathrm{si}} - p_i = q\theta_{\mathrm{si}} - p_s$. It is easily found that the first-order condition with respect to p_s and p_i yields the equilibrium

$$p_i^* = \frac{\delta\lambda q(\delta\lambda - 1)}{\delta\lambda - 4}, \quad \Pi_i^* = \frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2},$$
$$p_s^* = \frac{2q(\delta\lambda - 1)}{\delta\lambda - 4}, \quad \Pi_{sr}^* = \frac{4q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2}.$$

Thus, the imitator enters the market only when $\Pi_i^* > 0$, i.e., $\frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2} > C_i$.

Monopoly case. When $\frac{\delta\lambda q(1-\delta\lambda)X_H}{(\delta\lambda-4)^2} \leq C_i$, the imitator does not enter the market, and the startup chooses p_s to maximize the profit, that is,

$$\max_{p_s} \Pi_{sr}^{CM} = X_H p_s(1 - \frac{p_s}{q}).$$

It is easily found that the first-order condition with respect to p_s yields the equilibrium

$$p_s^* = \frac{q}{2}, \quad \Pi_{sr}^* = \frac{qX_H}{4}.$$

From Lemma 1, it is easily found that Π_i^* increases in δ and λ when $\delta\lambda \leq \frac{4}{7}$. Based on the assumption $\delta \leq \frac{4}{7}$, there is a unique root $0 < \delta_i \leq \frac{4}{7}$ to $\Pi_i^* = C_i$. The imitator does not enter the market if $\delta \leq \delta_i$ and enters the market if $\delta > \delta_i$ due to the montonicity. Anticipating this behavior, the startup can choose $\lambda \leq \lambda_{ci} = \frac{\delta_i}{\delta}$ to deter the entry or $\lambda > \lambda_{ci}$ and accommodate imitation, where λ_{ci} is also the unique root to $\frac{\delta\lambda(1-\delta\lambda)}{(-4+\delta\lambda)^2} = \mathrm{k}_i$. For simplicity of discussion, we assume the imitator enters the market only when $\Pi_i^* > C_i$. □

Proof of Proposition 2 In this stage, the startup chooses λ and p_c to maximize the expected profit, that is,

$$\begin{aligned} \max_{\lambda,p_c} \quad & \mathbb{E}_X[\Pi_s^C] = \alpha\beta p_c(1-\frac{p_c}{\lambda q})X_H + \mathbb{E}_X[\Pi_{sr}^*] - \beta k_s q X_H \\ \text{s.t.} \quad & \alpha\beta p_c(1-\frac{p_c}{\lambda q})X_H \geq \beta k_s q X_H \end{aligned}.$$

It is easily found that the first-order condition with respect to p_c yields $p_c^* = \frac{\lambda q}{2}$, and the objective function can be rewritten as

$$\begin{aligned} \max_{\lambda} \quad & \mathbb{E}_X[\Pi_s^C] = (\frac{1}{4}\alpha\lambda - k_s)\beta q X_H + \mathbb{E}_X[\Pi_{sr}^*] \\ \text{s.t.} \quad & \frac{1}{4}\alpha\lambda \geq k_s \end{aligned}.$$

From Lemma 1, it means that the startup can choose the monopoly case by deciding $\lambda \leq \lambda_{ci}$ or duopoly case by deciding $\lambda > \lambda_{ci}$. Thus, the objective function can be rewritten as

$$\begin{aligned} \max_{\lambda} \quad & \mathbb{E}_X[\Pi_s^C] = \begin{cases} (\frac{1}{4}\alpha\lambda + \frac{1}{4} - k_s)\beta q X_H & \lambda \in [0, \lambda_{ci}] \quad \text{Monopoly Case} \\ (\frac{1}{4}\alpha\lambda + \frac{4(1-\delta\lambda)}{(\delta\lambda-4)^2} - k_s)\beta q X_H & \lambda \in (\lambda_{ci}, 1] \quad \text{Duopoly Case} \end{cases}. \\ \text{s.t.} \quad & \frac{1}{4}\alpha\lambda \geq k_s \end{aligned}$$

Note that $\mathbb{E}_X[\Pi_s^C]$ increases in λ when $\lambda \in [0, \lambda_{ci}]$, and $\mathbb{E}_X[\Pi_s^C]$ is concave in λ when $\lambda \in (\lambda_{ci}, 1]$.

Case 1: $\frac{\alpha}{4} \leq k_s$. In this case, the crowdfunding strategy is not feasible, since the startup fails to reach the funding goal in a small crowdfunding market.

Case 2: $\frac{\alpha}{4} > k_s$ and $\delta \leq \delta_i$. In this case, the imitator does not enter the market due to the high barrier to entry. Thus, the objective function is

$$\max_{\lambda\in[0,1]} \quad \mathbb{E}_X[\Pi_s^C] = (\frac{1}{4}\alpha\lambda + \frac{1}{4} - k_s)\beta q X_H.$$

The startup can choose the level of information disclosure freely, and it is easily found that the first-order condition with respect to λ yields $\lambda^* = 1$.

Case 3: $\frac{\alpha}{4} > k_s$ **and** $k_i < \frac{1}{48}$ **and** $\delta > \delta_i$ **and** $\frac{4k_s}{\alpha} > \lambda_{ci}$**.** In this case, the imitator enters the market as long as $\lambda > \lambda_{ci}$. However, since $\frac{4k_s}{\alpha} > \lambda_{ci}$, the startup cannot hide enough crowdfunding information to expel the imitator due to financial constraint. The objective function is

$$\max_{\lambda \in [\frac{4k_s}{\alpha},1]} \quad \mathbb{E}_X[\Pi_s^C] = (\frac{1}{4}\alpha\lambda + \frac{4(1-\delta\lambda)}{(\delta\lambda-4)^2} - k_s)\beta q X_H.$$

Let λ_s denote the unique root to the first-order condition of the objective function, i.e., λ_s is the unique root to $\frac{\alpha}{4} + \frac{4\delta(2+\delta\lambda)}{(-4+\delta\lambda)^3} = 0$. Note that $\mathbb{E}_X[\Pi_s^C]$ increases in $[0, \lambda_s]$ and decreases in $(\lambda_s, 1]$. Case 4 can be classified into three cases.

Case 3-1: $\lambda_s < \frac{4k_s}{\alpha}$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ decreases in $[\frac{4k_s}{\alpha}, 1]$. Thus, the optimal decision should be $\lambda^* = \frac{4k_s}{\alpha}$.

Case 3-2: $\frac{4k_s}{\alpha} \leq \lambda_s < 1$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_s]$ and decreases in $(\lambda_s, 1]$. Thus, the optimal decision should be $\lambda^* = \lambda_s$.

Case 3-3: $1 \leq \lambda_s$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, 1]$. Thus, the optimal decision should be $\lambda^* = 1$.

Case 4: $\frac{\alpha}{4} > k_s$ **and** $k_i < \frac{1}{48}$ **and** $\delta > \delta_i$ **and** $\frac{4k_s}{\alpha} \leq \lambda_{ci}$**.** In this case, the imitator enters the market as long as $\lambda > \lambda_{ci}$. The objective function is

$$\max_{\lambda} \quad \mathbb{E}_X[\Pi_s^C] = \begin{cases} (\frac{1}{4}\alpha\lambda + \frac{1}{4} - k_s)\beta q X_H & \lambda \in [\frac{4k_s}{\alpha}, \lambda_{ci}] \quad \text{Monopoly Case} \\ (\frac{1}{4}\alpha\lambda + \frac{4(1-\delta\lambda)}{(\delta\lambda-4)^2} - k_s)\beta q X_H & \lambda \in (\lambda_{ci}, 1] \quad \text{Duopoly Case} \end{cases}.$$

Note that when $\lambda = \lambda_{ci}$, the profit under monopoly case is strictly greater than that under duopoly case. Let Π_s^{CM} and Π_s^{CD} denote the profit under monopoly and duopoly cases respectively. Case 5 can be classified into five cases.

Case 4-1: $\lambda_s < \lambda_{ci}$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_{ci}]$ and decreases in $(\lambda_{ci}, 1]$. Thus, the optimal decision should be $\lambda^* = \lambda_{ci}$.

Case 4-2-1: $\lambda_{ci} \leq \lambda_s < 1$ **and** $\Pi_s^{CM}(\lambda_{ci}) < \Pi_s^{CD}(\lambda_s)$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_{ci}]$, increases in $(\lambda_{ci}, \lambda_s]$ and decreases in $(\lambda_1, 1]$. Thus, the optimal decision should be $\lambda^* = \lambda_s$.

Case 4-2-2: $\lambda_{ci} \leq \lambda_s < 1$ **and** $\Pi_s^{CM}(\lambda_{ci}) \geq \Pi_s^{CD}(\lambda_s)$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_{ci}]$, increases in $(\lambda_{ci}, \lambda_s]$ and decreases in $(\lambda_1, 1]$. Thus, the optimal decision should be $\lambda^* = \lambda_{ci}$.

Case 4-3-1: $1 \leq \lambda_s$ **and** $\Pi_s^{CM}(\lambda_{ci}) < \Pi_s^{CD}(1)$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_{ci}]$, increases in $(\lambda_{ci}, 1]$. Thus, the optimal decision should be $\lambda^* = 1$.

Case 4-3-2: $1 \leq \lambda_s$ **and** $\Pi_s^{CM}(\lambda_{ci}) \geq \Pi_s^{CD}(1)$**.** In this case, $\mathbb{E}_X[\Pi_s^C]$ increases in $[\frac{4k_s}{\alpha}, \lambda_{ci}]$, increases in $(\lambda_{ci}, 1]$. Thus, the optimal decision should be $\lambda^* = \lambda_{ci}$.

Let "C" denotes the crowdfunding strategy, "M" and "D" denote the monopoly and duopoly cases respectively, "F" and "P" denote the cases of full and partial information disclosure respectively. That is, case "CMF" includes case 2, case "CMP" includes case 4-1, case 4-2-2 and case 4-3-2, case "CDF" includes case 3-3 and case 4-3-1, case "CDP1" includes case 3-1, and case "CDP2" includes case 3-2 and case 4-2-1. The equilibrium results are summarized in Table A.2.

Table A.2: Equilibrium results

Case	λ^*	p_c^*	p_s^*	p_i^*	$\mathbb{E}_X[\Pi_{sc}]^*$	$\mathbb{E}_X[\Pi_i]^*$	$\mathbb{E}_X[\Pi_{sr}]^*$	$\mathbb{E}_X[C_s]^*$
CMF	1	$\frac{q}{2}$	$\frac{q}{2}$	-	$\frac{1}{4}\alpha\beta qX_H$	-	$\frac{1}{4}\beta qX_H$	$k_s\beta qX_H$
CMP	λ_{ci}	$\frac{q\lambda_{ci}}{2}$	$\frac{q}{2}$	-	$\frac{\lambda_{ci}}{4}\alpha\beta qX_H$	-	$\frac{1}{4}\beta qX_H$	$k_s\beta qX_H$
CDF	1	$\frac{q}{2}$	$\frac{2(1-\delta)}{4-\delta}q$	$\frac{(\delta-1)\delta}{\delta-4}q$	$\frac{1}{4}\alpha\beta qX_H$	$\frac{(1-\delta)\delta}{(\delta-4)^2}\beta qX_H$	$\frac{4(1-\delta)}{(\delta-4)^2}\beta qX_H$	$k_s\beta qX_H$
CDP1	$\frac{4k_s}{\alpha}$	$\frac{2qk_s}{\alpha}$	$\frac{\alpha-4\delta k_s}{2(\alpha-\delta k_s)}q$	$\frac{\delta k_s(\alpha-4\delta k_s)}{\alpha(\alpha-\delta k_s)}q$	$k_s\beta qX_H$	$\frac{\delta k_s(\alpha-4\delta k_s)}{4(\alpha-\delta k_s)^2}\beta qX_H$	$\frac{\alpha(\alpha-4\delta k_s)}{4(\alpha-\delta k_s)^2}\beta qX_H$	$k_s\beta qX_H$
CDP2	λ_s	$\frac{q\lambda_s}{2}$	$\frac{2(1-\delta\lambda_s)}{4-\delta\lambda_s}q$	$\frac{\delta\lambda_s(\delta\lambda_s-1)}{\delta\lambda_s-4}q$	$\frac{\lambda_s}{4}\alpha\beta qX_H$	$\frac{\delta\lambda_s(1-\delta\lambda_s)}{(\delta\lambda_s-4)^2}\beta qX_H$	$\frac{4(1-\delta\lambda_s)}{(\delta\lambda_s-4)^2}\beta qX_H$	$k_s\beta qX_H$
Bank	-	$\frac{q}{2}$	$\frac{q}{2}$	-	$\frac{1}{4}\alpha\beta qX_H$	-	$\frac{1}{4}\beta qX_H$	k_sqX_H

Note: $p_c^* = \frac{q\lambda^*}{2}, p_s^* = \frac{2(1-\delta\lambda^*)}{4-\delta\lambda^*}q$, $p_i^* = \frac{\delta\lambda^*(1-\delta\lambda^*)}{4-\delta\lambda^*}q$, and the case for bank financing will be discussed in later section.

□

Proof of Proposition 3 **Monopoly case.** On the basis of Proposition 2, the monopoly case includes case "CMF" and case "CMP". Note that case "CMF" occurs when $\delta \leq \delta_i$, and case "CMP" includes case 4-1, case 4-2-2 and case 4-3-2. Since all these cases occur only when $\frac{4k_s}{\alpha} \leq \lambda_{ci}$, the lower α bound for the monopoly case when $\delta > \delta_i$ is $\frac{4k_s}{\delta_i}\delta$. The upper α bound for the monopoly case depends on whether δ is greater or smaller than δ_s. When $\delta_i < \delta \leq \delta_s$, that is, in case 4-3-2, the upper α bound should be the root to $\Pi_s^{CM}(\lambda_{\text{ci}}) = \Pi_s^{CD}(1)$, i.e., $\overline{\alpha}_M = \frac{\delta^2(\delta+8)}{(\delta-4)^2(\delta-\delta_i)}$. When $\delta_s < \delta \leq \frac{4}{7}$, that is, in case 4-1 and 4-2-2, the upper α bound should be the root to $\Pi_s^{CM}(\lambda_{\text{ci}}) = \Pi_s^{CD}(\lambda_s)$.

To summarize, if $\delta \leq \delta_i$ or ($\delta_i < \delta \leq \frac{4}{7}$ and $\frac{4k_s}{\delta_i}\delta \leq \alpha \leq \overline{\alpha}_M$), the startup monopolizes the market; otherwise, the imitator will enter the market.

Case of partial information disclosure. On the basis of Proposition 2, the case of partial information disclosure includes case "CMP" and case "CDP", where case "CMP" includes case 4-1, case 4-2-2 and case 4-3-2, and case "CDP" includes case 3-1, case 3-2 and case 4-2-1. Since the condition for case 4-1, case 4-2-1 and case 4-2-2 is $\frac{4k_s}{\alpha} \leq \lambda_{ci}$ and $\lambda_s < 1$, and the condition for case 3-1 and case 3-2 is $\frac{4k_s}{\alpha} > \lambda_{ci}$ and $\lambda_s < 1$. When $\delta > \hat{\delta}$ ($\lambda_s < 1$), the startup hides some quality information, i.e., $\lambda^* < 1$. If $\delta_i < \delta \leq \hat{\delta}$, case 4-3-2 provides the lower α bound $\frac{4k_s}{\delta_i}\delta$ ($\frac{4k_s}{\alpha} \leq \lambda_{ci}$) and the upper α bound $\frac{\delta^2(\delta+8)}{(\delta-4)^2(\delta-\delta_i)}$ ($\Pi_s^{CM}(\lambda_{\text{ci}}) \geq \Pi_s^{CD}(1)$).

To summarize, if $\delta > \hat{\delta}$ or ($\delta_i < \delta \leq \hat{\delta}$ and $\frac{4k_s}{\delta_i}\delta < \alpha < \frac{\delta^2(\delta+8)}{(\delta-4)^2(\delta-\delta_i)}$), the startup hides some quality information to weaken or exclude the imitator, i.e., $\lambda^* < 1$; otherwise, the startup discloses full quality information, i.e., $\lambda^* = 1$. □

Proof of Proposition 4 Obviously, in case "CMF" and case "CDF", $\lambda^* = 1$ is constant in α and δ.

Case "CMP". In this case, $\lambda^* = \lambda_{ci} = \frac{\delta_i}{\delta}$. Thus, λ^* is constant in α and decreases in δ.

Case "CDP1". In this case, $\lambda^* = \frac{4k_s}{\alpha}$. Thus, λ^* is constant in δ and decreases in α.

Case "CDP2". In this case, $\lambda^* = \lambda_s$. Note that λ_s is the unique root to $\frac{\alpha}{4} + \frac{4\delta(2+\delta\lambda)}{(-4+\delta\lambda)^3} = 0$, and λ^* increases in α and decreases in δ by the implicit function theorem.

Obvisously, in case "CMF" and "CMP", λ^* is constant in α and weakly decreases in δ. In case "CDF" and "CDP", λ^* is non-monotonic in α since λ^* decreases and increases in α in case "CDP1" and "CDP2" respectively. Moreover, in case "CDF" and "CDP", λ^* weakly decreases in δ. $\square$

Proof of Corollary 1 On the basis of conditions on Appendix A.1, we first introduce some key conditions and then show that the cases of equilibrium region regarding the crowdfunding market α and the imitation efficiency δ can be classified into seven cases.

Based on the above conditions, the condition $k_s = \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$ captures the situation where $\lambda_s = 1$, $\delta = \delta_i$ and $\alpha = 4k_s$ intersect at the same point, which means $\frac{4k_s}{\alpha}$, λ_{ci} and λ_s are equal on the same line. Furthermore, this condition generates some useful properties:

(i) When $k_s > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$, the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$ is above the curve $\lambda_s = \lambda_{\text{ci}}$. In addition, the case $\lambda_{ci} > \frac{4k_s}{\alpha}$ and $\lambda_{ci} > \lambda_s$ can be excluded, that is, **case 4-1** can be excluded. The feasible region can be partitioned into folowing cases:

- $\lambda_s > \lambda_{\text{ci}} > \frac{4k_s}{\alpha}$ in the region above the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$.
- $\lambda_s > \frac{4k_s}{\alpha} > \lambda_{\text{ci}}$ in the region between the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$ and the curve $\frac{4k_s}{\alpha} = \lambda_s$.
- $\frac{4k_g}{\alpha} > \lambda_s > \lambda_{\text{ci}}$ in the region between the curve $\frac{4k_s}{\alpha} = \lambda_s$ and the line $\lambda_s = \lambda_{\text{ci}}$.
- $\frac{4k_s}{\alpha} > \lambda_{\text{ci}} > \lambda_s$ in the region below the line $\lambda_s = \lambda_{\text{ci}}$.

(ii) When $k_s < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$, the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$ is below the curve $\lambda_s = \lambda_{\text{ci}}$. In addition, the case $\lambda_s > \frac{4k_s}{\alpha} > \lambda_{\text{ci}}$ can be excluded, that is, **case 4-2** and **case 4-3** can be excluded. The feasible region can be partitioned into folowing cases:

- $\lambda_s > \lambda_{\text{ci}} > \frac{4k_s}{\alpha}$ in the region above the line $\lambda_s = \lambda_{\text{ci}}$.
- $\lambda_{\text{ci}} > \frac{4k_s}{\alpha} > \lambda_{\text{s}}$ in the region between the line $\lambda_s = \lambda_{\text{ci}}$ and the curve $\frac{4k_s}{\alpha} = \lambda_s$.
- $\lambda_{\text{ci}} > \lambda_s > \frac{4k_s}{\alpha}$ in the region between the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$ and the curve $\frac{4k_s}{\alpha} = \lambda_s$.
- $\frac{4k_s}{\alpha} > \lambda_{\text{ci}} > \lambda_s$ in the region below the line $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$.

Let λ_s region denotes the region between $\lambda_s = 0$ and $\lambda_s = 1$. Based on $\alpha = 4k_s$, $\lambda_s = 0$ and $\lambda_s = 1$, the equilibrium results can be discussed according to three segments regarding k_s: $k_s \in [0, \frac{1}{14})$, $k_s \in [\frac{1}{14}, \frac{7}{48})$ and $k_s \in [\frac{7}{48}, +\infty)$. Based on $\lambda_s = 1$ and $\frac{4k_s}{\alpha} = \lambda_{\text{ci}}$, we derive another condition $\frac{4k_s}{\delta_i} = \frac{49}{48}$. Note that when $\frac{4k_s}{\delta_i} > \frac{49}{48}$, $\frac{4k_s}{\alpha} > \lambda_{\text{ci}}$ holds in λ_s region, and there exists α and λ such that $\frac{4k_s}{\alpha} < \lambda_{\text{ci}}$ in λ_s region if $\frac{4k_s}{\delta_i} < \frac{49}{48}$. Based on $\alpha = 4k_s$, $\delta = \delta_i$ and $\lambda_s = 1$, we derive another condition $k_s = \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Note that when $k_s > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$, the point $(\delta = \delta_i, \alpha = 4k_s)$ is above the line $\lambda_s = 1$, and the point $(\delta = \delta_i, \alpha = 4k_s)$ is below the line $\lambda_s = 1$ if $k_s < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Based on $\alpha = 4k_s$ and $\lambda_s = \lambda_{ci}$, we derive another condition $4k_s = \frac{64(\delta_i(\delta_i+2))}{7(4-\delta_i)^3}$. Note that when $4k_s > \frac{64(\delta_i(\delta_i+2))}{7(4-\delta_i)^3}$, $\lambda_s > \lambda_{ci}$ in λ_s region. Thus, given k_s and δ_i, the cases of equilibrium region regarding the crowdfunding market α and the imitation efficiency δ can be classified into seven cases.

Case A: $\delta_i \geq \frac{4}{7}$. In this case, the imitator does not enter the market due to financial constraint. **Case A** includes **case 1** and **case 2**.

Case B: $\delta_i < \frac{4}{7}$ and $k_s \geq \frac{7}{48}$. In this case, $\lambda_s > 1$ in the region where the crowdfunding strategy is feasible since $k_s \geq \frac{7}{48}$. Thus, **case B** includes **case 1**, **case 2**, **case 3-3**, **case 4-3-1** and **case 4-3-2**.

Case C: $\frac{4k_s}{\delta_i} > \frac{49}{48}$ **and** $\frac{1}{14} < k_s < \frac{7}{48}$**.** In this case, $\frac{4k_s}{\alpha} > \lambda_{ci}$ in λ_s region since $\frac{4k_s}{\delta_i} > \frac{49}{48}$. Thus, **case C** includes **case 1**, **case 2**, **case 3-1**, **case 3-2**, **case 3-3**, **case 4-3-1** and **case 4-3-2**.

Case D: $\frac{4k_s}{\delta_i} < \frac{49}{48}$ **and** $\mathrm{k_s} > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$ **and** $\delta_i > \frac{8}{49}$**.** In this case, $\Pi_s^{CM}(\lambda_{\mathrm{ci}}) > \Pi_s^{CD}(\lambda_s)$ in λ_s region since $\delta_i > \frac{8}{49}$, and $\lambda_s < \lambda_{ci}$ and $\frac{4k_s}{\alpha} \leq \lambda_{\mathrm{ci}}$ cannot hold simultaneously since $R_s > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Thus, **case D** includes **case 1**, **case 2**, **case 3-1**, **case 3-2**, **case 3-3**, **case 4-2-2**, **case 4-3-1** and **case 4-3-2**.

Case E: $\frac{4k_s}{\delta_i} < \frac{49}{48}$ **and** $\mathrm{k_s} > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$ **and** $\delta_i < \frac{8}{49}$**.** In this case, $\lambda_s < \lambda_{ci}$ and $\frac{4k_s}{\alpha} \leq \lambda_{\mathrm{ci}}$ cannot hold simultaneously since $k_s > \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Thus, **case E** includes **case 1**, **case 2**, **case 3-1**, **case 3-2**, **case 3-3**, **case 4-2-1**, **case 4-2-2**, **case 4-3-1** and **case 4-3-2**.

Case F: $\mathrm{k_s} < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$ **and** $\delta_i > \frac{8}{49}$**.** In this case, ${\Pi_s}^{CM}(\lambda_{\mathrm{ci}}) > \Pi_s^{CD}(\lambda_s)$ in λ_s region since $\delta_i > \frac{8}{49}$, and $\lambda_s > \frac{4k_s}{\alpha} > \lambda_{\mathrm{ci}}$ cannot hold since $k_s < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Thus, **case F** includes **case 1**, **case 2**, **case 3-1**, **case 4-1**, **case 4-2-2**, **case 4-3-1** and **case 4-3-2**.

Case G: $\mathrm{k_s} < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$ **and** $\delta_i < \frac{8}{49}$**.** In this case, there exists α and δ such that ${\Pi_s}^{CM}(\lambda_{\mathrm{ci}}) < \Pi_s^{CD}(\lambda_s)$ in λ_s region since $\delta_i < \frac{8}{49}$, and $\lambda_s > \frac{4k_s}{\alpha} > \lambda_{\mathrm{ci}}$ cannot hold since $k_s < \frac{4\delta_i(\delta_i+2)}{(4-\delta_i)^3}$. Thus, **case F** includes **case 1**, **case 2**, **case 3-1**, **case 4-1**, **case 4-2-1**, **case 4-2-2**, **case 4-3-1** and **case 4-3-2**.

These cases regarding to k_s and δ_i is illustrated by Figure A.1, and Table A.3 also summarizes the difference of these cases. On the basis of these cases, it is easy to see that λ^* is non-monotonic in both α and δ.

□

Proof of Proposition 5 We first prove the monotonicity in each cases, and then show that the monotonicity holds for the startup and does not hold for the imitator when the case transfers from monopoly to duopoly or duopoly to monopoly.

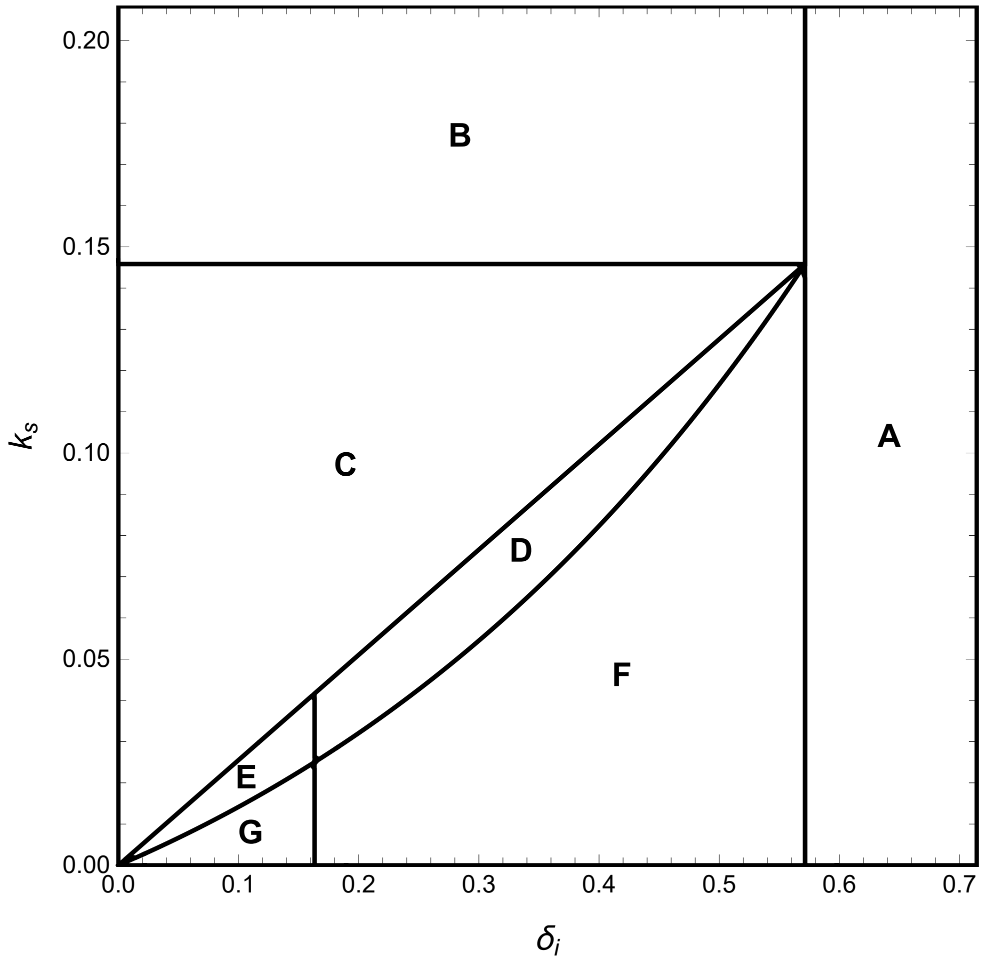


Figure A.1: Equilibrium Cases

Case "CMF": $\mathbb{E}_X[\Pi_s]^* = (\frac{1}{4} + \frac{1}{4}\alpha - k_s)\beta q X_H$. $\mathbb{E}_X[\Pi_s]^*$ increases in α and is constant in δ.

$$\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} = \frac{1}{4}\beta q X_H > 0$$
$$\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} = 0$$

Case "CMP": $\mathbb{E}_X[\Pi_s]^* = (\frac{1}{4} + \frac{1}{4}\lambda_{ci}\alpha - k_s)\beta q X_H$. $\mathbb{E}_X[\Pi_s]^*$ increases in α and

Table A.3: Equilibrium cases

	Case A	Case B	Case C	Case D	Case E	Case F	Case G
Case 1	Y	Y	Y	Y	Y	Y	Y
Case 2	Y	Y	Y	Y	Y	Y	Y
Case 3-1			Y	Y	Y	Y	Y
Case 3-2			Y	Y	Y		
Case 3-3		Y	Y	Y	Y		
Case 4-1						Y	Y
Case 4-2-1					Y		Y
Case 4-2-2				Y	Y	Y	Y
Case 4-3-1		Y	Y	Y	Y	Y	Y
Case 4-3-2		Y	Y	Y	Y	Y	Y

Note: Here "Y" lies in the row of case i and the column of case j means that case j includes case i.

decreases in δ.

$$\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} = \frac{1}{4}\lambda_{ci}\beta q X_H > 0$$
$$\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} = -\frac{1}{4}\frac{\delta_i}{\delta^2}\alpha\beta q X_H < 0$$

Case "CDF": $\mathbb{E}_X[\Pi_s]^* = (\frac{1}{4}\alpha + \frac{4(1-\delta)}{(\delta-4)^2} - k_s)\beta q X_H$**.** $\mathbb{E}_X[\Pi_s]^*$ increases in α and decreases in δ.

$$
\begin{aligned}
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} &= \frac{1}{4}\beta q X_H > 0 \\
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} &= -\frac{4(2+\delta)}{(4-\delta)^3}\beta q X_H < 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \alpha} &= 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \delta} &= \frac{4-7\delta}{(4-\delta)^3}\beta q X_H > 0
\end{aligned}
$$

Case "CDP1": $\mathbb{E}_X[\Pi_s]^* = \frac{\alpha(\alpha-4\delta k_s)}{4(\alpha-\delta k_s)^2}\beta q X_H$**.** $\mathbb{E}_X[\Pi_s]^*$ increases in α and decreases in δ.

$$
\begin{aligned}
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} &= \frac{\delta k_s(\alpha+2\delta k_s)}{2(\alpha-\delta k_s)^3}\beta q X_H > 0 \\
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} &= -\frac{\alpha k_s(\alpha+2\delta k_s)}{2(\alpha-\delta k_s)^3}\beta q X_H < 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \alpha} &= -\frac{\delta k_s(\alpha-7\delta k_s)}{4(\alpha-\delta k_s)^3}\beta q X_H < 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \delta} &= \frac{\alpha k_s(\alpha-7\delta k_s)}{4(\alpha-\delta k_s)^3}\beta q X_H > 0
\end{aligned}
$$

Case "CDP2": $\mathbb{E}_X[\Pi_s]^* = (\frac{\lambda_s}{4}\alpha + \frac{4(1-\delta\lambda_s)}{(\delta\lambda_s-4)^2} - k_s)\beta q X_H$**.** $\mathbb{E}_X[\Pi_s]^*$ increases in α and decreases in δ.

$$\begin{aligned}
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \alpha} &= \frac{\alpha(\delta\lambda_s - 4)^4 + 16\delta\left(3\delta^2\lambda_s^2 + 8\delta\lambda_s - 8\right)}{128\delta^2(\delta\lambda_s + 5)}\beta q X_H \\
&= \frac{\lambda_s}{4}\beta q X_H > 0 \\
\frac{\partial \mathbb{E}_X[\Pi_s]^*}{\partial \delta} &= \frac{16\delta(\delta\lambda_s + 2)^2 - \alpha(\delta\lambda_s - 4)^2\left(\delta^2\lambda_s^2 + 12\delta\lambda_s + 8\right)}{8\delta^2(\delta\lambda_s - 4)^2(\delta\lambda_s + 5)}\beta q X_H \\
&= -\frac{4\lambda_s(\delta\lambda_s + 2)}{(4 - \delta\lambda_s)^3}\beta q X_H < 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \alpha} &= \frac{(4 - \delta\lambda_s)(4 - 7\delta\lambda_s)}{32\delta(\delta\lambda_s + 5)}\beta q X_H > 0 \\
\frac{\partial \mathbb{E}_X[\Pi_i]^*}{\partial \delta} &= -\frac{(4 - 7\delta\lambda_s)\left(\delta^2\lambda_s^2 + 12\delta\lambda_s + 8\right)}{2\delta(4 - \delta\lambda_s)^3(\delta\lambda_s + 5)}\beta q X_H < 0
\end{aligned}$$

On the basis of Corollary 1, the startup's profit $\mathbb{E}_X[\Pi_s]^*$ always weakly increases in α and weakly decreases in δ, otherwise the startup will not transfer to other cases. And the imitator's profit $\mathbb{E}_X[\Pi_i]^*$ is non-monotonic in α and δ.

□

Proof of Proposition 6 We prove this proposition via comparing the profit under bank financing to that under crowdfunding.

Case "CMF". In this case, the profit under crowdfunding is strictly greater than that under bank financing as long as $\beta < 1$.

Case "CMP". In this case, the profit under crowdfunding is strictly greater than that under bank financing as long as $\beta < \frac{4\delta k_s}{\alpha(\delta - \delta\lambda) + 4\delta k_s}$.

Case "CDF". In this case, the profit under crowdfunding is strictly greater than that under bank financing as long as $\beta < \frac{4(\delta-4)^2 k_s}{\delta(\delta+8) + 4(\delta-4)^2 k_s}$.

Case "CDP1". In this case, the profit under crowdfunding is strictly greater than that under bank financing as long as $\beta < \frac{4k_s(\alpha - \delta k_s)^2}{\alpha^3 + (\alpha+1)\delta^2 k_s^2 - 2(\alpha-1)\alpha\delta k_s}$.

Case "CDP2". In this case, the profit under crowdfunding is strictly greater than that under bank financing as long as $\beta < \frac{4k_s}{\alpha+4k_s+\alpha(-\lambda_s)+\frac{16(\delta\lambda_s-1)}{(\delta\lambda_s-4)^2}+1}$.

Thus, if $\beta > \hat{\beta}$ and $\delta > \delta_i$, it is always optimal for the startup to choose the bank financing strategy; otherwise, the startup should choose the crowdfunding strategy, where $\hat{\beta}$ is defined by

$$\hat{\beta} = \begin{cases} \frac{4(\delta-4)^2k_s}{\delta(\delta+8)+4(\delta-4)^2k_s} & \text{Case CDF} \\ \frac{4\delta k_s}{\alpha(\delta-\delta_i)+4\delta k_s} & \text{Case CMP} \\ \frac{4k_s(\alpha-\delta k_s)^2}{\alpha^3+(\alpha+1)\delta^2k_s^2-2(\alpha-1)\alpha\delta k_s} & \text{Case CDP1} \\ \frac{4k_s}{\alpha+4k_s+\alpha(-\lambda_s)+\frac{16(\delta\lambda_s-1)}{(\delta\lambda_s-4)^2}+1} & \text{Case CDP2} \end{cases}.$$

□

Proof of Corollary 2 Based on the definition of $\hat{\beta}$ and the proof of Proposition 3, $\hat{\beta}$ decreases in δ in each cases respectively.

$$\frac{\partial\hat{\beta}}{\partial\delta} = \begin{cases} -\frac{64(4-\delta)(\delta+2)k_s}{(\delta(\delta+8)+4(\delta-4)^2k_s)^2} < 0 & \text{Case CDF} \\ -\frac{4\alpha\delta_i k_s}{(\alpha(\delta-\delta_i)+4\delta k_s)^2} < 0 & \text{Case CMP} \\ -\frac{8\alpha k_s^2(\alpha-\delta k_s)(\alpha+2\delta k_s)}{(\alpha^3+\delta^2k_s^2-2\alpha^2\delta k_s+\alpha\delta k_s(\delta k_s+2))^2} < 0 & \text{Case CDP1} \\ -\frac{64k_s\lambda_s(4-\delta\lambda_s)(\delta\lambda_s+2)}{(-\alpha(\lambda_s-1)(\delta\lambda_s-4)^2+\delta\lambda_s(\delta\lambda_s+8)+4k_s(\delta\lambda_s-4)^2)^2} < 0 & \text{Case CDP2} \end{cases}$$

Note that the threshold $\hat{\beta}$, where the startup is indifferent between bank financing and crowdfunding, is based on the following equation

$$\hat{\beta}\Pi_s^{C*} - \hat{\beta}C_s = \hat{\beta}\Pi_s^{B*} - C_s.$$

Thus, $\hat{\beta}$ can be expressed as $\frac{C_s}{\Pi_s^{B*}-\Pi_s^{C*}+C_s}$. On the basis of Proposition 5, Π_s^{C*} weakly decreases in δ and $\hat{\beta}$ decreases in δ. □

Proof of Corollary 3 Based on the proof of Proposition 1 and the proof of Proposition 3, this corollary can be proved via the first-order condition. □

Proof of Proposition 7 Under bank fianncing, the consumer surplus is

$$\mathbb{E}_X\left[CS^B\right]^* = \mathbb{E}_X\left[(\alpha+1)X\int_{\frac{1}{2}}^{1}(q\theta - p_b^*)\,d\theta\right] = \frac{1}{8}(\alpha+1)\beta q X_H.$$

The consumer surplus under crowdfunding can be calculated in a similar way. However, consumers' anticipated surplus may be different if the startup hides crowdfunding information. The results of consumer surplus is summarized in Table A.4. It is easily found that the consumer surplus under crowdfunding is weakly greater than that under bank financing.

Table A.4: Consumer Surplus

Case	$\mathbb{E}_X[ACS_{sc}]^*$	$\mathbb{E}_X[CS_{sc}]^*$	$\mathbb{E}_X[CS_i]^*$	$\mathbb{E}_X[CS_{sr}]^*$
CMF	$\frac{\alpha}{8}\beta q X_H$	$\frac{\alpha}{8}\beta q X_H$	-	$\frac{1}{8}\beta q X_H$
CMP	$\frac{\alpha\lambda_{ci}}{8}\beta q X_H$	$\frac{\alpha(3-2\lambda_{ci})}{8}\beta q X_H$	-	$\frac{1}{8}\beta q X_H$
CDF	$\frac{\alpha}{8}\beta q X_H$	$\frac{\alpha}{8}\beta q X_H$	$\frac{\delta}{2(\delta-4)^2}\beta q X_H$	$\frac{2(\delta+1)}{(\delta-4)^2}\beta q X_H$
CDP1	$\frac{k_s}{2}\beta q X_H$	$(\frac{3\alpha}{8} - k_s)\beta q X_H$	$\frac{\alpha\delta k_s}{8(\alpha-\delta k_s)^2}\beta q X_H$	$\frac{\alpha(\alpha+4\delta k_s)}{8(\alpha-\delta k_s)^2}\beta q X_H$
CDP2	$\frac{\alpha\lambda_s}{8}\beta q X_H$	$\frac{\alpha(3-2\lambda_s)}{8}\beta q X_H$	$\frac{\delta\lambda_s}{2(\delta\lambda_s-4)^2}\beta q X_H$	$\frac{2(\delta\lambda_s+1)}{(\delta\lambda_s-4)^2}\beta q X_H$
Bank	-	$\frac{\alpha}{8}\beta q X_H$	-	$\frac{1}{8}\beta q X_H$

□

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