Product-driven Entrepreneurs and Online Crowdfunding

Abstract

Advancements in information technology is known for enabling new business models and new market mechanisms. Online crowdfunding is one such new mechanism through which entrepreneurs can advertise their potential products and attract investors from the mass. In this study, we advance the existing theory on online crowdfunding markets by recognizing that online crowdfunding provides not only a venue of fundraising to entrepreneurs but also a venue for them to obtain demand information before production and to signal their intention. We formulate a spatial competition model between profit-driven entrepreneurs and product-driven entrepreneurs and find that on average profit-driven entrepreneurs earn higher profits, but their advantage is constrained by the mechanism of the crowdfunding campaign, and product-driven entrepreneurs earn a significant fraction of the market. Comparing to the Keep-it-all funding scheme we used in the baseline model, the All-or-nothing scheme is more favorable for product-driven entrepreneur, under which the two type entrepreneurs earn equal market shares. We further discuss model implications for consumer satisfaction of the platform and find that including more product-driven entrepreneurs, or adopting All-or-nothing funding scheme improves the overall quality of the platform, but the effects on design popularity and consumer welfare are subtle.

Keywords: Crowdfunding; Entrepreneurs; Spatial Competition; Signaling

1. Introduction

Recent revolutionary development of information technology creates a plethora of new opportunities for entrepreneurs and has fundamentally changed the business ecosystem. The emergence of new business models, funding avenues and marketing strategies facilitates the rising of heterogeneously motivated entrepreneurs ([22]).

One such example is online crowdfunding platform. The business model of crowdfunding, on the one hand, makes it possible for entrepreneurs to access funds from "the crowd" through websites, social media and mobile apps etc. On the other hand, it provides a platform for entrepreneurs to tell background stories that convey their ideas and devotions about their products. This capability enables the thriving of non-pecuniary entrepreneurs.

A vast literature on entrepreneurship suggests that entrepreneurs have non-pecuniary motivations and conscientiousness is an essential personal trait to entrepreneurs. (See [15] and references therein.) They value their preference on products and devote to improving the quality of their ideal products ([21]). For instance, Elon Musk describes his motivation of being an entrepreneur: "My motivation for all my companies has been to be involved in something that I thought would have a significant impact on the world ([17])." As addressed by the entrepreneurship literature, entrepreneurs value both profit and other non-pecuniary factors such as their own preferences on products. But they differ in the extent that they value profits over products.

Online crowdfunding helps heterogeneous entrepreneurs grow a successful business. For instance, the crowdfunding campaign of PAKT One–a travel bag designed for the minimalism travelers–on Indiegogo helps the founder build a brand that matched their own taste and standard of quality ([11]). In the meantime, online crowdfunding platforms aim to enlarge or maintain a stable customer base, which can help them generate sustainable profits or future investments, since a stable customer base is one of the core competency. Thus, it is important to understand how a platform can improve consumer satisfaction in order to maintain a stable customer base. In particular, should the platforms include a larger fraction of heterogeneous entrepreneurs? Would competition among heterogeneous entrepreneurs improve consumer satisfaction? A first step to understand these questions is to understand the strategic interaction among entrepreneurs and then we can further understand whether their strategic interactions affect the interest of the platform.

To this end, we build a spatial competition model where heterogeneously motivated entrepreneurs compete for a fund in a crowdfunding campaign, while consumers with heterogeneous preferences on product designs locate on a line. We suppose that entrepreneurs have preferences on their ideal products—they care about their ideal designs of the product and have a quality pursue. They vary in how much they value their ideal products over funding or revenue, and thus we call entrepreneurs are of either *product-driven* or *profit-driven* type. Entrepreneurs' types are private information and drawn from a publicly known distribution. The model allows us to understand the effect of competition of heterogeneously motivated entrepreneurs on their product choices, based

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on which we can further study the implications for crowdfunding platforms. It's worth noting that we have no intention to separate profit and product as entrepreneurs' motivations. We only use the two types to capture the heterogeneity of the extent to which entrepreneurs value product features over funding or revenue. Alternatively, this can be viewed as the case where product-driven entrepreneurs incur lower cost in making products which are of high quality or match their ideal designs.

More specifically, our model focuses on competitive product market, so that the entrepreneurs take market price as given. We find that, in equilibrium, heterogeneous entrepreneurs tend to choose (moderately) diversified designs of products, i.e., target the niche market, whereas in traditional markets price-taking entrepreneurs choose the same products catering towards the median, i.e, serve the mass market ([24]). Moreover, on average, profit-driven entrepreneurs earn higher profits but their advantage is limited by the mechanism of the crowdfunding campaign, and product-driven entrepreneurs earn a significant fraction of the market. Comparing to the Keep-it-all funding scheme we used in the baseline model, the scheme All-or-nothing is more favorable for product-driven entrepreneur, under which the two type entrepreneurs earn equal market shares. We further discuss model implications on consumer satisfaction of the platform and find that including more product-driven entrepreneurs, or adopting All-or-nothing funding scheme improves overall quality of the platform, but the effects on design popularity and consumer welfare are subtle.

1.1. Related Literature

First, our work relates to the theoretical literature of crowdfunding. Most of the literature emphasizes a single firm's problem and study its strategies and associated consequences on consumers and crowdfunding platforms, while ours addresses the role of competition among entrepreneurs. For instance, [14] studies optimal pricing and product strategy of a single firm facing heterogeneous consumers. [23] addresses how crowdfunding market alleviates moral hazard problem of the entrepreneur through reduction of demand uncertainty. [20] investigates entrepreneur's optimal strategies of attracting funds from venture capital and/or crowdfunding. [10] assumes away the entrepreneur's moral hazard problem and characterizes the optimal reward-based crowdfunding mechanism. [5] discusses a single firm's crowdfunding strategy in a dynamic setting with the focus on firm's learning on consumer demand.

Second, our study relates to the literature using spatial competition model, which considers spatial competition among homogeneously motivated entrepreneurs (mostly profit-driven). This literature stems from [13], arguing that, price-taking entrepreneurs or firms compete on locations and result in converging to the same location, while price-setting entrepreneurs try to differentiate themselves as much as possible so as to maximize profit. (See [24] for a comprehensive survey.) There are recent studies using spatial competition model to study online market behaviors. For instance, [2] discusses how spatial competition among video game platforms influence platforms' investment strategies and performance. [12] studies the impact of spatial competition between online cashback platforms on cashback rate of the market and consumers' choices.

Third, our study relates to the literature discussing non-pecuniary motivations of individuals. A large literature on entrepreneurship documents entrepreneurs' non-pecuniary motivations. (See [15] for a comprehensive survey.) In the meantime, researchers in many fields study the effects of individuals' non-pecuniary motivations on their behaviors and associated outcomes (e.g., [1], [4], [7] and [8]).

Moreover, our paper relates to a theoretical literature of advertising and signaling, which investigates whether firms can use advertising as signals of product quality (See [3] for a comprehensive survey). For instance, [16] presents a model where firms as competitive price takers use advertisements to signal quality and find that advertisement alone is not informative about quality, i.e., non-existence of a separating equilibrium. [18] establishes the existence of separating equilibrium in an alternative setting where a monopoly firm jointly use advertising and price to serve as signals of quality. Thus, in these models, advertisement alone is not informative about quality and the most desirable equilibrium (by consumers) is the separating equilibrium, where advertisement and/or price are informative about quality of the product. By contrast, our model introduces heterogeneity in motivation and allows for competition among entrepreneurs, so that design alone is informative about quality. In the meantime, uninformative equilibrium (pooling equilibrium) can be more desirable by consumers as well as the platform—the overall quality of the products sold on the platform is highest under pooling equilibrium comparing to that under separating or hybrid equilibrium.

Finally, our paper relates to a growing literature about signaling behavior of online market. For instance, [25] finds that firms use online branding strategies as signals of quality. [19] shows that small online retailers issue warranties in order to signal the quality of products. [9] studies whether adding charitable donations to eBay auctions can provide an informative signal about product quality.

2. The Model

Consider a reward-based crowdfunding campaign with two entrepreneurs and a unit mass of consumers. Entrepreneurs produce the same kind of products but with heterogeneous features. They post features of their products on a crowdfunding platform to attract investors. Here, we focus on the competitive product market such as the market of video games.[1] Thus, entrepreneurs on a crowdfunding platform do not have the market power to set product price, and so take the market price as given.

Entrepreneur $e \in \{A, B\}$ cares about funding size, product design and quality. Entrepreneur e has an ideal design. We assume that the two entrepreneurs' ideal designs are symmetric. That is, entrepreneur A's design is $-d$, and entrepreneur B's design is d, where $d \in [0, 1]$.[2] The ideal design could be broadly explained. In practice, some crowdfunding entrepreneurs initially generate their ideas when they were consumers and then launch a crowdfunding campaign with their favorite designs. Besides, entrepreneurs may have a specialty in producing products with certain designs, so it is less costly for them to make products with their ideal designs.

Moreover, each entrepreneur e has a random type $t_e \in \{0, T\}$ ($T > 0$), which measures how she values her ideal product over profit. We call an entrepreneur profit-driven if $t_e = 0$ and product-driven if $t_e = T$. The type is private information and the prior probability of $t_e = 0$ is $\lambda \in [0, 1]$. Here, we set the (relatively) profit-driven entrepreneur's type to be 0 for simplicity, and the results hold qualitatively if we allow the profit-driven type to be greater than 0 and smaller than T. Moreover, T can be any arbitrary positive number. As T increases, the product-driven entrepreneur cares more about the product. The utility of the entrepreneurs e is

$$u_e(\boldsymbol{x}, \boldsymbol{q}; d_e, t_e) = -t_e \left[(d_e - x_e)^2 + (1 - q_e)^2\right] + p s_e(\boldsymbol{x}) - \gamma q_e^2, \quad (1)$$

where $x_e \in [-1, 1]$ is e's product design, and $\boldsymbol{x} = (x_A, x_B)$; t_e is e's type; $s_e \in [0, 1]$ is e's share of fund, and $\sum_{e \in \{A,B\}} s_e = 1$; and p is the unit price of the product as an investment. Throughout, we assume $x_A \leq 0 \leq x_B$ without loss of generality. The quality of entrepreneur e's product is represented by $q_e \in [0, 1]$, and $\boldsymbol{q} = (q_A, q_B)$. Thus $(1 - q_e)^2$ represents entrepreneur e's disutility from producing low-quality products.

The marginal development cost of improving product quality is γ, and the cost of delivering q_e quality product is γq_e^2. The marginal development cost does not vary with the number of products but does increase with the product quality. In reality, we can think about it as the cost of adopting new production technology or the cost of improving managerial practice to conduct better quality control.

Consumers value both design and quality of the product, and each consumer c decides to invest one unit of investment in Entrepreneur A or B. We slightly abuse notation by writing consumer c's ideal design as c, which is uniformly distributed in $[-1, 1]$. Suppose consumer c invests in a product whose realized characteristics are represented by $(\hat{x}, \hat{q})$, then the utility of the consumer is $u_c(\hat{x}, \hat{q}; c) = I_c - \left[(c - \hat{x})^2 + (1 - \hat{q})^2\right] - p$, where $I_c > 5 + p$ (so that u_c is always positive). Here I_C measures the consumer c' desirability of the product. If consumer do not invest in either platform, she receives zero utility. This implicitly assumes consumer will always prefer investing to not investing, which simplifies our analysis. Relaxing this assumption will not affect the qualitative nature of our results.

The timeline of the game is as follows.

1. Nature randomly chooses each entrepreneur's type t_e, and entrepreneurs observe their types.
2. Each entrepreneur announces her product design x on the crowdfunding platform.
3. Consumers observe the designs and decide whether to invest.
4. Each entrepreneur gets funded. Entrepreneur e chooses the quality of product q_e and pays the cost γq_e^2 to develop the product; otherwise, they exit the market.
5. Products are delivered to consumers, and quality q is realized.

The game we have described is essentially a signaling game, which has two senders (entrepreneurs) and multiple receivers (consumers). The solution concept here is *Perfect Bayesian Equilibrium*, where the entrepreneurs and consumers optimize their utilities at every history given the beliefs. Beliefs are derived by Bayes' rule whenever possible. For analytical

[1] For instance, most of the video games launched on Kickstarter or Indiegogo are base price around $ 25 to $30. The commonly adopted price for the traditional video game industry is around $ 30 ([26]).

[2] The assumption of symmetry makes the computationally hard problem solvable through dimensionality reduction. In the meantime, it gives us a clean environment so that we can focus on the competition of entrepreneurs with heterogeneous motivations without ignoring the tension from the spatial competition. Relaxing the assumption would complicate the computation of the equilibrium (which can only be solved numerically) and may not bring extra insights.

simplicity, we restrict attention to symmetric equilibria.[3] Besides, we assume consumers do not use weakly dominated strategies, and they only invest for the entrepreneur that maximize their expected utility.

Consumers do not observe entrepreneurs' types and so product quality when they make investment decisions. However, the information carried by the description of the product design can help them to draw inferences about the type (and in turn the product quality). That is, the announced design may be able to serve as a signal of product quality.

The consumers' posterior belief that the entrepreneur e is profit-driven, given observing design x, is $\mu_e(x)$. Write $\mu = (\mu_A(x_A), \mu_B(x_B))$. Taking entrepreneurs' equilibrium design $\boldsymbol{x}^*$ as given, the expected utility of consumer c investing in e's product is

$$\mathbb{E}_{t_e}\left[u_c(x_e^*;c)|\mu_e(x_e^*)\right] = I_c - p - \left\{(c-x)^2 + \mathbb{E}_{t_e}\left[(1-\hat{q})^2|\mu_e(x_e^*)\right]\right\}.$$

Each consumer c forms a posterior belief and makes a binary decision of investing in A or B by comparing the associated expected utilities. In equilibrium, all consumers' decisions can be summarized by the market share of entrepreneur B, $s(\boldsymbol{x}^*)$. The market share of entrepreneur A is simply $1 - s(\boldsymbol{x}^*)$.

Entrepreneur e's strategy can be written as $\boldsymbol{r}_e = (x_{et}, q_{et})_{\forall t\in\{0,T\}}$, and we denote $r_{et} = (x_{et}, q_{et})$ for $t \in \{0, T\}$. Taking all consumers' strategies, and the opponent entrepreneur $-e$'s announced design $x^*_{-e}(t_{-e})$ as given, entrepreneur e's strategy $r_{et} = (x_{et}, q_{et})$ maximizes his expected utility at each information set:

$$\mathbb{E}_{t_{-e}}\left[u_e(x_{et},x^*_{-e},q_{et};d,t)\right] = p\mathbb{E}_{t_{-e}}[s_e(x_{et},x^*_{-e})] - t\left[(d-x_{et})^2 + (1-q_{et})^2\right] + -\gamma q_{et}^2.$$

2.1. The Crowdfunding Platform

The revenue of most crowdfunding platforms comes from platform fee, transaction fee, or service charge. Besides, many crowdfunding platforms can get more investment from institutional investors if they show a sustainable market growth.[4] Therefore, a large part of a crowdfunding platform's revenue would rely on a stable and growing customer base, and thus we assume the platform's objective is to to maintain a stable customer base through improving the customer satisfaction. In particular, we measure consumer satisfaction from three aspects—overall quality, design diversity, and consumer welfare.

We define the overall product quality of the platform by the average quality of all funded products in equilibrium: $\bar{Q} = \frac{1}{2}\mathbb{E}[(1-s(\boldsymbol{x}^*))q^*_{At} + s(\boldsymbol{x}^*)q^*_{Bt}]$. Consumer's feedback of the overall product quality of the platform is critical for attracting future customers, since the quality of each product is private information of the entrepreneur when she announces the product on the crowdfunding platform.

We define design popularity of a platform by aggregating all consumers preference on designs of the funded products in equilibrium: $U_x = I_c - \frac{1}{2}\mathbb{E}\left[\int_{\mathbf{C}_A} -(c-x^*_{At})^2 dc + \int_{\mathbf{C}_B} -(c-x^*_{Bt})^2 dc\right]$, where $\mathbf{C}_A$ (respectively, $\mathbf{C}_B$) represents the set of consumers that invest in entrepreneur A (respectively, B). Design popularity measures how consumers are satisfied with the design of the product, which has a great impact on the platform's market reputation. Converging designs would benefit the consumers who prefer median designs most while overlooking those who prefer the extreme. Over diversified designs, on the contrary, would benefit those prefer the extreme but overlook those prefer the median.

Finally, we combine consumer's preference on quality and design and study consumers' overall experience measured by consumer welfare. In particular, we define consumer welfare by the total utility of all consumers: $W = \frac{1}{2}\mathbb{E}\left[\int_{\mathbf{C}_A} u_c(x^*_{At},q^*_{At};c)dc + \int_{\mathbf{C}_B} u_c(x^*_{Bt},q^*_{Bt};c)dc\right]$.

3. Equilibrium Analysis

We start our equilibrium analysis by analyzing the special case where all entrepreneurs are profit-driven. Then we turn to characterize equilibria of the general case and compare the predictions.

3.1. Benchmark: Profit-driven Entrepreneurs

When entrepreneurs are both profit-driven, i.e., $\lambda = 1$, our model has the same prediction as in the literature of spatial competition models: Price-taking entrepreneurs choose the same design–the ideal design of the median consumer. This is because that profit-driven entrepreneurs cater towards the median when they are price takers. ([24]).

3.2. Equilibrium Characterization

We now turn to characterize the equilibria of the baseline model. For the rest of the paper, unless specified, we consider $\lambda \in (0,1)$, i.e., entrepreneurs

[3] In our setting, a symmetric equilibrium is an equilibrium such that the entrepreneur's equilibrium action satisfies following condition: $(\sigma^*_{et}(x), q^*_{et}) = (\sigma^*_t(x), q^*_t)$, for $e \in \{A, B\}$ and $t \in \{0, T\}$.

[4] https://www.4thway.co.uk/candid-opinion/zopa-review/

are heterogeneously motivated. Since the environment is symmetric, our analysis will focus on entrepreneur B's equilibrium strategy, and entrepreneur A plays a symmetry strategy accordingly.

We solve equilibrium backwards and start with backing out the entrepreneur's choice of quality. Consumers aim to infer entrepreneurs' types so as to predict quality. Inferring one's type is confound and determined through the strategic interactions among players. But predicting product quality given one's type is clear and described by following Lemma.

Lemma 1. *In equilibrium, the product quality of type t entrepreneur B (if that entrepreneur succeeds the crowdfunding campaign) is $q_B^* = \frac{t}{t+\gamma}$.*

By Lemma 1, in any equilibrium, we have $q_0^* = 0$, and $q_T^* = \frac{T}{T+\gamma}$ for both entrepreneurs. For ease of notation, let $\boldsymbol{q}^* = (q_0^*,q_T^*)$. This lemma implies a simple yet important property of the equilibrium—product quality is increasing in one's type. As a consequence, ceteris paribus, consumers prefer products from entrepreneurs that are product-driven.

Next, we turn to the entrepreneur's decision on design. Since profit-driven entrepreneurs are less concerned about the design, they are more willing to compromise on design for profit, which results in a (weakly) greater expected market share and expected revenue. In the meanwhile, product-driven entrepreneurs would choose designs that are closer to the ideal ones. Lemma 2 formally states this property.

Lemma 2. *In any equilibrium, the following statements hold: (i) Product-driven entrepreneurs choose product design located weakly closer to their own ideal design, i.e., $|x_{B0}^* - d| \geq |x_{BT}^* - d|$. (ii) Profit-driven entrepreneurs earn weakly greater market shares ex-ante. That is, $\mathbb{E}_{t_A}[s(x_{B0}^*,x_{At}^*)] \geq \mathbb{E}_{t_A}[s(x_{BT}^*,x_{At}^*)]$.*

In general, there are many equilibria in our game, since *Perfect Bayesian Equilibrium* allows for arbitrary off-equilibrium-path beliefs. To restrict the off-equilibrium-path beliefs in a reasonable way, we characterize equilibrium under the requirement of *Condition D1*. The idea is as follows. If type t entrepreneur benefits more from a deviation than type t', then after observing the deviation, consumers would think that type t' is less likely to be the deviator, and Condition D1 pushes the logic to the limit, so that, consumers would assign probability zero to type t'. The concept of Condition D1 is originated from [6].

The rest of this section characterizes the equilibrium under Condition D1. By Lemma 1, consumers prefer product-driven entrepreneurs ceteris paribus due to quality concern, which creates an incentive for entrepreneurs to separate and mimic: Product-driven entrepreneurs wish to separate from profit-driven entrepreneurs and signal their types to consumers, whereas profit-driven entrepreneurs seek to mimic product-driven entrepreneurs and hide their types from consumers.

First, if the entrepreneurs' ideal design is close to the median design 0, the median consumer may prefer to buy a high-quality product which locates at entrepreneur's ideal design rather than a low-quality product which locates at the median. In this case, a profit-driven entrepreneur would have an incentive to mimic the product-driven type to hide his type from consumers. Meanwhile, a product-driven entrepreneur cannot separate the profit-driven type even if she sticks to her own ideal design.

Second, if the ideal design is far from 0, so that median consumer would rather choose the product with median design and low quality than the product with relatively extreme design and high quality. Since profit-driven type cares only about market share, she would no longer mimic the product-driven type; instead, she would pick the design at the median 0 which gives him the highest market share. In this case, product-driven type separates from the profit-driven type, moving towards her ideal design.

Third, if the ideal design is in (d_1,d_2) or $(-d_2,-d_1)$, the median consumer may be indifferent between the product with median design and low quality, and the product with relatively extreme design and high quality. In this case, product-driven type chooses her ideal design, while profit-driven type adopts a mixed strategy: either mimicking the product-driven or and deviating to the median design. Theorem 1 summerizes the equilibrium:

Theorem 1. *There exists an equilibrium for all $d \in [0,1]$. In any equilibrium, where $q_{e0}^* = 0$, and $q_{eT}^* = \frac{T}{T+\gamma}$ for all e. Equilibrium designs depend on where entrepreneurs' ideal designs locate:*

i) Pooling equilibrium: *If $d \in [0,d_1]$, $-x_{At}^* = x_{Bt}^* = d$, for all $t \in \{0,T\}$.*

ii) Separating equilibrium: *If $d \in [d_2,1]$, $x_{A0}^* = x_{B0}^* = 0$, and $-x_{AT}^* = x_{BT}^* \in [d_2,d)$. Moreover, x_{eT}^* for each e is unique if $T < \frac{\lambda d_2^2}{4d^3}$ or $T > \frac{1}{4d_2}$. In particular, $-x_{AT}^* = x_{BT}^* = d_2$ if $T < \frac{\lambda d_2^2}{4d^3}$; and $-x_{AT}^* = x_{BT}^* > d_2$ if $d > d_2 + \frac{1-\lambda}{8T}$.*

iii) Hybrid equilibrium: *If $d \in (d_1,d_2)$, $-x_{AT}^* = x_{BT}^* = d$, $x_{A0}^* = x_{B0}^* = 0$ with probability σ^* and $-x_{A0}^* = x_{B0}^* = d$ with probability $1 - \sigma^*$.*

3.3. Alternative Funding Scheme

So far, the model implicitly assumes that the crowdfunding platform adopts the Keep-it-all (henceforth, KIA) funding scheme, i.e., entrepreneurs keep the raised fund unconditionally. In practice, some crowdfunding platforms such as Indiegogo use this scheme. Meanwhile, other platforms such as Kickstarter use the scheme of All-or-nothing (henceforth, AON), which allows entrepreneurs to keep the raised fund only if the funding goal has been reached. Now instead, we consider the AON scheme and assume the funding goal is $\frac{p}{2}$. That is, the entrepreneur can keep the fund only if she obtains a half share of the market. Then we compare how consumer satisfaction varies across different funding schemes. The AON funding scheme effectively increases competition among entreprenurs. When funding goal is $\frac{p}{2}$, it is the case where "winner takes all", which gives entrepreneurs more incentive to occupy the market.[5]

In this case, the model remains the same except the entrepreneurs' utility, which now changes to

$$u_e(\boldsymbol{x},\boldsymbol{q};d_e,t_e) = -t_e\left[(d_e - x_e)^2 + (1-q_e)^2\right] + \mathbf{1}_{s_e \geq 1/2}\, p s_e(\boldsymbol{x}) - \gamma q_e^2,$$

where $\mathbf{1}_{s_e \geq 1/2}$ is a dummy variable which equals 1 if and only if $s_e \geq 1/2$.

Following the same logic of the analysis in Section 3.2, we obtain the equilibrium predictions as follows.

Corollary 1. *There exists a unique equilibrium for all $d \in [0,1]$. In any equilibrium, where $q_{e0}^* = 0$, and $q_{eT}^* = \frac{T}{T+\gamma}$ for all e. Equilibrium designs depend on where entrepreneurs' ideal designs locate: i) If $d \in [0,d_1]$, $-x_{At}^* = x_{Bt}^* = d$, for all t. ii) If $d \in (d_1,d_2)$, $-x_{AT}^* = x_{BT}^* = d$, $x_{A0}^* = x_{B0}^* = 0$ with probability σ^* and $-x_{A0}^* = x_{B0}^* = d$ with probability $1-\sigma^*$. iii) If $d \in [d_2,1]$, $x_{A0}^* = x_{B0}^* = 0$, and $-x_{AT}^* = x_{BT}^* = d_2$.*

Under this AON scheme, the entrepreneur has to win at least half of the market to get funded. Then the product-driven entrepreneur faces a tighter constraint of moving toward ideal design. Had she move too close to the ideal design, she might lose the median consumer so that the entire funding. As a consequence, she chooses the design d_2 that makes the median consumer indifferent between profit-driven and product-driven entrepreneurs in equilibrium so that she earns half of the market. Recall that, under KIA scheme, she would choose design $x_T^* \geq d_2$ that maximizes her expected utility by considering the tradeoff of profit vs. product unconditionally. Therefore she chooses a design closer to the median and earns a weakly higher market share under the AON scheme than that under the KIA scheme.

[5]The assumption of "winner takes all" also gives us tractability of the model. Relaxing this assumption to allowing for any arbitrary funding goal, would complicate the computation but would not provide extra insights.

4. Model Implications

4.1. Entrepreneurs' Behavior

Design Diversification. In the benchmark, competition among homogenous types of entrepreneurs drives them to the converging designs catering towards the median consumer. As crowdfunding campaign attracts heterogeneous types of entrepreneurs, the latter may be able to convey information about their products (including privately known quality) through announcements of product designs. Accordingly, consumers make inferences from entrepreneurs' actions and choose products based on announced designs and inferred quality. In response to consumers' demand for high-quality products as well as preferred designs, entrepreneurs are deliberately mimicking or differentiating from others, which results in design diversification: Profit-driven entrepreneurs target more towards the mass market, whereas product-driven entrepreneurs tend to serve the niche market.

Profit of Entrepreneurs. Which kinds of entrepreneurs earn higher market shares and/or higher profits? In general, profit-driven entrepreneurs focus more on attracting consumers rather than sticking to their own ideal designs and improving quality. Thus, on average, profit-driven entrepreneurs obtain (weakly) larger customer base. As consumers become sophisticated on forming beliefs about the preferences of varying kinds of entrepreneurs, product-driven entrepreneurs attract half of the market share when information is not revealed, i.e., $d < d_1$. Otherwise, they earn a smaller size of the market than the profit-driven ones.

Meanwhile, profit-driven entrepreneurs are less willing to pay effort to improve product quality. Indeed, in equilibrium, they produce low-quality products and incur less cost in production. As a consequence, they expect higher profits than those product-driven entrepreneurs. Proposition 1 summarizes the results of entrepreneurs' expected profit.

Proposition 1. *Write π_t and $\pi_t^\dagger$ for the expected profit of type $t \in \{0,T\}$ entrepreneur in equilibrium under KIA and AON scheme respectively. The following statements hold true: (i) π_T is decreasing in λ and d, whereas π_0 is increasing in λ and d; (ii) $\pi_T^\dagger$ is strictly decreasing in γ and strictly increasing in T, whereas $\pi_0^\dagger$ is strictly increasing in γ and strictly decreasing in T; (iii) $\pi_0 > \pi_T$, and $s_0^* \geq s_T^*$ (the inequality is strict when*

$d > d_1$); (iv) $\pi_0^\dagger > \pi_T^\dagger$, whereas $s_0^* = s_T^*$.

First, under KIA scheme, how entrepreneurs' profit vary across T or γ is ambiguous: High devotions in products or low marginal development costs reduce production costs while decrease revenue. Nonetheless, the expected profit of a product-driven (respectively, profit-driven) entrepreneur is decreasing (respectively, increasing) in the fraction of profit-driven entrepreneurs and her ideal design.

Under the AON scheme, product-driven entrepreneurs earn higher profits; they earn the same share of the market as the profit-driven ones. In this case, high devotions in products or low marginal development costs increase product-driven entrepreneurs' profits, which are weakly higher than that in KIA scheme.

4.2. Crowdfunding Platform Design

We discuss implications for platform design from two aspects: (i) How can we improve the level of consumer satisfaction from the platform's perspective? (ii) How does consumers' feedback vary across different funding schemes? We further investigate the measures of consumer satisfaction across different funding schemes (KIA and AON).

Overall Quality. Whom should the platform include in the crowdfunding platform from the perspective of product quality? Proposition 2 answers the question. First, on average, products appear to be of high quality under pooling equilibrium under both schemes, i.e., when $d \in [0,d_1]$. Second, under each of the funding schemes, the overall quality is decreasing in the fraction of profit-driven entrepreneurs and marginal development cost while increasing in the extent of the entrepreneur's devotion of the product. Finally, the overall quality under AON scheme is weakly higher than that under KIA scheme.

Proposition 2. *Write $\bar{Q}^p$, $\bar{Q}^s$ and $\bar{Q}^h$ for overall quality under KIA funding scheme in pooling equilibrium, separating equilibrium and hybrid equilibrium respectively; write $\bar{Q}^{p\dagger}$, $\bar{Q}^{s\dagger}$ and $\bar{Q}^{h\dagger}$ for overall quality under the AON funding scheme in pooling equilibrium, separating equilibrium and hybrid equilibrium respectively. The overall quality $\bar{Q}$ and $\bar{Q}^\dagger$ of the platform have following properties: i) $\bar{Q}^p > \bar{Q}^h > \bar{Q}^s$; ii) $\bar{Q}$ and $\bar{Q}\dagger$ are strictly decreasing in λ and γ, weakly decreasing in d, while strictly increasing in T; iii) $\bar{Q}^{p\dagger} = \bar{Q}^p$, $\bar{Q}^{s\dagger} \geq \bar{Q}^s$ and $\bar{Q}^{h\dagger} \geq \bar{Q}^h$.*

Not surprisingly, to improve overall product quality on the platform, we should include more product-driven entrepreneurs, especially if they have higher devotion in products (i.e., T is high). Yet interestingly, we want all the entrepreneurs to end up with announcing the same design so that no information about quality is revealed through the design announcements. Therefore, to improve overall quality, we could include more product-driven entrepreneurs whose ideal designs are not too far away from the median.

Another effective way of improving product quality is by helping entrepreneurs reduce marginal development cost (γ). For instance, the platform can subsidize technology adoption and provide consultant service for improving the managerial practice of production.

Moreover, adopting the AON scheme weakly improves overall quality. On the one hand, under pooling equilibrium and $d \leq d_1$, the overall quality is still the highest and does not depend on whether the funding scheme is AON or KIA. But on the other hand, if $d > d_1$, adopting the AON scheme increases the overall quality of the platform.

Design Popularity. Proposition 3 discusses how design popularity varies across marginal development cost, entrepreneurs' devotion to products, and the fraction of profit-driven entrepreneurs.

Proposition 3. *Write $U_x^\dagger$ for design popularity under AON scheme. The design popularity under KIA and AON scheme U_x and $U_x^\dagger$ have the following properties: i) U_x and $U_x^\dagger$ is independent of γ, T and λ when $d < d_1$, and it is increasing in γ and decreasing in T when $d \in [d_1,d_2]$; ii) $U_x^\dagger$ is decreasing in λ when $d > d_2$; iii) $U_x^\dagger = U_x$ when $d \in [0,d_2]$.*

It's less clear, from the perspective of design popularity, whether the platform should include more product-driven entrepreneurs, or how entrepreneurs' ideal designs affect consumer satisfaction. In pooling equilibrium (i.e., $d \in [0,d_1]$), the most popular pair of designs among all consumers is $\pm\min\{d_1,1/2\}$. At the very least, the platform would not want to include entrepreneurs whose ideal designs are very close to the median. But beyond that, the result is ambiguous, especially under the KIA scheme. Under the AON scheme, when $d > d_2$, design popularity increases when we include more product-driven entrepreneurs.

On the other hand, when $d \in [d_1,d_2]$, reducing marginal development costs or including entrepreneurs with higher devotions in products decreases design popularity. In contrast, doing so will benefit the platform from the perspective of overall quality. Finally, whether adopting AON can improve design diversity is ambiguous, unlike in the case of overall quality, it potentially has a negative impact on the platform from the perspective of design popularity.

Consumer Welfare. In pooling equilibrium, consumer welfare reaches its maximum at $d = \min\{d_1, 1/2\}$. This is consistent with the results of overall quality and design popularity: Fixing $d \in [0, d_1]$, the overall quality is independent of d, and design diversity reaches its maximum at $d = \min\{d_1, 1/2\}$. Consumer welfare is increasing in q_T^*, and thus it is decreasing in γ. This is because, under pooling equilibrium, the overall quality is decreasing in γ whereas design popularity is independent of γ.

In separating equilibrium, the relationship between consumer welfare and marginal development cost is more ambiguous. Reducing marginal development cost increases overall quality, but decreases design popularity. Thus, how it affects consumer welfare depends on which effect dominates the other. Under hybrid equilibrium, consistent with the case of design popularity, the relationship between consumer welfare and entrepreneurs' ideal designs are not clear. Moreover, since marginal development cost has opposite effects on overall quality and design popularity, its impact on consumer welfare is ambiguous. Proposition 4 summarize the results of consumer welfare.

Proposition 4. *Write $W^\dagger$ for consumer welfare under funding scheme AON. i) W and $W^\dagger$ is decreasing in γ and λ and increasing in T when $d \in [0, d_1]$; ii) $W = W^\dagger$ when $d \in [0, d_2]$.*

The takeaway is threefold. First, if entrepreneurs' ideal designs are not that far from the median consumer so that $d < d_1$, then it's the best for the platform to include entrepreneurs with ideal designs close to $1/2$. In the case where $d < d_1$, adopting strategies that can help entrepreneurs reduce marginal development cost improves consumer welfare. Second, beyond the above situation, the answer is not clear. In particular, whether the platform should help entrepreneurs reduce development cost can depend on whether the platform is more inclined to improve overall quality or design popularity. Finally, the consumer welfare is the same with the case under KIA scheme when $d \in [0, d_2]$. In separating equilibrium, the impact of adopting AON on consumer welfare is ambiguous, depending on whether its positive effect on quality dominates its potential negative impact on design popularity.

5. Concluding Remarks

We make the first attempt to address how online crowdfunding facilitates competition among heterogeneously motivated entrepreneurs. To this end, we formulate a spatial competition model between profit-driven entrepreneurs and product-driven entrepreneurs, discuss its implications for entrepreneur behavior and crowdfunding platform. In the meantime, we acknowledge the limitation of the analysis. First, we assume the competition only come from the two firms, which cannot capture the whole reality. We think duopolistic competition is an important step and can help us to understand the effect of competition on entrepreneurs and crowdfunding platform, though it cannot capture the whole reality. For instance, it is less convenient to discuss the effect of different degree of competitiveness.

Moreover, we assume that each entrepreneur is of either profit-driven or product-driven type. We use the binary types to capture the heterogeneity of entrepreneurs' motivations, while, in reality, there may be many more or even continuous types.

Finally, we assume that the platform earns profit from its stable customer base so that their main objective is to improve consumer satisfaction. We acknowledge that platforms can have other objectives and, believe that what we study is the first step and hope to explore the consequence of other objectives in future research.

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A. Proofs of Main Theorems

Proof of Lemma 2.

Consider an equilibrium with strategy profile $\boldsymbol{r} = (\boldsymbol{r}_A, \boldsymbol{r}_B)$, where $r_e = \{(x_{et}, q_{et})\}_{t\in\{0,T\}}$ for $e \in \{A,B\}$ We now focus on entrepreneur B's strategy, and entrepreneur A plays a symmetric strategy in equilibrium. The expected utility of entrepreneur B of type t entrepreneur is
$\mathbb{E}_{t_A}[u_B(x^*_{Bt}, x^*_{At}, q^*_{Bt}; d,t)] = -t\big[(d - x^*_{Bt})^2 + (1 - q^*_{Bt})^2\big] + \mathbb{E}_{t_A}[s(x^*_{Bt}, x^*_{At})] - \gamma {q^*}^2_{Bt}$.

In any equilibrium, the following must hold:

$$\mathbb{E}_{t_A}[u_B(x^*_{B0}, x^*_{At}, q^*_{B0}; d,0)] \geq \mathbb{E}_{t_A}[u_B(x^*_{BT}, x^*_{At}, q^*_{BT}; d,0)],$$
$$\mathbb{E}_{t_A}[u_B(x^*_{BT}, x^*_{At}, q^*_{BT}; d,T)] \geq \mathbb{E}_{t_A}[u_B(x^*_{B0}, x^*_{At}, q^*_{B0}; d,T)],$$

or equivalently

$$0 \leq \mathbb{E}_{t_A}[s(x^*_{B0}, x^*_{At})] - \mathbb{E}_{t_A}[s(x^*_{BT}, x^*_{At})] \leq T\big[(d - x^*_{B0})^2 - (d - x^*_{BT})^2\big]. \quad (2)$$

It further implies $\mathbb{E}_{t_A}[s(x^*_{BT}, x^*_{At})] \geq \mathbb{E}_{t_A}[s(x^*_{B0}, x^*_{At})]$ and $|x^*_{B0} - d| \geq |x^*_{BT} - d|$. ■

Proof of Theorem 1 (i) pooling equilibrium.

We show this in two steps. First, we show the strategy profile $\boldsymbol{r}^* = (-d, -d, \boldsymbol{q}^*; d, d, \boldsymbol{q}^*)$, is an equilibrium if and only if $d \in [0, d_1]$. Next, we show, for $e \in \{A,B\}$, there does not exist a pooling equilibrium with $x_{et} \neq d$. Then we establish the desired results. Since the equilibrium is symmetric, for simplicity, we fix $\boldsymbol{r}^*_A = (-d, -d, \boldsymbol{q}^*)$, and only consider entrepreneur B's problem.

Step 1: Suppose the strategy profile $\boldsymbol{r}^*$ is an equilibrium. Apparently, in equilibrium $\mathbb{E}_{t_A}[s(d, (-d, -d))] = \frac{1}{2}$, and $\mu_A(-d) = \mu_B(d) = \lambda$. As a result, the expected utility of type t entrepreneur B is
$\mathbb{E}_{t_A}[u_B(x^*_{Bt}, x^*_A, q^*_{Bt}; d,t)] = -t[(1 - q^*_{Bt})^2] + \frac{1}{2} - \gamma q^{*2}_{Bt}$, where $q^*_{Bt} = q^*_T$. Now suppose instead type t entrepreneur B deviates to $r'_{Bt} = (x', q^*_T)$ where $x' \neq d$. By Condition D1, for any deviation $x' \neq d$, $\mu_B(x') = 1$. Thus $\mathbb{E}_{t_A}[s(x', x^*_A)] = \frac{1}{2} + \frac{d-x'}{4} - \frac{(1-\lambda)[1-(1-q^*_T)^2]}{4(d+x')}$. Then, the expected utility of type t entrepreneur B deviating to x' is
$\mathbb{E}_{t_A}[u_B(x', x^*_A, q^*_{Bt}; d,t)] = -t\big[(d - x')^2 + (1 - q^*_T)^2\big] + \mathbb{E}_{t_A}[s(x', x^*_A)] - \gamma {q^*_T}^2$.

For $\boldsymbol{r}^*$ to be an equilibrium, we must have $\mathbb{E}_{t_A}[u_B(x^*_{Bt}, x^*_A, q^*_{Bt}; d,t)] \geq \mathbb{E}_{t_A}[u_B(x', x^*_A, q^*_{Bt}; d,t)]$, or equivalently, $-t(d - x')^2 + \frac{d-x'}{4} - \frac{(1-\lambda)[1-(1-q^*_T)^2]}{4(d+x')} \leq 0$, for all $t \in \{0,T\}$. This holds if and only if $\frac{d-x'}{4} - \frac{(1-\lambda)[1-(1-q^*_T)^2]}{4(d+x')} \leq 0$.

If $x' > d$, the above holds vacuously. Otherwise, it holds if and only if $d^2 - x'^2 \leq (1-\lambda)[1 - (1 - q^*_T)^2]$. Since $x' \in [0,1]$, the above is equivalent to $d_1 \equiv \sqrt{(1-\lambda)[1 - (1 - q^*_T)^2]} \geq d$.

Step 2: Now we show $\boldsymbol{r}^*$ is the unique pooling equilibrium. Suppose not, then there exists a pooling equilibrium $\boldsymbol{r}^{**} = (\boldsymbol{r}^*_A; x^{**}, x^{**}, \boldsymbol{q}^*)$, where $x^{**} \neq d$. Towards contradiction, we show there is aways a profitable deviation for type T entrepreneur B.

Consider a deviation $r'_{Bt} = (x', q^*_T)$, where $(d - x')^2 = (d - x^*)^2 - \varepsilon$ and $\varepsilon \to 0$. Then
$\mathbb{E}_{t_A}[u_B(x^*_{Bt}, x^*_A, q^*_{Bt}; d,t)] - \mathbb{E}_{t_A}[u_B(x^{**}, x^*_A, q^*_{Bt}; d,t)]$
$= -t[(d - x^*)^2 - (d - x')^2] + \mathbb{E}_{t_A}[s(x^{**}, x^*_A)] - \mathbb{E}_{t_A}[s(x', x^*_A)]$
$= -t\varepsilon + \mathbb{E}_{t_A}[s(x^{**}, x^*_A)] - \mathbb{E}_{t_A}[s(x', x^*_A)] < 0$

The last inequality is established as follows. By Condition D1, $\mu_B(x') = 0$, and thus $\mu_B(x') \leq \mu_B(x^{**}) = \lambda$. Therefore, by $\mathbb{E}_{t_A}[s(x^{**}, x^*_A)]$ is decreasing in $\mu_B(x^{**})$, we have $\mathbb{E}_{t_A}[s(x^{**},x_A^*)] - \mathbb{E}_{t_A}[s(x',x_A^*)] \leq 0$. ■

Proof of Theorem 1 (ii) separating equilibrium. We first show, $d \geq d_2$ is a necessary condition for the existence of separating equilibrium. Next we show under that condition, a separating equilibrium does exist. Finally, we discuss the condition for uniqueness.

Step 1: Suppose there is a separating equilibrium $\boldsymbol{r}^* = (-x_0^*,-x_T^*,\boldsymbol{q}^*;x_0^*,x_T^*,\boldsymbol{q}^*)$. Then by the proof of Lemma 2, Condition (2) must hold in equilibrium. Lemma 2 also suggests $x_0^* \leq x_T^*$, and thus by definition of separating equilibrium, we have $x_0^* < x_T^*$. Moreover, in any separating equilibrium, $x_0^* = 0$. This is because in any separating equilibrium, $\mu_B(x_0^*) = 1$ and thus fixing type T entrepreneur B's strategy, the expected utility of type 0 entrepreneur B is:

$$\mathbb{E}_{t_A}[u_B(x_{B0}^*,x_A^*,q_{B0}^*;d,0) = \tfrac{1}{2} + \tfrac{\lambda x_0^*+(1-\lambda)x_T^*}{4} - \tfrac{(1-\lambda)[1-(1-q_T^*)^2]}{4[\lambda x_0^*+(1-\lambda)x_T^*]}. \tag{3}$$

Therefore, the optimal design for type 0 entrepreneur B is $x_0^* = 0$. By the fact that $x_0^* = 0$, we have $\mathbb{E}_{t_A}[s(x_{B0}^*,x_A^*)] - \mathbb{E}_{t_A}[s(x_{BT}^*,x_A^*)] = \frac{x_T^*}{4} - \frac{1-(1-q_T^*)^2}{4x_T^*} = \frac{1}{4}\left(x_T^* - \frac{{d_2}^2}{x_T^*}\right)$.

Substituting the above into Condition (2), we obtain the equilibrium conditions for any separating equilibrium:

$$0 \leq \tfrac{1}{4}\left(x_T^* - \tfrac{{d_2}^2}{x_T^*}\right) \leq T[d^2 - (d - x_T^*)^2]. \tag{4}$$

The left inequality implies $x_T^* \geq d_2$. Note that, the strategy $r_{BT} = (x_T,q_T^*)$ for any $x_T > d$ is dominated by (d,q_T^*) as all else equal, moving to the right of B's ideal design would decrease the market share and incur more loss from ideal design. As a result, in equilibrium $x_T^* \leq d$ and, in turn, we have $d \geq x_T^* \geq d_2$.

Step 2: In this step, we show when $d \in [d_2,1]$, there exists a separating equilibrium. That is, there exists a x_T^* such that $\boldsymbol{r}^* = (0,-x_T^*,\boldsymbol{q}^*;0,x_T^*,\boldsymbol{q}^*)$ is an equilibrium. If so, then (i) x_T^* satisfy Condition (4); and (ii) Type T entrepreneur B has no incentive to deviation from x_T^* to any $x' \neq 0$ given consumers' off equilibrium path beliefs $\mu_B(x')$ under the requirement of Condition D1.

Denote the set of x_T^* that satisfy Condition (4) as X_{se}, then $X_{se} \subseteq [d_2,d]$. By Condition D1, if consumers observe any deviation $x' \in X_{se}$, then $\mu_B(x') = 0$, i.e., the consumers believe the deviator to be of type T with probability one. This is because it is less profitable for type 0 entrepreneur B deviating from $x_0^* = 0$ to any $x' \in X_{se}$ than type T entrepreneur B. As a result, it would not change consumers' belief of entrepreneur B if she deviates from x_T^* to any $x' \in X_{se}$. Therefore, taking $\boldsymbol{r}_A^*$ and r_{B0}^* and $\mu_B(x')$ as given, x_T^* solves the following optimization problem

$$x_T^* \in \operatorname{argmax}_{x' \in X_{se}} \mathbb{E}_{t_A}[u_B(x',x_A^*,q_{BT}^*;d,T)]. \tag{5}$$

We define the set of such x_T^* by X_T^*. In what follows, we show X_T^* is nonempty. First, we show there exists some x_T satisfy Condition (4), i.e, $x_T \in [d_2,d]$ and $T[d^2 - (d - x_T)^2] - \frac{x_T}{4} + \frac{1-(1-q_T^*)^2}{4x_T} \geq 0$. Define the left hand side by $F(x_T)$:

$$F(x_T) = T[d^2 - (d - x_T)^2] - \tfrac{x_T}{4} + \tfrac{1-(1-q_T^*)^2}{4x_T}. \tag{6}$$

Note that $F(d_2) = T[d^2 - (d - d_2)^2] - \frac{d_2}{4} + \frac{d_2}{4} = T[d^2 - (d - d_2)^2] \geq 0$. Therefore, $d_2 \in X_{se}$, and so X_{se} is nonempty. Moreover, if $d > d_2$, then $F(d_2) > 0$, and by continuity of $F(\cdot)$, there exists $[d_2,d_2 + \varepsilon] \subseteq X_{se}$. Notice that $X_{se} \subseteq [d_2,d]$, so X_{se} is bounded, and it is also closed as it is determined by a system of weak inequalities. Thus X_{se} is a compact set. We now turn to Condition (5). Rearrange terms of Condition (5):

$$x_T \in \operatorname{argmax}_{x' \in X_{se}} \left\{-T(d - x')^2 - \tfrac{x'}{4} + \lambda \tfrac{1-(1-q_T^*)^2}{4x'}\right\}. \tag{7}$$

Define the objective function by $G(x')$:

$$G(x') = -T(d - x')^2 - \tfrac{x'}{4} + \lambda \tfrac{1-(1-q_T^*)^2}{4x'}. \tag{8}$$

Since $G(\cdot)$ is continous and X_{se} is compact, by Weierstrass Theorem there must exists a solution to the optimization problem defined by Condition (7). That is, X_T^* is nonempty. In addition, $X_T^* \subseteq [d_2,d)$ since $G'(d) = -\frac{1}{4} - \frac{\lambda d_2^2}{4d^2} < 0$.

Step 3: Whether there is a unique separating equilibrium is determined by if there is a unique solution of the optimization problem defined by Condition (7), which is determined by the properties of the objective function function $G(\cdot)$ and the domain $X_{se} = \{x \in [d_2,d] | F(x) \geq 0\}$. The first order and second order derivatives of functions $F(\cdot)$ and $G(\cdot)$ are as follows: $F'(x) = 2T(d - x) - \frac{1}{4} - \frac{d_2^2}{4x^2}$, $F''(x) = -2T + \frac{d_2^2}{2x^3}$, $G'(x) = 2T(d - x) - \frac{1}{4} - \frac{\lambda d_2^2}{4x^2}$, and $G''(x) = -2T + \frac{\lambda d_2^2}{2x^3}$. Thus, in general, the concavity of $G(\cdot)$ and the convexity of the set X_{se} are not determined. As a consequence, separating equilibrium may not be unique. We now discuss under what conditions we have a unique separating equilibrium.

First, we show when

$$T < \tfrac{\lambda d_2^2}{4d^3}, \tag{9}$$

there is a unique equilibrium where $x_0 = 0$, and $x_T = d_2$. Notice that Condition (9) implies $G''(d) > 0$. Since $G''(x)$ is decreasing in x, we have $G''(x) > 0$ for all $x < d$, and thus $G(\cdot)$ is convex, i.e. $G''(x) > 0$, for $x \in [d_2,d]$.Moreover, $G'(d) < 0$ implies $G'(x) < 0$ for $x \in [d_2,d]$ as $G''(x) > 0$. Then $G(x)$ reaches its unique maximum at d_2, and by $F(d_2) \geq 0$, X_T^* is a singleton. Thus, there is a unique symmetric separating equilibrium where B's strategy is $(0,d_2,0,q_T)$. Then we show when

$$T > \tfrac{1}{4d_2}, \tag{10}$$

there is a unique equilibrium with $x_T \in [d_2,d)$. Notice that Condition (10) implies $F''(d_2) < 0$. Since $F''(x)$ is decreasing in x, $F''(x) < 0$ for all $x > d_2$, and thus $F(\cdot)$ is concave, i.e. $F''(x) < 0$, for $x \in [d_2,d]$. By $G''(x) < F''(x)$, we also have $G''(x) < 0$ for $x \in [d_2,d]$. Finally, by $F(d_2) > 0$ and $F'(d) < 0$, it must be either $F(x)$ cross 0 once before d or $F(x) \geq 0$ for $x \in [d_2,d]$. Thus $X_{se} = [d_2,\min\{d,\hat{d}\}]$, and $\hat{d}$ is determined by $F(x) = 0$ for $x \in [d_2,\infty)$. So X_{se} must be convex, and together with strict concavity of $G(\cdot)$, there is a unique solution to the problem described in Condition 7. As a result, X_T^* is a singleton, and this completes the proof. ■

Proof of Theorem 1 (iii) hybrid equilibrium. Theorem 1 (i-ii) show that there is no separating or pooling equilibrium for $d \in (d_1,d_2)$. We now show there is a unique hybrid equilibrium. First by Condition D1, we have $x_{BT}^* = d$ in hybrid equilibrium. When type t entrepreneur separates from type 0, any strategy with $x_{BT} = x^* \neq d$ is dominated by the strategy with $x_{BT} = x'$ and all else equal, where x' is ε closer to d, i.e., $(x' - d)^2 - \varepsilon = (x^* - d)^2$ where $\varepsilon \to 0$. Choosing a design closer to his ideal design further makes type T entrepreneur better off from product preference; this makes $\mu_B(x') = 0$, and thus increases market share.

Moreover, by Equation (3), type 0 entrepreneur B would only assign positive probability to $x = x_T^*$ and/or $x_{B0} = 0$ in equilibrium. All else equal, suppose type 0 entrepreneur B chooses design $x' \neq x_T^*$, then $x_{B0} = 0$ maximizes type 0 entrepreneur B's expected utility, i.e. Equation (3). As a result, type 0 entrepreneur B would only assign zero probability on any $x_{BT} \neq 0$ or x_T^*. Consequently, if there exists a hybrid equilibrium, we can write the equilibrium as $\boldsymbol{\sigma} = (\sigma^*(0,-d),-d,\boldsymbol{q}^*;\sigma^*(0,d),d,\boldsymbol{q}^*)$, where $\sigma(0,d)$ (respectively, $\sigma(0,-d)$) represents the probability the entrepreneur assign to 0, and thus $1 - \sigma(0,d)$ (respectively, $1 - \sigma(0,-d)$) represents the probability the entrepreneur assign to d (respectively, $-d$). By symmetry, in equilibrium, $\sigma^*(0,d) = \sigma^*(0,-d)$. For ease, write $\sigma^* = \sigma^*(0,d) = \sigma^*(0,-d)$.

Next, we show there exists $\sigma^* \in (0,1)$ such that $\boldsymbol{\sigma}$ is an equilibrium. Suppose $\boldsymbol{\sigma}^*$ is an equilibrium. Then by Bayes rule, consumers' posterior about entrepreneur B is $\mu_B(0) = 1$ and $\mu_B(d) = \frac{(1-\sigma^*)\lambda}{1-\sigma^*\lambda}$. Notice that if type 0 entrepreneur is willing to randomize between $x_{B0} = 0$ and $x_{B0} = d$, it must be that she is indifferent between $x_{B0} = 0$ and $x_{B0} = d$. The expected utility of type 0 entrepreneur B choosing $x = 0$ is

$$\sigma^*\lambda\tfrac{1}{2} + (1 - \sigma^*\lambda)\left[\tfrac{1}{2} + \tfrac{d}{4} - \tfrac{1-\lambda}{4d(1-\sigma^*\lambda)}(1 - (1 - q_T^*)^2)\right], \tag{11}$$

and the expected utility of type 0 entrepreneur B choosing $x = d$ is

$$\sigma^*\lambda\left[\tfrac{1}{2} - \tfrac{d}{4} + \tfrac{1-\lambda}{4d(1-\sigma^*\lambda)}(1 - (1 - q_T^*)^2)\right] + (1 - \sigma^*\lambda)\tfrac{1}{2}. \tag{12}$$

Equalize Equation (11) and Equation (12) $\sigma^* = \frac{1}{\lambda}\left[1 - \frac{(1-\lambda)(1-(1-q_T^*)^2)}{d^2}\right]$. By $d_1 < d < d_2$, it is easy to check $\sigma^* = \frac{1}{\lambda}\left[1 - \frac{d_1^2}{d^2}\right] > 0$, and $\sigma^* = \frac{1}{\lambda}\left[1 - (1 - \lambda)\frac{d_2^2}{d^2}\right] < \frac{1}{\lambda}[1 - (1 - \lambda)] = 1$. ■