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Quality Signaling through Crowdfunding Pricing

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Abstract

Problem definition: This paper studies an entrepreneur's pricing strategy in a reward-based crowdfunding campaign under asymmetric product quality information. We propose two signaling mechanisms and investigate the relative performance of these mechanisms under different market conditions.

Academic/practical relevance: This problem is relevant to practice, as asymmetric quality information is a major concern in reward-based crowdfunding; high-quality entrepreneurs are looking for credible mechanisms to signal their quality to customers. Methodology: We develop a stylized game-theoretic signaling model with both funding and regular selling periods that captures asymmetric quality information between an entrepreneur and customers.

Results: For a high-quality entrepreneur who lacks a strong fanbase, we propose a new theory on quality signaling. In many cases, a low funding price might be the only signaling tool needed (i.e., one-price signaling); a high-quality entrepreneur should offer a good deal to customers in the funding period to increase the chance of a successful campaign to reach the regular selling period. However, such an entrepreneur can increase his funding price, if he commits to his future price in the regular selling period (i.e., two-price signaling). We characterize financing target levels that allow entrepreneurs to signal quality through one- or two-price mechanisms. In particular, we show that two-price signaling is plausible for a broad range of financing target levels. When both one- and two-price signaling are plausible (i.e., when the financing target level is not large), the gap in potential high- and low-quality levels and the accuracy of the market signal on customers valuation of the product in the regular selling period determine the more efficient signaling mechanism. *Managerial implications:* Entrepreneurs should be mindful of pricing in both funding and regular selling periods, as it plays an essential role in signaling quality information. Our findings suggest practical quality signaling in crowdfunding. We demonstrate a trade-off between signaling costs and the value of learning of consumer preferences in reward-based crowdfunding. We demonstrate how price commitment significantly increases the possibility of quality signaling for high-quality entrepreneurs without serious funding price compromises, thus making crowdfunding platforms attractive to high-quality entrepreneurs.

Keywords: Reward-based crowdfunding, quality signaling, price commitment

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History:

1. Introduction

Crowdfunding is increasingly being used as a mechanism to finance start-ups, alongside classical financing methods, such as venture capitals and bank financing. Crowdfunding helps entrepreneurs who are creative but lack capital raise funds from individuals all around the world through the Internet. The world market for crowdfunding is estimated to be $10.2 billion in 2018 and is expected to reach $28.8 billion by the end of 2025 (QYResearch Report 2019). There is a large variety of crowdfunding campaigns, like reward-based, equity-based, debt-based, and donation. In this paper, we focus on the most widely practiced one, i.e., reward-based crowdfunding. The most successful platforms running reward-based crowdfundings, such as Kickstarter and Indiegogo, have raised billions of dollars for entrepreneurs[1].

In reward-based crowdfunding, an entrepreneur (who usually lacks money to make his project happen) starts a campaign on an online platform by announcing a funding price and a financing target level. Customers can back the campaign and pre-order through the Internet by paying the funding price. After a certain period of online display (usually several weeks or months), the campaign will succeed if the collected fund during the campaign surpasses the announced financing target level; otherwise, the campaign fails and the raised fund is returned to backers (on some platforms such as Indiegogo, collected funds might not be returned to backers, even if the campaign fails). The funds raised in a successful campaign would be used to set up a business, e.g., hire labor, buy materials, and produce the final product. A successful crowdfunding campaign has benefits beyond the immediate realized trade between entrepreneurs and their funders. Many buyers are entirely unaware of potentially attractive products offered on crowdfunding platforms; they only find out about a product once it hits the retail market. Thus, after running a successful campaign, entrepreneurs might choose to continue to sell to other potential customers after delivering pre-ordered products (Sayedi and Baghaie 2017, Kumar et al. 2020).[2]

In reward-based crowdfunding, customers decide whether to buy the product based on their taste and their beliefs about product quality. While entrepreneurs know the true quality of their products, potential backers in the funding period can only form their beliefs about a product's quality based on the released information on crowdfunding platforms

[1] https://www.kickstarter.com/help/stats

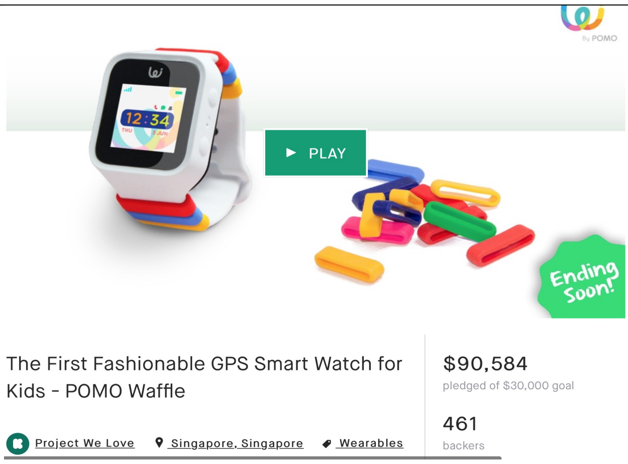
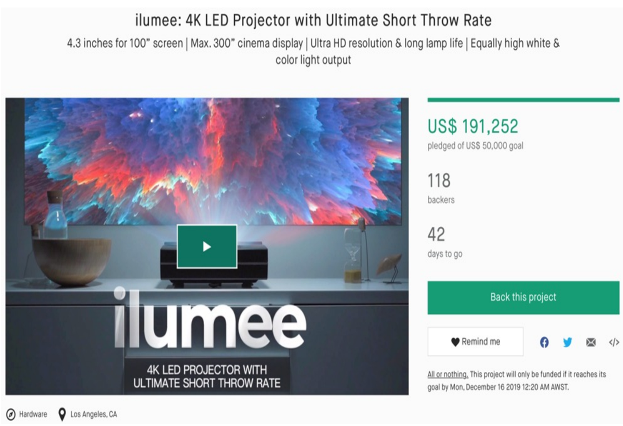
[2] Some entrepreneurs decide not to continue the business and just pocket the profit of the funding period (Hu et al. 2015).

(e.g., online demos, pictures, descriptions, etc.). In practice, many quality issues have been reported after pre-order customers received their products, and fundraisers failed to deliver what they promised to their funders (Tang 2016, Chakraborty and Swinney 2020). Since customers' belief about a product's quality directly affects their decision to support a campaign, it is essential that entrepreneurs find ways to signal their project quality credibly (Kauffman foundation 2016). Empirical studies have established that underlying project quality is associated with the success of crowdfunding efforts. These studies show that methods such as visual techniques have been successfully used to signal product quality to potential consumers (Mollick 2014). However, such signaling methods are not credible and far from perfect. As Mollick (2014) put it into words "The nature of how entrepreneurs signal quality, legitimacy and preparedness is much less defined in the virtual setting of crowdfunding than in traditional new venture settings, and future scholarship into this process may add to existing theory in this important area." Characterizing quality signaling tools can help high-quality entrepreneurs who are in desperate need of cash increase their chance of financing their projects.

Reward-based crowdfunding, as it currently exists, can be seen as another form of advance selling, except for the fact that an entrepreneur can sell to consumers only after running a successful crowdfunding campaign. Corporations frequently use advance selling schemes to cover development costs, profit from price discrimination, and test the market. The literature on advance selling has studied pricing as a major quality signaling tool (e.g., Chen and Jiang 2020) and has highlighted challenges in credible signaling through first period prices. We wanted to understand if such challenges persist in a crowdfunding setting, recognizing both similarities (price and sell in two periods) and differences (second period selling only if first period funding is successful) with advance selling.

Examining 2400 reward-based crowdfunding campaigns in the field of technology on Kickstarter, we observe that about 80% of these campaigns only post their funding prices while 20% of these campaigns post their retail prices alongside their funding prices. For example, Figure 1(a) shows a crowdfunding campaign for a smartwatch that only posts its funding price at $109, while Figure 1(b) depicts a campaign that posts not only its funding price ($1899), but also the retail price of its product, ilumee at $3267. In a typical reward-based crowdfunding campaign (even when a retail price is posted), no commitment is made to protect early customers, but given the continuous innovative flux of the crowdfunding industry, it is safe to assume that this will change soon (Grell 2015). There are several

Table 1: Crowdfunding Campaigns with and without Retail Price Commitment

	Reward-based Crowdfunding Campaign	Pricing Mechanism
(a) Without retail price commitment		Pledge $109 or more Believer Available colors 'Blue' 'Pink' or 'White'. We will contact after the campaign to pick the color you want. INCLUDES: • POMO WAFFLE Smartwatch • 2× Waffle Band ESTIMATED DELIVERY Mar 2017 SHIPS TO Anywhere in the world Limited 123 backers
(b) With retail price commitment		Pledge $1,899 or more ilumee projector Kickstarter Special Enjoy your exclusive discount where you will get: ilumee 4K LED Projector * 1, Power Adapter * 1, Power Cable *1, Remote Control * 1 Will retail for $3,267 | 42% off retail INCLUDES: • ilumee 4K projector • Power Adapter • Power Cable • Remote Control ESTIMATED DELIVERY May 2020 SHIPS TO Anywhere in the world 1 backer

Source. https://www.kickstarter.com

recent examples of crowdfunding campaigns that they have actually implemented price commitment, e.g., ZeTime Watch[3] and Wangyi Cloud Sound[4], as their retail prices are the same as the pre-announced retail prices. In this paper, we refer to campaigns with no commitment to retail prices as the one-price mechanism, while the two-price mechanism refers to retail price commitment in crowdfunding campaigns.

[3] Crowdfunding on *https://www.kickstarter.com/projects/1282890542/zetime-worlds-first-smartwatch-with-hands-over-tou* and regular online selling on *https://www.mykronoz.com/eu/en/zetime.html*.

[4] Crowdfunding on JD.com (NASDAQ: JD) *https://z.jd.com/project/details/103073.html* and regular online selling on *http://m.you.163.com/item/detail?id=3477020&_stat_subject=13579#/?_k=ukrj7m*.

We construct a two-stage model to study an entrepreneur's pricing strategy as he launches a reward-based crowdfunding campaign. If the campaign is successful, he continues to sell to customers in a regular selling period. We assume that potential customers in the funding period are heterogeneous; in particular, they are comprised of fans (avid supporters) with high valuation and regular customers with an unknown but lower valuation of the product. The entrepreneur sets a funding price and announces his financing target level at the beginning of the first period (in the two-price mechanism, he also posts his regular selling price). The product quality is unknown to customers; observing the posted price (pair of prices in two-price mechanism), customers update their belief about product quality and decide whether to contribute to the campaign or not. The funding campaign will succeed if the backers' contribution exceeds the posted target level. After a successful campaign, the entrepreneur sets up the business to deliver the product to backers at the end of the funding period. At the beginning of the regular selling period, the second group of customers arrives, and they observe the true quality of the product. Next, the entrepreneur conducts his market research, which generates a signal on customers' valuation of the product in the regular selling period. Then the entrepreneur posts his price in the regular selling period (if he has not yet committed to), and the second group of consumers decides whether to buy. The entrepreneur's objective is to maximize the total expected profit in both the funding and the regular selling periods.

There is a vast literature on quality signaling in advance selling, characterizing potential quality signaling tools. In particular, it has been shown that in the presence of informed customers, where high quality is associated with higher marginal costs, higher prices can signal higher quality levels; the presence of informed customers makes it costly for low-quality firms to mimic the high-quality firms' pricing strategy (Bagwell and Riordan 1991). Given the nature of the crowdfunding phenomenon, it is innocuous to assume that most customers are unaware of the true quality of the entrepreneur's product. Interestingly, even when established firms are behind crowdfunding campaigns, they try to hide their involvement (which can ensure the quality) with the project as it might discourage customers to contribute to the project in the funding period (Sayedi and Baghaie 2017). The existing literature on advance selling (e.g, Chen and Jiang 2020) predicts that when there is no informed customers, quality signaling through the funding price (first period price in their setting) is not plausible. We want to understand if this result extends to a reward-based crowdfunding setting, where it is explicitly recognized that the selling season (second period) can only happen if the funding period (first period) is successful, with such success depends on the funding price set.

Assuming a successful campaign needs both fans and regular customers' contribution to the campaign (i.e., an entrepreneur with a weak fanbase), we show that a high-quality entrepreneur would be able to signal quality by charging a low price in the funding period if the financing need of the project allows it. For a high-quality entrepreneur, charging a low price increases his chance of surviving the funding period by attracting price-sensitive customers. Reaching the regular selling period, revealed high-quality levels justify high market prices to compensate losses in the funding period. For the low-quality entrepreneur, low quality makes the regular selling period less lucrative as charging high market prices is not an option due to the low-quality level. In other words, long term returns from a successful funding campaign are greater for a high-quality product, and low funding prices increase the chance of reaching the high future returns, which serves as the underlying mechanism for one-price signaling.

Charging a low price in the funding period to signal a high-quality level might not be very attractive to a high-quality entrepreneur. In fact, signaling through the funding price is quite costly for the entrepreneur as he has to reduce his funding price drastically; for relatively high financing needs, quality signaling through low funding prices is not even viable. We propose a commitment to a regular selling price to address this issue. By reducing the distortion in the funding price, two-price signaling reduces the signaling cost and expands the range of financing target levels that allow quality signaling. While price commitment reduces the signaling cost, it makes the entrepreneur forgo the market signal on customers' valuation of the product (i.e., the marketing role of crowdfunding) as he has already committed to the market price in the regular selling period, which negatively affects the performance of two-price signaling.

While a high financing level requires two-price signaling, low financing levels make both signaling mechanisms plausible. We compare the relative performance of the one- and two-price signaling mechanisms to show that the gap in potential quality levels and the accuracy of the market signal on customers' valuation of the product drive the relative performance of these mechanisms. While for a small gap in potential quality levels one-price dominates two-price signaling, due to the value of learning from the market signal; as the gap in potential quality levels increases, the cost of distortion in the funding price in one-price signaling exceeds the cost of commitment to future prices (i.e., forgoing the market signal) in the regular selling period. Therefore, two-price signaling dominates one-price signaling. We also show that as the accuracy of the market signal increases, then the range of quality gaps over which one-price dominates two-price signaling also expands.

The rest of this paper is organized as follows. We introduce the relevant literature in the next section. We define the problem and the equilibrium concept in Section 3. In Sections 4 and 5, we study the one- and two-price signaling mechanisms, respectively. Section 6 compares the relative performance of these two signaling mechanisms, and we conclude in Section 7. All proofs have been relegated to the Appendix A. We provide the interested readers the existence of a separating equilibrium for an entrepreneur with a relatively strong fanbase in Appendix B.1, and Appendix B.2 presents the refinement of pooling equilibrium.

2. Literature Review

The success of online crowdfunding platforms have attracted the attention of numerous empirical researchers (Agrawal et al. 2015). Most of these studies have examined potential factors contributing to the success of crowdfunding campaigns and issues that complicate crowdfunding campaign design (e.g., Mollick 2014, Zhang and Liu 2012, Freedman and Jin 2011). For a comprehensive overview of this literature please refer to Belleflamme et al. (2015) and the references therein.

Besides empirical studies, a growing body of theoretical works has been devoted to crowdfunding. Chang (2016) studies fixed and flexible crowdfunding campaigns; in the former, the contributed money would be refunded if the target investment level is not met while in the latter, raised funds would be seized by the firm even if the campaign is a failure. They show that fixed campaigns generate more revenue, which complements the borrowing since it helps the firm learn its product market value. Du et al. (2019) study three stimulus policies: Seeding, feature upgrade and limited-time offer to improve the success probability of reward-based crowdfunding. Strausz (2017) argues the deferred payment and conditional pledge can eliminate the moral hazard problem associated with the reward-based crowdfunding. Xu et al. (2019) develop a two-period model to study the effect of network externalities, social learning, and financial constraints between a reward-based crowdfunding entrepreneur and strategic consumers. Finally, Kumar et al. (2020) show that crowdfunding can serve as a price-discrimination mechanism that forces the funders to pay higher. They show that when the cost of external financing decreases, it might encourage creators to rely more on price discrimination and to decrease their production. None of the above papers study quality issues that might arise in crowdfunding campaigns.

Empirical studies in crowdfunding have established that the underlying quality of a project has a direct effect on its crowdfunding campaign success (Mollick 2014). Hu et al. (2015) have conducted one of the pioneering theoretical studies on optimal product quality and pricing decisions in crowdfunding. They show that the fundraiser should offer different quality products if consumers are sufficiently heterogeneous in their valuations. Sayedi and Baghaie (2017) study how entrepreneurs can signal their competency to customers; in particular, they show that customers benefit from not knowing the entrepreneurs level of competency. Chakraborty and Swinney (2020)'s work is closer to our paper. They consider a model in which creators signal their quality via their campaign design. Our paper differs from theirs in several key ways. Most notably, Chakraborty and Swinney (2020) do not consider the regular selling period. Interestingly, in the absence of the regular selling period, they predict a unique pooling equilibrium for our model. We show that regular selling period returns after a successful campaign are a major driver for the existence of a separating equilibrium. In addition, Chakraborty and Swinney (2020) assume a mix of informed and uninformed backers, and this mixture drives their insights. We assume that customers are uninformed about the quality in funding period, however, customers heterogeneity is captured in their product valuation.

In the marketing literature, several different quality signaling mechanisms have been proposed: Pricing (Bagwell and Riordan 1991, Chen and Jiang 2020), advertisement (Kihlstrom and Riordan 1984, Paul Milgrom 1986), scarcity (Stock and Balachander 2005), capacity rationing (Yu et al. 2015) and warranties (Lutz 1989), etc. Among these methods, quality signaling through pricing is the closest to this paper. Signaling through pricing has received considerable attention in the marketing literature (Rao and Monroe 1989, Bagwell and Riordan 1991, Moorthy and Srinivasan 1995). Bagwell and Riordan (1991) study quality signaling in a market where part of consumers are informed of quality while the rest are not. They show that when high-quality products are associated with higher production costs, higher prices can be used to signal higher quality. As the ratio of informed consumers increases over time, they show that high and declining prices signal high quality. In the absence of cost differences, Chen and Jiang (2020) show that in advance selling quality signaling just through the price in the first period is not plausible. They show that commitment to the price in the second period helps the firm signal quality. In our paper, assuming the same marginal cost for both quality types, we study both one- and two-price signaling mechanisms, and demonstrate how just a funding price might signal quality in crowdfunding settings. This paper contributes to this literature by investigating whether pricing in crowdfunding can be used as a quality signal tool.

3. The Model

We study an entrepreneur (later referred to as "he") who launches a reward-based crowdfunding campaign to fund his project by pre-selling his product. The campaign is a success if the total fund raised in the campaign exceeds a pre-announced threshold. If the set threshold is not met, the campaign fails, and all backers of the project get their money back. After a successful campaign, the entrepreneur is obliged to deliver the product to customers who have paid for the product in the funding period. He may also continue to sell in a regular selling period to a new set of customers.

When the entrepreneur introduces the product on a crowdfunding platform, he knows the true quality of the product while customers only receive product information through the online platform (e.g., ads, descriptions and demos); therefore, we assume that they are not aware of the true product quality. Similar to most of the existing literature on quality signaling (e.g., Moorthy and Srinivasan 1995, Yu et al. 2015), we assume that the product quality can be either low (q_L) or high (q_H, $q_H > q_L$), which is private information for the entrepreneur at the beginning of the crowdfunding period, and customers only hold a belief that the product is of high quality with probability a ($0 \leq a \leq 1$). In this model, we focus on experience goods and assume that the true quality would be revealed to customers (after a successful campaign) in the regular selling period when the final product is available in the retail market. We also assume that the entrepreneur's marginal production cost is the same for both types of product quality and is normalized to zero. This is a common assumption in the literature (e.g, Stock and Balachander 2005, Chen and Jiang 2020, Jiang and Tian 2018, Chakraborty and Swinney 2020): Srinivasan et al. (1997) show that from a consumer's perspective, higher design quality does not necessarily entail higher production cost. In addition, by normalizing the marginal production cost of both types to zero, we abstract away the role of cost differences in facilitating quality signaling (Bagwell and Riordan 1991). This assumption is particularly true for products like photo journals, music albums and video games on crowdfunding platforms. After sunk development cost, the production cost is not necessarily a function of the intrinsic quality of photos, songs, and developed games (Sayedi and Baghaie 2017). In what follows, we describe customers and the entrepreneur's problems and define the sequence of events in the game.

3.1. Crowdfunding Period

At the beginning of the crowdfunding period (later referred to as the funding period), the entrepreneur introduces his product through demos and ads on a platform and posts his funding price alongside a financing target level, $T > 0$. Customers check the project on the platform and decide whether to back it or not. $U = \theta q - p$ gives customers utility, where $\theta \in \{\theta_1, \theta_2\}$ denotes customers' taste parameter in each of the two selling periods, capturing different valuations of the product in the funding and regular selling periods, p is the posted price, and q is the perceived product quality.

We assume that customers in the funding period are heterogeneous and mainly comprised of high valuation customers (i.e., fans, who come from the entrepreneurs' social circle or they are avid fans of the product) and regular customers (Kuppuswamy and Bayus 2017, Paolo et al. 2018). The high valuation customers have the maximum taste for the product, which we normalize to one, i.e., $\theta_1 = 1$, or equivalently, $U = q - p_1$, where p_1 denotes the posted price in the funding period. Regular customers are also interested in the project, but their enthusiasm for the project is less than the avid fans. Their taste parameter is assumed to be unknown but uniformly distributed between 0 and 1, i.e., $\theta_1 \sim U[0,1]$. We normalize the market sizes of the high and regular valuation customers to α and $1 - \alpha$ $(0 < \alpha < 1)$, respectively, to normalize the market size in the funding period to one.

This model mainly focuses on products at their later stage of $R\&D$, and hence there is less uncertainty on the features and cost of the project, like video games and smartphone apps. These products fit well with our next assumption on the financing target levels. We follow Zhang et al. (2017) and Du et al. (2019) to assume that the funding target level T is exogenously given, as it is the cash needed to set up the business. We can refer to T as the fixed cost needed to move from the design and prototyping phase to full-scale production (Chakraborty and Swinney 2020).

Since we have normalized the potential market size in the funding period to one, the campaign would fail for sure if $p_1 < T$. As the customers' taste parameter satisfies $0 \le \theta \le 1$, the crowdfunding price satisfies $p_1 \le q$; otherwise, no one will buy the product. We can characterize the campaign's success as follows. When $T > \alpha q$, the maximum contribution from fans (i.e., αq) is insufficient for the campaign's success; thus the entrepreneur needs support from both types of customers, and the campaign's success probability is $(1-\frac{p_1}{q})$ with $T \leq p_1 \leq q$. When $T \leq \alpha q$, we have the following two cases: When $p_1 \in [T, T/\alpha)$, the campaign will succeed if both types of the customers support it, thus campaign success probability is still given by $(1-\frac{p_1}{q})$; when $p_1 \in [T/\alpha, q]$, the campaign will succeed for sure as the high valuation customers' contribution to the campaign, αp_1 exceeds T.

3.2. Regular selling period

If the raised fund in the funding period exceeds the campaign's financing target level T, the campaign will succeed, and the entrepreneur receives the money from the platform to set up his business and deliver the product to backers in the funding period. A successful entrepreneur, after delivering to his backers, can produce and sell his product in a regular selling period while the market interest for the new product can be high or low (Sayedi and Baghaie 2017). We assume that customers' taste parameter can be characterized as relatively high or low; in particular, when customers taste is uniformly distributed over $[0,1/2]$, i.e., $\theta_2 \sim U[0,1/2]$, denoted as θ^L, the new product is of low interest. Similarly, when customers taste is uniformly distributed over $[1/2,1]$, i.e., $\theta_2 \sim U[1/2,1]$, denoted as θ^H, the new product is of the high interest. Ex-ante, the entrepreneur assigns the same probability to each of the high- or low-interest scenarios.

It is known that some firms and entrepreneurs look at the funding period as a market research tool (Robles 2017). In particular, when the final product is readily available, and it has been experienced by some customers (i.e., backers in the funding period), investigating product reviews or social media reaction to the delivered product generates a signal of customers' taste in the regular selling season (Fretwell 2015).

We assume that the entrepreneur conducts a market research at the beginning of the regular selling period which generates a signal $s \in \{G, B\}$. When customers in the regular market have a relatively high or low valuation of the product, the probability that the entrepreneurs' market research reveals the true relative valuation of customers to the entrepreneur is b. In particular, the probability of G signal when $\theta_2 = \theta^H$ or B signal when $\theta_2 = \theta^L$ is b; therefore, $Pr(s=G|\theta_2=\theta^H)=b$, $Pr(s=B|\theta_2=\theta^H)=1-b$, $Pr(s=G|\theta_2=\theta^L)=1-b$ and $Pr(s=B|\theta_2=\theta^L)=b$, with $1/2 \leq b \leq 1$.[5] While the prior belief about customers' taste in the regular selling period assigns the same probability to the high or

[5] The proposed structure for the market signal is similar to the confusion matrix in the multi-class classification problem, where b and $1-b$ are essentially sensitivity and specificity for a binary classification problem.

low interest scenarios, the market signal G reveals to the entrepreneur that the probability $\theta_2 = \theta^H$ is

$$Pr(\theta_2 = \theta^H | s = G) = \frac{Pr(s = G | \theta_2 = \theta^H) Pr(\theta_2 = \theta^H)}{Pr(s = G)} = \frac{\frac{1}{2}b}{\frac{1}{2}b + \frac{1}{2}(1-b)} = b, \quad (1)$$

and $Pr(\theta_2 = \theta^L | s = G) = 1 - b$. Similarly, $Pr(\theta_2 = \theta^H | s = L) = 1 - b$ and $Pr(\theta_2 = \theta^L | s = L) = b$.

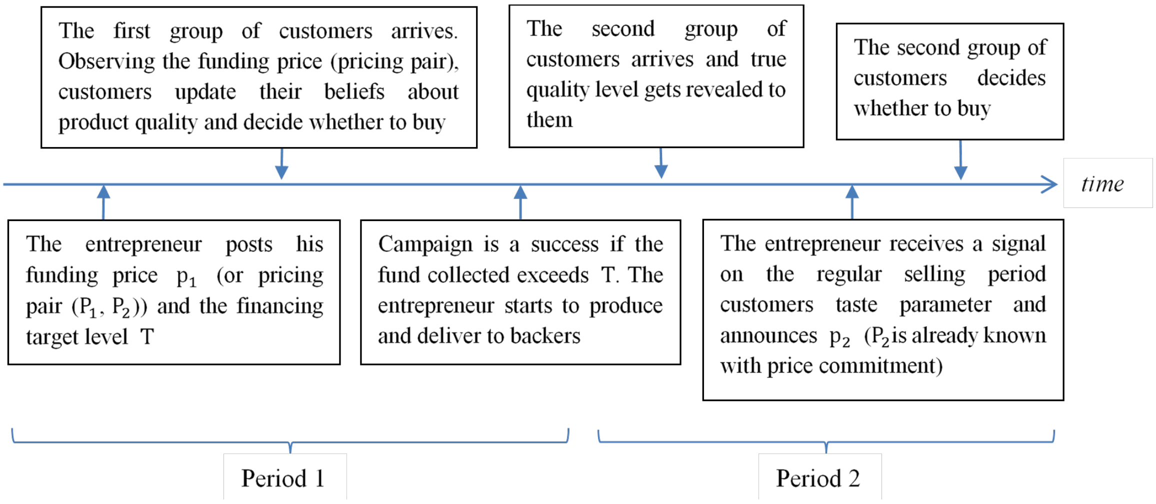
An implicit assumption in the above model is that customers' taste parameters in the first and second periods are independent. This model of product quality and consumer periodical heterogeneity has been widely adopted in economics and marketing literature (Mussa and Rosen 1978, Jiang and Tian 2018). This assumption might be even less restrictive in crowdfunding settings as to how customers evaluate the product in the funding, and regular selling periods is quite different. Customers in the funding period form their taste for the product based on a virtual product (Mollick 2014). However, once the final physical product is available in the regular selling period, customers' valuation might be quite different. In particular, post-delivery customers' comments at the end of the funding period might be informative about customers' taste in the regular selling season. Most crowdfunding platforms allow customers to leave their comments even after the end of campaigns. For example, in the case of POMO WAFFLE watch, customers in the funding period form their taste based on the functions and features promised in the online campaign. Once customers get their hands on the final product, then their comments might serve as a more accurate signal of customers' taste in the regular selling period.

In our model, we assume that learning mainly happens as backers experience the product and reveal their valuation to the public through their comments and reviews on crowdfunding platforms, social media, or free product review websites like G2 Crowd and Angies List (or even through correspondence with the entrepreneur). However, it is also possible that an entrepreneur uses his crowdfunding campaign design as a marketing research tool, to uncover potential market size or valuation of customers (Chemla and Tinn 2020). This is beyond the scope of our paper and has been relegated to future research.

3.3. The Game

We investigate whether an entrepreneur with a high-quality product can credibly separate himself from a low-quality type through pricing. We study two signaling mechanisms: One-price signaling, where the entrepreneur signals his quality through a funding price, and

Figure 1: Sequence of Events



two-price signaling, where the entrepreneur commits to the regular selling price at the beginning of the funding period.

In the first scenario (second scenario), the entrepreneur posts his price p_1 (pair of prices (P_1,P_2))[6] and his target financing level, T, then backers who are not aware of the true product's quality arrive. Upon observing the entrepreneur's price (pair of prices), backers update their beliefs about the quality of the product. Let $a'(p_1)$ $(a'(P_1,P_2))$ denote customers' updated belief as a function of price (prices) offered by the entrepreneur at the beginning of the funding period. Based on their updated beliefs, customers decide whether to back the project by purchasing the promised product. If backers contribute enough to the campaign, the entrepreneur starts to produce and deliver the product to the first group of customers at the end of the first period. At the beginning of the regular selling period, the second group of customers arrives; since the final product is now available, the true quality is revealed to customers. The entrepreneur receives a signal s on the distribution of customers' taste parameter in the regular selling period before posting his price in the regular selling period (the regular selling price has been already committed in two-price signaling). Based on their taste parameters and the entrepreneur's posted price, customers decide whether to buy in the regular selling period. The sequence of events is depicted in Figure 1.

To tease out the effect of the gap in potential quality levels and the financing target levels on equilibrium characterization, and disentangle it from the effect of regular selling

[6] We use capital letters for the two-price mechanism's notation.

period market size, we normalize the expected regular selling period market size to one. The entrepreneur's objective is to maximize the total expected profit from both the funding and the regular selling periods; we set the discount rate in the second period to one and normalize the salvage value of unsold units to zero.

We use the Perfect Bayesian Equilibrium (PBE) to analyze two potential equilibrium outcomes: Separating and pooling. In a separating equilibrium, backers can perfectly separate the high-quality product from the low-quality one based on the funding price (pair of prices), i.e., $a'(\cdot) = 0$ or 1, while in a pooling equilibrium, both types of entrepreneurs set the same price (pair of prices), thus backers cannot separate them, i.e., $a'(.) = a$. We also assume that if a price (pair of prices) is off the equilibrium path, backers would believe the product quality is low, i.e., $a' = 0$. To limit the number of equilibria, we apply *intuitive criterion* introduced by Cho and Kreps (1987) to refine the set of equilibria.

4. One Price Signaling

In most crowdfunding campaigns, an entrepreneur announces a funding price alongside a financing target level, without any commitment to the future market price of the product. Assuming the financing target level is the minimum investment needed to launch a project, we study an entrepreneur's quality signaling problem when the only credible signaling tool is the entrepreneur's funding price. First, we investigate the pricing strategy of an entrepreneur in a benchmark model with full information on the entrepreneur's quality level. Table 2 summarizes our notation of this paper.

4.1. Benchmark: Full Information with No Price Commitment

We study the pricing strategy of an entrepreneur in the funding period when customers are aware of the true product quality. We solve this problem backward. With no price commitment, after a successful campaign and at the beginning of the regular selling period, the entrepreneur receives a signal $s \in \{G, B\}$ on market potential of the product. Then, he posts his price in the regular selling period. When $s = G$, the probability that the product is of high potential in the market, i.e., θ^H is b, and the probability of low potential for the product, i.e., θ^L is $1 - b$. When the entrepreneur sets a price $p_2 \in [q/2, q]$, if customers have low interest in the product, they would not buy. Only if customers have a high interest in the product they might buy; in particular, when their taste exceeds p_2, customers will purchase the product. The probability of purchase for these customers is $2(1 - p_2/q)$. When the entrepreneur sets a price $p_2 \in [0, q/2]$, customers with high interest will buy the

Table 2: Table of Notations

α	Proportion of high valuation customers (fans) in the funding period
T	Crowdfunding financing target level
q_H, q_L	Quality levels for the product (entrepreneur)
p_1, p_2	Funding and regular selling prices with no price commitment
(P_1, P_2)	Pricing pair with price commitment
$\theta_1,\ \theta_2$	Customers taste in the funding and regular selling periods
$a, a'(\cdot)$	Pre- and post-belief of customers about the product quality
$s \in \{G, B\}$	Market signal on customers taste in the regular selling period
$\theta^H,\ \theta^L$	High and low market potentials in the regular selling period
$\pi^H(p_1), \pi^L(p_1)$ $(\Pi^H(P_1, P_2), \Pi^L(P_1, P_2))$	Entrepreneur's profit if customers hold the right belief in one-price (two-price) signaling
$\pi^{HL}(p_1), \pi^{LH}(p_1)$ $(\Pi^{HL}(P_1, P_2), \Pi^{LH}(P_1, P_2))$	Entrepreneur's profit if customers hold a wrong belief in one-price (two-price) signaling
p^i_{1se}, (P^i_{1se}, P^i_{2se})	Separating equilibrium price(s) in one-price (two-price) signaling for $i = \{H, L\}$
π^{ij*} (Π^{ij*})	Optimal profit for type i entrepreneur when he is believed to be of type j in one-price (two-price) signaling, $i, j = \{H, L\}$
π^i_2	Expected profit of type i entrepreneur in the regular selling period with no price commitment
$\overline{p}_1, \overline{p}'_1$	Thresholds on the funding price with $\pi^{L*} = \pi^{LH}(\overline{p}_1) = \pi^{LH}(\overline{p}'_1)$ when $T \le \overline{p}_1 < \overline{p}'_1 < T/\alpha$ in one-price signaling
$\underline{p}_1, \underline{p}'_1$	Threshold on the funding price with $\pi^{HL*} = \pi^H(\underline{p}_1) = \pi^H(\underline{p}'_1)$ when $T \le \underline{p}_1 < \underline{p}'_1 < T/\alpha$ in one-price signaling
(P'_1, P'_2), (P''_1, P''_2) $P'_1 > P''_1$	Intersection points of the two iso-profit curves $(1 - \frac{P_1}{q_H})(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}$ and $(1 - \frac{P_1}{q_H})(P_1 + (1 - P_2/q_H)P_2) = \Pi^{HL*}$
$\mathbb{Q}$ $(\mathbb{Q}')$	Feasible range (region) for the high-quality entrepreneur in separating equilibriums of one-price (two-price) signaling
$\tilde{P}_1$	Solution for $P_1 < \frac{q_H}{2}$ to $4P_1 + P_2 = 2q_H$ and $(1 - \frac{P_1}{q_H})(P_1 + (1 - \frac{P_2}{q_L})P_2) = \Pi^{L*}$
$\tilde{P}_2$	Solution for $P_2 > \frac{q_L}{2}$ to $\Pi^{LH}(P^H_{1se}, P_2) = \Pi^{L*}$
$\dot{P}_1, \ddot{P}_1$	Funding prices that satisfy $\Pi^{LH}(P_1, q_L) = \Pi^{L*}$ when $q_H \ge 4\Pi^{L*}$

product while customers with low interest might purchase the product with probability $2(1/2 - p_2/q)$. Therefore, the expected profit function for the entrepreneur in the regular selling period, when $s = G$ can be written as,

$$\pi_2(p_2)|_{s=G} = \begin{cases} 2b(1 - p_2/q)p_2 & q/2 \le p_2 \le q, \\ bp_2 + 2(1-b)(1/2 - p_2/q)p_2 & 0 < p_2 < q/2. \end{cases} \tag{2}$$

For $s = L$, we can derive the expected profit of the entrepreneur, similarly. The following lemma characterizes the optimal expected profit for the entrepreneur in the regular selling period, π_2.

LEMMA 1. *The expected profit of the entrepreneur in the regular selling period is given by* $\pi_2 = \frac{q}{4}(b + \frac{1}{4b})$.

The expected profit of the entrepreneur in the regular selling period is clearly a function of the accuracy of the market signal as it increases in b. Moving backward, at the beginning of the funding period, the entrepreneur has to announce his funding price, alongside the required financing level. The level of financing needed directly affects the entrepreneur's pricing decision in the funding period. In particular, for relatively high financing levels, i.e. when $T > \alpha q$ (equivalently, a relatively weak fanbase, $\alpha < T/q$), the campaign's success needs support from both fans and regular customers as the maximum contribution from fans (i.e., αq) cannot cover the initial required investment T. In this case, as the regular customers' contribution is needed to finance the project, the success probability of the crowdfunding campaign is given by $(1 - \frac{p_1}{q})$, with $T \leq p_1 \leq q$. Let $\pi(p_1)$ denote the expected profit of the entrepreneur at the beginning of the funding period. The objective function for the entrepreneur can be written as,

$$\max_{p_1 \in [T,q]} \; \pi(p_1) = (1 - \frac{p_1}{q})(p_1 + \pi_2), \tag{3}$$

where the optimal funding price is bounded from bottom by the required financing level and the quality level at the top.

For relatively low financing levels, i.e., $T \leq \alpha q$ (equivalently, a strong fanbase, $\alpha \geq T/q$), the entrepreneur encounters the following problem: If the entrepreneur posts a relatively low funding price, i.e., $p_1 \in [T, T/\alpha)$, the campaign would succeed only if both types of customers support the project, thus the campaign success probability is still given by $(1 - \frac{p_1}{q})$, and the entrepreneur's profit function is the same as (3). However, the entrepreneur can also set a high price, i.e., $p_1 \in [T/\alpha, q]$, which guarantees a successful campaign as the contribution from fans would exceed the required financing level, i.e., $\alpha p_1 \geq T$. Therefore, the entrepreneur's profit function when $T \leq \alpha q$ can be written as,

$$\pi(p_1) = \begin{cases} (1 - \frac{p_1}{q})(p_1 + \pi_2) & T \leq p_1 < T/\alpha, \\ \alpha p_1 + (1-\alpha)(1 - \frac{p_1}{q})p_1 + \pi_2 & T/\alpha \leq p_1 \leq q. \end{cases} \tag{4}$$

The following lemma characterizes the optimal funding price under full information.

LEMMA 2. *If $T > \alpha q$, the optimal funding price for the entrepreneur is given by $p_1^* = \max\{\frac{q-\pi_2}{2}, T\}$. Otherwise,*

$$p_1^* = \begin{cases} \frac{q-\pi_2}{2} & \overline{T} < T \leq \alpha q \text{ and } 0 < \alpha \leq \frac{q-\pi_2}{2q}, \\ (T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q & \text{otherwise}^7, \end{cases} \tag{5}$$

where $\overline{T} > \frac{\alpha q}{2(1-\alpha)}$ is the solution for T to $\pi(\frac{q-\pi_2}{2}) = \pi(\frac{T}{\alpha})$.

Note that $p_1 = (T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q$ guarantees a successful campaign through charging high prices to fans since $\alpha p_1 > T$. Lemma 2 indicates that the entrepreneur charges high prices to finance the entire project through his fans when the financing target level is lower than a threshold given by $\overline{T}$ or the fanbase is greater than $\frac{q-\pi_2}{2q}$. Otherwise, the entrepreneur prefers to attract both fans and regular customers to his project.

The characterization of the optimal funding price demonstrates how the required financing level affects the entrepreneur's optimal pricing decision. In particular, for relatively high financing levels, the entrepreneur has to seek the contribution of both fans and regular customers, while low financing levels allow the entrepreneur to charge high prices to finance the entire project through avid supporters. In the rest of the paper, we mainly focus on the case that a high financing level requires the entrepreneur to sell to both fans and regular customers to finance the project (i.e., $T > \alpha q$). This case seemingly represents most campaigns on crowdfunding platforms where often unknown entrepreneurs seek backers, including a relatively small group of fans alongside price sensitive customers, to finance their projects; in these projects, there is a considerable chance of failure as regular customers might not contribute enough to these campaigns.[8] It is possible that a large fanbase allows an entrepreneur to finance his project entirely through his fans.[9] Analysis of such cases is available from the authors upon request.

4.2. Quality Signaling with No Price Commitment

We assume the true quality of the product is high or low (i.e., q_i, $i = \{H, L\}$), and is unknown to customers in the funding period. Since the campaign financing level is exogenously given and known to customers, a potential signaling tool for the entrepreneur is

[7] $x \vee y = \max(x, y)$, $x \wedge y = \min(x, y)$.

[8] On average, 50% of crowdfunding campaigns fail.

[9] An example of this case in practice is BLOCKS, a modular watch on Kickstarter.

his funding price. Observing a funding price p_1, customers update their belief on product quality q_j according to the following belief structure,

$$q_j(p_1) = \begin{cases} q_H & \text{if } p_1 \in \mathbb{Q}, \\ q_L & \text{otherwise}, \end{cases} \tag{6}$$

where $\mathbb{Q}$ is the feasible range for a high-quality entrepreneur to set his funding price p_1 in a separating equilibrium. Under this belief structure, if $p_1 \in \mathbb{Q}$, p_1 must satisfy the following conditions:

$$\pi^{L*} \geq \pi^{LH}(p_1), \tag{7}$$

$$\pi^{H}(p_1) \geq \pi^{HL*}, \tag{8}$$

where $\pi^{ij}(p_1),\ i,j = \{H, L\}$ is the expected profit of an entrepreneur with true product quality q_i when his product is believed to be of quality q_j.[10] The necessary condition in (7) guarantees that a low-quality entrepreneur has no incentive to mimic the high quality type's price in $\mathbb{Q}$ to be perceived as the high-quality one by customers in the funding period. The sufficient condition in (8) makes sure that deviation from the equilibrium price in $\mathbb{Q}$ is not profitable for the high-quality entrepreneur. We investigate the *necessary and sufficient conditions* (N&S conditions, hereafter) in what follows.

Since we are assuming $T > \alpha q_H \geq \alpha q_L$[11], campaign's success requires support from both fans and regular customers in the funding period, independent of the customers' belief on the quality level of the entrepreneur, q_j. The objective function for an entrepreneur with the true quality q_i when he is believed to be of quality q_j is given by,

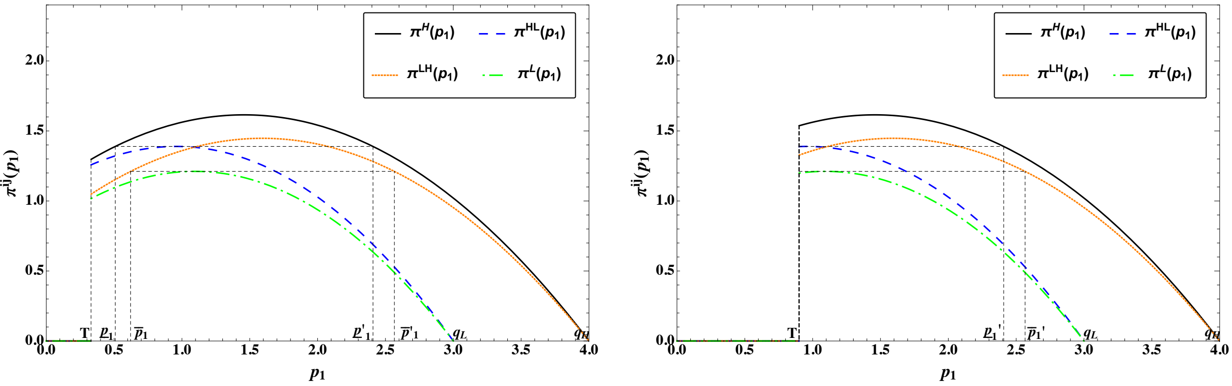
$$\max_{p_1 \in [T, q_j]} \pi^{ij}(p_1) = (1 - \frac{p_1}{q_j})(p_1 + \pi_2^i), \tag{9}$$

where $(1 - \frac{p_1}{q_j})$ is campaign's success probability as a function of customers' perceived quality q_j and $\pi_2^i = \frac{q_i}{4}(b + \frac{1}{4b})$ is the type i entrepreneur's expected profit in the regular selling period. The optimal funding price for the entrepreneur is bounded by the financing target level at the bottom and the perceived quality level at the top. It is straightforward to check that $\pi^{ij}(p_1)$ is concave in p_1 for $i, j = \{H, L\}$. The following lemma helps us characterize the separating equilibrium.

[10] To simplify the notation, we reduce the superscript ij to i for $\pi^{ij}(.)$ and p_k^{ij}, for $k = 1, 2$, when $i = j$. Similar convention for later $\Pi^{ij}(.)$ and P_k^{ij}.

[11] Cases for $T \leq q_L < T/\alpha < q_H$ and $T < T/\alpha \leq q_L < q_H$ are studied in Appendix B.1.

Figure 2: Profit functions for the entrepreneur with no price commitment, $T \le q_L < q_H < T/\alpha$



(a) $T \le \overline{p}_1$ (b) $T > \overline{p}_1$

Notes. The separating equilibrium $p_{1se}^H = \overline{p}_1$ where $q_L = 3$, $q_H = 4$, $\alpha = 0.04$, $b = 0.75$, $T = 0.2$ for (a) and no separating equilibrium when $q_L = 3$, $q_H = 4$, $\alpha = 0.04$, $b = 0.75$, $T = 0.9$ for (b).

LEMMA 3. *There exists a unique $\overline{p}_1$ such that for $T \le \overline{p}_1$:*

i) There exists a unique $\overline{p}_1'$ that satisfies $\pi^{L*} = \pi^{LH}(\overline{p}_1) = \pi^{LH}(\overline{p}_1')$ with $\overline{p}_1 < p_1^{L*} < \overline{p}_1'$.

ii) There are unique $\underline{p}_1$ and $\underline{p}_1'$ that satisfy $\pi^{HL*} = \pi^H(\underline{p}_1) = \pi^H(\underline{p}_1')$ with $\underline{p}_1 < p_1^{HL*} < \underline{p}_1'$.

iii) Moreover, $\overline{p}_1 > \underline{p}_1$ and $\overline{p}_1' > \underline{p}_1'$.

Part (i) of Lemma 3 indicates that if the high-quality entrepreneur sets an equilibrium price $p_1 < \overline{p}_1$ or $p_1 > \overline{p}_1'$, the low-quality entrepreneur has no incentive to mimic p_1, since he earns more by revealing his low quality to customers as $\pi^{LH}(p_1) < \pi^{L*}$. Similarly, part (ii) demonstrates that in a separating equilibrium, the high-quality entrepreneur must set a funding price that satisfies $\underline{p}_1 \le p_1 \le \underline{p}_1'$; if in a separating equilibrium $p_1 < \underline{p}_1$ or $p_1 > \underline{p}_1'$, the high-quality entrepreneur has the incentive to deviate from p_1 to be perceived as a low-quality entrepreneur, as $\pi^{HL*} > \pi^H(p_1)$.

Part (iii) of Lemma 3 has important implications for separating equilibrium characterization. Since $\overline{p}_1 > \underline{p}_1$, there exits a feasible range for the funding price p_1, i.e., $[\underline{p}_1, \overline{p}_1]$ that satisfies the N&S conditions. If a high-quality entrepreneur charges a price in this range, the low-quality entrepreneur does not have any incentive to mimic it. Similarly, the high-type entrepreneur cannot increase his profit by deviating from this price as deviation results in customers believe that the entrepreneur is of low-quality. Since $\underline{p}_1' < \overline{p}_1'$, the funding price might lie in $[\underline{p}_1', \overline{p}_1']$. It is straightforward to see that a funding price in this range does not satisfy the N&S conditions; the low-quality entrepreneur has the incentive to mimic the high-quality entrepreneur's price if the funding price lies in this range. Similarly, the high-quality entrepreneur has the incentive to deviate from a price in this range as he earns more if customers believe that he is of low quality. This observation has been depicted in Figure 2a. Therefore, $[\underline{p}_1, \overline{p}_1]$ is the only feasible range for the funding price that satisfies the N&S conditions.

Lemma 3 also demonstrates how the required financing level affects the feasible range for the funding price in the signaling game. Since the funding price is bounded from the bottom by T (i.e., $p_1 \geq T$), if $T > \overline{p}_1$, then the feasible range for the separating equilibrium would be empty. In particular, the range of p_1 that satisfies N&S conditions is given by $\mathbb{Q} = [\max\{\underline{p}_1, T\}, \overline{p}_1]$ (Figure 2a). Clearly, when $T > \overline{p}_1$, $\mathbb{Q} = \emptyset$, as it is depicted in Figure 2b.

The following proposition characterizes the separating equilibrium in one-price signaling.

PROPOSITION 1. *There exists a unique equilibrium that survives the intuitive criterion refinement when* $T < \overline{p}_1$. *The equilibrium prices are* $p^H_{1se} = \overline{p}_1 = \frac{q_H - \pi^L_2 - \sqrt{(q_H/q_L - 1)(q_H q_L - (\pi^L_2)^2)}}{2}$ *and* $p^L_{1se} = \frac{q_L - \pi^L_2}{2}$ *for the high-and low-quality entrepreneurs, respectively. Otherwise, only a pooling equilibrium exists.*

Proposition 1 characterizes the unique separating equilibrium for the high-quality entrepreneur to signal his quality to customers in the funding period. If the financing requirement of the project is low enough (i.e., $T \leq \overline{p}_1$), setting the right funding price is enough to signal high quality to customers in the funding period. Moreover, as Figure 2a demonstrates, parts (i) and (iii) of Lemma 3 indicate that $p^H_{1se} < p^L_{1se}$, i.e., in the separating equilibrium, the funding price set by the high-quality entrepreneur is lower than the price set by the low-quality one.

In fact, multiple equilibria might exist in our settings; there is also a pooling equilibrium where entrepreneurs with both high- and low-quality products set the same price in the funding period. In particular, when the required financing level is relatively high (i.e., $T > \overline{p}_1$), the only potential equilibrium under one-price mechanism is a pooling equilibrium. But, when the separating equilibrium exists, we show that the pooling equilibrium does not survive the intuitive criterion refinement (Cho and Kreps 1987). The separating equilibrium is the only equilibrium that survives the intuitive criterion refinement.[12]

The literature on quality signaling in advance selling predicts that in the absence of marginal cost differences and informed customers, the first period price is not a credible

[12] Details are available in Appendix B.2.

quality signaling tool (Chen and Jiang 2020). However, in crowdfunding settings, we show that a high-quality entrepreneur could signal quality through a low funding price if the required financing level is low enough. A high-quality entrepreneur expects a high payoff in the regular selling period, as the revealed high quality allows him to charge high prices; a priority for the high-quality entrepreneur is to survive the funding period and reach the regular selling period. This incentive is not strong for the low-quality entrepreneur, as a low-quality level prevents the entrepreneur from charging a high price in the regular selling period. Decreasing his funding price, the high-quality entrepreneur increases his chance of running a successful campaign and he reduces the low type's incentive to mimic his pricing strategy. Proposition 1 proves such a low funding price separating the high- and low-quality entrepreneurs exists. If such a funding price can cover the financial needs of the project (i.e., $p_{1se}^{H} \geq T$), then a separating equilibrium to signal quality exists.

Proposition 1 has important implications in practice. A high-quality entrepreneur who is relatively unknown, and therefore is deprived of a strong fanbase to finance his entire project, needs the price sensitive customers' contribution to finance his project. Such an entrepreneur should avoid posting high funding prices to signal his high quality; low-quality entrepreneurs always have the incentive to mimic a high funding price set by a high-quality entrepreneur.

For a high-quality entrepreneur, the required distortion in the funding price from the first-best solution can be quite significant (please refer to Figure 2a). It is straightforward to show that as the gap in high- and low-quality levels increases, the distortion in the funding price needed to signal quality also increases (i.e., $p^{H*} - p_{1se}^{H}$ is increasing in q_H for a given q_L). The distortion in the funding price is the cost incurred by a high-quality entrepreneur to signal his type. The signaling cost in one-price signaling gives rise to the next question. Can additional commitment to a regular season market price help the entrepreneur reduce his cost of quality signaling? Such price commitment fails to leverage the market signal on customers' taste at the beginning of the regular selling period. However, it may still be worthwhile in reducing the signaling cost. Next, we investigate whether the additional price commitment in the regular season is a viable quality signaling mechanism.

5. Signaling through Price Commitment

As in advance selling, an entrepreneur in a crowdfunding campaign has the option to commit to the price of the product in the regular selling period. There are recent examples of crowdfunding campaigns that have implemented price commitment, like Wangyi

Cloud Sound campaign. We investigate whether an entrepreneur can signal his quality to customers in the funding period through price commitment. In the funding period, the entrepreneur posts his market price in the regular selling period alongside a funding price. Customers are unaware of the true quality, so observing the price pair posted by the entrepreneur, they revise their belief on the entrepreneur's quality level. The belief structure is similar to (7), in particular,

$$q_j(P_1,P_2)=\begin{cases} q_H & \text{if } (P_1,P_2)\in\mathbb{Q}', \\ q_L & \text{otherwise.}\end{cases} \tag{10}$$

Similar to the one-price signaling case, first we characterize the feasible region, $\mathbb{Q}'$ for the high-quality entrepreneur to signal his type, that is when $(P_1,P_2)\in\mathbb{Q}'$ customers in the funding period believe that the product is of high quality. The feasible region $\mathbb{Q}'$ for a high-quality entrepreneur in a separating equilibrium satisfies the following necessary and sufficient conditions (N&S conditions):

$$\Pi^{L*}\geq \Pi^{LH}(P_1,P_2), \tag{11}$$

$$\Pi^{H}(P_1,P_2)\geq \Pi^{HL*}, \tag{12}$$

where the profit functions are given by

$$\Pi^{LH}(P_1,P_2)=\begin{cases} (1-\frac{P_1}{q_H})(P_1+(1-P_2/q_L)P_2) & T\leq P_1\leq q_H \textit{ and } 0\leq P_2\leq q_L, \\ (1-\frac{P_1}{q_H})P_1 & T\leq P_1\leq q_H \textit{ and } q_L<P_2\leq q_H,\end{cases} \tag{13}$$

$$\Pi^{i}(P_1,P_2)=(1-\frac{P_1}{q_i})(P_1+(1-P_2/q_i)P_2) \quad T\leq P_1\leq q_i, \quad i=\{H,L\} \tag{14}$$

and

$$\Pi^{HL}(P_1,P_2)=(1-\frac{P_1}{q_L})(P_1+(1-P_2/q_H)P_2) \quad T\leq P_1\leq q_L. \tag{15}$$

$(1-P_1/q_j)$ is the probability of a successful campaign when the quality is believed to be q_j, and $(1-P_2/q_i)P_2$ is the expected profit in the regular selling period at the beginning of the funding period. It is straightforward to show that $\Pi^L(P_1,P_2)$ and $\Pi^{HL}(P_1,P_2)$ are jointly concave in (P_1,P_2) and are maximized at $(\max\{\frac{3q_L}{8},T\},\frac{q_L}{2})$ and $(\max\{\frac{4q_L-q_H}{8},T\},\frac{q_H}{2})$, respectively. Under full information, the low-quality entrepreneur has no incentive to set

$P_2 \geq q_L$, as q_L is the maximum price he can charge in the regular selling period. However, under asymmetric information, the low-quality entrepreneur might have the incentive to mimic the high-quality entrepreneur's price to set $P_2 > q_L$, if it makes customers believe that the product is of high quality. This happens when the gain from being treated as a high-quality entrepreneur in the funding period covers the complete lack of sales in the selling period. Therefore, the profit function for the low-quality entrepreneur when he is believed to be of high quality $\Pi^{LH}(P_1, P_2)$ has two different forms for $0 \leq P_2 < q_L$ and $q_L \leq P_2 \leq q_H$ as in (13).

Because of the piece-wise characteristic of $\Pi^{LH}(P_1, P_2)$, we characterize $\mathbb{Q}'$ in the following two cases.

i) Small gaps in quality levels: For a small gap in quality levels of the product, the low-quality entrepreneur has less incentive to mimic the high-quality entrepreneur's price, therefore, to prevent the low type's mimicking, the high-quality entrepreneur does not need to post such high market prices that exclude the low type from the regular selling period (i.e., $P_2 \geq q_L$). In particular, we can show when $q_H < 4\Pi^{L*}$, there is no $P_2 \geq q_L$ on the iso-profit curve $\Pi^{LH}(P_1, P_2) = \Pi^{L*}$ (Figure 3)[13]. The following lemma helps us characterize the separating equilibrium.

LEMMA 4. *The pricing pair* $(P_1, P_2) \in \mathbb{Q}'$ *that maximizes* $\Pi^H(P_1, P_2)$ *lies on the intersection of the iso-profit curve of constraint (11) and the feasible region for constraint (12) (shown as the highlighted curve in Figure 3); the optimal pricing pair is unique.*

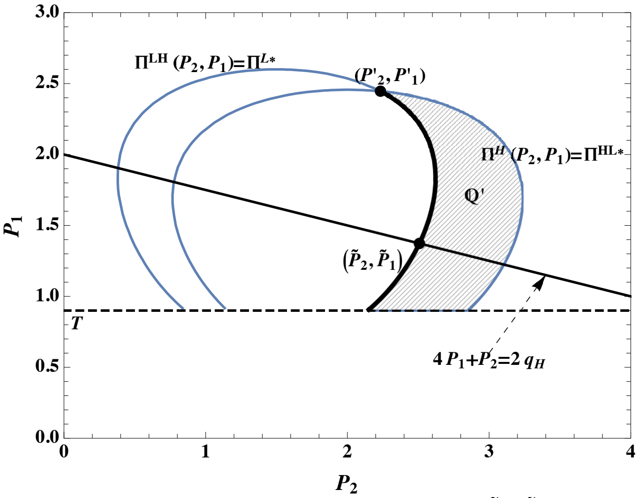
This lemma indicates that the potential separating equilibrium is unique and it satisfies $\Pi^{LH}(P_1, P_2) = \Pi^{L*}$, which guarantees that the low type has no incentive to mimic the high type's pricing strategy. The shaded area in Figure 3 depicts $\mathbb{Q}'$, and the dashed line for T demonstrates how financing target levels affect the feasible region for the separating equilibrium. In particular, when $T > P_1'$,[14] $\mathbb{Q}'$ is empty and, therefore, there is no separating equilibrium.

To characterize the separating equilibrium, we maximize $\Pi^H(P_1, P_2)$ over the feasible region for $\mathbb{Q}'$. The following proposition characterizes the separating equilibrium of the two-price signaling game when the gap in quality levels is small.

[13] We use P_2 as the horizontal axis and P_1 as the vertical axis for expositional purposes; let $\Pi^{ij}(P_2, P_1)$ denote the entrepreneur's profit in all figures, hereafter.

[14] $P_1' > \frac{q_H}{2}$ is the solution for P_1 to $(1 - \frac{P_1}{q_H})(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}$ and $(1 - \frac{P_1}{q_H})(P_1 + (1 - P_2/q_H)P_2) = \Pi^{HL*}$.

Figure 3: Feasible region for the high type entrepreneur when $q_H < 4\Pi^{L*}$



Notes. The equilibrium pricing pair for the high-quality entrepreneur $(\tilde{P}_2, \tilde{P}_1)$, when $q_L = 3$, $q_H = 4$, $\alpha = 0.1$ and $T = 0.9$.

PROPOSITION 2. *A separating equilibrium exists when $T < P'_1$; the refined equilibrium pricing pair for the high-quality entrepreneur is given by (P^H_{1se}, P^H_{2se}), where $P^H_{1se} = \max\{\tilde{P}_1, T\}$*[15] *and $P^H_{2se} > \frac{q_H}{2}$ is the solution for P_2 to $\Pi^{LH}(P^H_{1se}, P_2) = \Pi^{L*}$. The pricing pair for the low-quality type is given by $(P^L_{1se}, P^L_{2se}) = (\max\{\frac{3q_L}{8}, T\}, \frac{q_L}{2})$.*

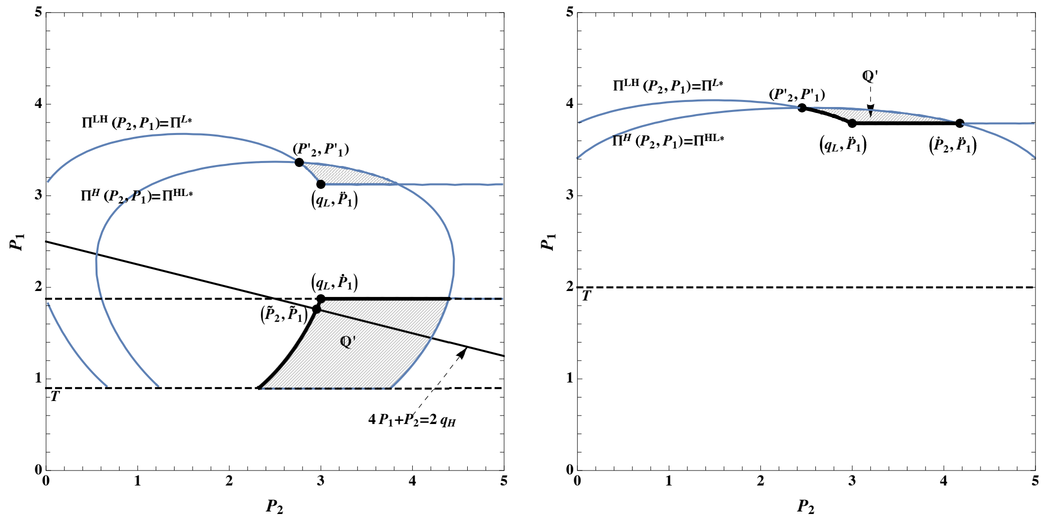
In the proof of proposition 2, we show that in the absence of a financing target level (i.e., $T = 0$), to maximize the high-quality entrepreneur's profit over the feasible region $\mathbb{Q}'$, the optimal pricing pair must satisfy $4P_1 + P_2 = 2q_H$. In other words, the optimal pricing pair lies at the intersection of the characterized curve in Lemma 4 and the line characterized by $4P_1 + P_2 = 2q_H$, which is denoted by $(\tilde{P}_1, \tilde{P}_2)$ in figure 3.

In the presence of a financing target level, as long as $T \leq \tilde{P}_1$, the equilibrium pricing strategy can be characterized by $(\tilde{P}_1, \tilde{P}_2)$, but as the financing target level exceeds $\tilde{P}_1$, the entrepreneur has to increase his funding price to T to finance the project. Unlike the one price signaling case, the entrepreneur might still signal his type by committing to a regular selling price that satisfies $\Pi^{LH}(T, P_2) = \Pi^{L*}$.

Under full information, the optimal price pair for the high-quality type is given by $(\max\{\frac{3q_H}{8}, T\}, \frac{q_H}{2})$. In our example, in Figure 3, under full information the optimal price pair for a high-quality entrepreneur is $(\frac{3}{2}, 2)$. Under asymmetric information, the high-quality entrepreneur reduces his funding price to signal his quality, but this distortion is

[15] $\tilde{P}_1 < \frac{q_H}{2}$ is the solution for P_1 to $4P_1 + P_2 = 2q_H$ and $(1 - \frac{P_1}{q_H})(P_1 + (1 - \frac{P_2}{q_L})P_2) = \Pi^{L*}$ and $\tilde{P}_2$ satisfies $\Pi^{LH}(P^H_{1se}, \tilde{P}_2) = \Pi^{L*}$.

Figure 4: Feasible region for the high type entrepreneur when $q_H \geq 4\Pi^{L*}$



(a) $T \leq \dot{P}_1$ (b) $\dot{P}_1 < T < P_1'$

Notes. The equilibrium pricing pair for the high-quality entrepreneur $(\tilde{P}_2, \tilde{P}_1)$ when $q_L = 3$, $q_H = 5$, $\alpha = 0.1$, $T = 0.9$ for (a) and $(q_L, \ddot{P}_1)$ when $q_L = 3$, $q_H = 5$, $\alpha = 0.1$, $T = 2$ for (b).

not large as he also distorts his regular selling price upwards. As we expect, the additional signaling tool, i.e., the regular selling price, helps the entrepreneur minimize the distortion in his funding price.

ii) Large gaps in quality levels: When the gap in quality levels is relatively large, a low-quality entrepreneur has a stronger incentive to mimic the high-quality one's pricing strategy. Therefore, to reduce the low-quality entrepreneurs' incentive to mimic his pricing strategy, the high-quality entrepreneur might commit to a high price in the regular selling period that drives the low-quality one out of the regular selling period market. In particular, when $q_H \geq 4\Pi^{L*}$, there exists $P_2 \geq q_L$ on the iso-profit curve that satisfies $\Pi^{LH}(P_1, P_2) = \Pi^{L*}$. Let $\dot{P}_1$ and $\ddot{P}_1$ $(\dot{P}_1 < \ddot{P}_1)$ denote the solutions for P_1 to $\Pi^{LH}(P_1, q_L) = \Pi^{L*}$ (Figure 4a). The following proposition characterizes the separating equilibrium in this case.

Proposition 3. *When $T \leq \dot{P}_1$, there exists a unique separating equilibrium that survives the intuitive criterion refinement, and*

$$(P_{1se}^H, P_{2se}^H) = \begin{cases} (\dot{P}_1, q_H/2) & q_H \geq 2q_L, \\ ((T \vee \tilde{P}_1) \wedge \dot{P}_1, \min\{\tilde{P}_2, q_L\}) & 4\Pi^{L*} < q_H < 2q_L. \end{cases} \tag{16}$$

where $\tilde{P}_2$ *is the solution to* $\Pi^{LH}(P^H_{1se}, P_2) = \Pi^{L*}$. *When* $\dot{P}_1 < T < P'_1$ *and* $P'_1 > \ddot{P}_1$, *the separating equilibrium still exists and,*

$$(P^H_{1se}, P^H_{2se}) = \begin{cases} (\max\{T, \ddot{P}_1\}, q_H/2) & q_H \geq 2q_L, \\ (\max\{T, \ddot{P}_1\}, \tilde{P}_2) & 4\Pi^{L*} < q_H < 2q_L. \end{cases} \tag{17}$$

The pricing pair for the low-quality entrepreneur is $(\max\{\frac{3q_L}{8}, T\}, \frac{q_L}{2})$.

Figure 4 demonstrates the feasible regions for the separating equilibrium as a function of the financing target level, T. For relatively small financing target levels (i.e., $T \leq \dot{P}_1$), when the gap in potential quality levels is not very large (i.e., $4\Pi^{L*} \leq q_H < 2q_L$), the funding price is less than $\dot{P}_1$, but as the gap in potential quality levels increases, the funding price increases to $\dot{P}_1$; at the same time the regular selling price increases to q_L, to increase the cost of mimicking for the low-quality entrepreneur.

When the financing target level is relatively high, i.e., $\dot{P}_1 < T < P'_1$, it might be still possible to signal high quality to the market. In particular, when $P'_1 \geq \ddot{P}_1$ (i.e., when feasible region for $\mathbb{Q}'$ is not empty), then the maximum of the financing target level T and $\ddot{P}_1$ characterizes the unique separating equilibrium in the funding period, as it is depicted in Figure 4b.

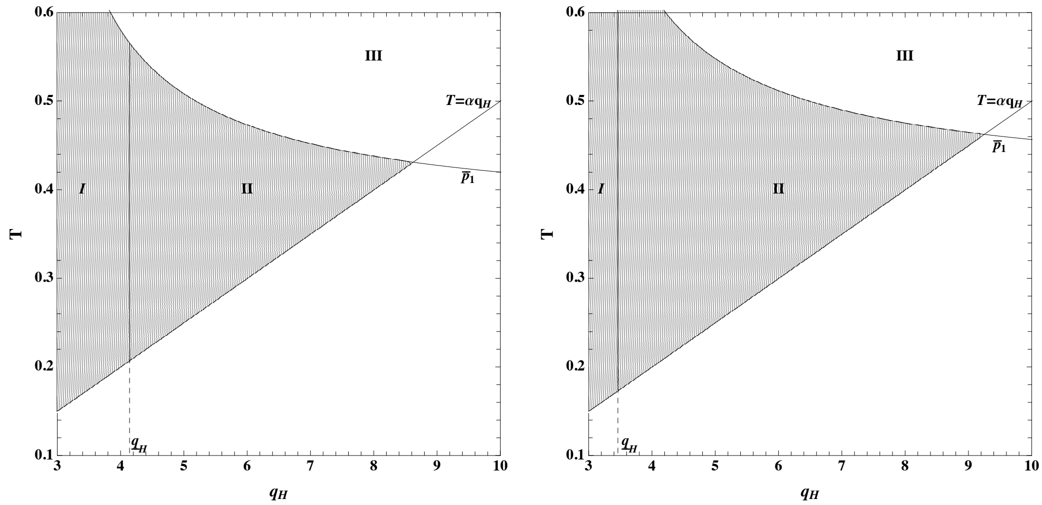
For relatively large gaps in quality levels, i.e., $q_H \geq 2q_L$, the optimal regular selling price for the high-quality entrepreneur is already large enough that it excludes any mimicking low-quality entrepreneurs from the regular market (i.e., $P^H_{2se} = q_H/2 \geq q_L$). In the separating equilibrium, it is enough for the funding price to satisfy $\Pi^{LH}(P_{1se}, q_H/2) = \Pi^{LH}(P_{1se}, q_L) = \Pi^{L*}$.

In Figure 4a, the optimal price pair for the high-quality entrepreneur under full information is given by $(\frac{15}{8}, \frac{5}{2})$. Under asymmetric information, the high-quality entrepreneur has to slightly reduce his funding price while he increases the market price to signal his high quality. In Figure 4b, a high financing target level forces the entrepreneur to deviate from his optimal price pair and increase his funding price, which significantly reduces his chance of running a successful campaign. However, quality signaling through price commitment is still plausible amid high financing target levels.

6. When Is Price Commitment Necessary?

We have established two potential quality signaling mechanisms for a high-quality entrepreneur who needs to get beyond a loyal fanbase to finance his entire project. The

Figure 5: Profit comparison for the high-quality entrepreneur when $T \leq q_L < q_H < T/\alpha$



(a) $q_L = 3$, $b = 0.95$, $\alpha = 0.05$ (b) $q_L = 3$, $b = 0.75$, $\alpha = 0.05$

separating equilibrium with one-price (funding price) signaling mechanism can be quite costly as it requires a drastic reduction in the funding price. The two-price signaling mechanism (commitment to both funding and selling season prices) is costly as it forgoes market signals on consumer taste in setting the regular selling period price. We show that while the gap in potential quality levels and the accuracy of the market signal (i.e., b) drive the relative performance of these mechanisms, the required financing level determines the existence of the separating equilibrium for these signaling mechanisms. First, we characterize the region where both of these signaling mechanisms are viable. The next lemma helps us simplify the exposition.

LEMMA 5. *For one- and two-price signaling we can show $\overline{p}_1 < \dot{P}_1 < P_1'$; thus, the separating equilibria under both mechanisms exist only when $T \leq \overline{p}_1$.*

Lemma 5 indicates that the separating equilibrium under two-price signaling exists for a broader range of financing target levels. In other words, whenever the entrepreneur can signal his quality through his funding price, he can also do so through a price pair, committing to the regular selling period market price (please notice that according to Propositions 2 and 3, $T \leq \dot{P}_1$ is enough to guarantee the existence of a separating equilibrium). This is not surprising given that the entrepreneur has an extra tool (i.e., regular market price) to signal his quality level in two-price signaling. Figure 5 demonstrates this finding; while quality signaling is plausible in regions I, II, and III, region III depicts a region where quality signaling requires commitment to the regular selling price.

Let $\Delta = \pi^H(p^H_{1se}) - \Pi^H(P^H_{1se}, P^H_{2se})$ denote the profit gap between one- and two-price signaling for the high-quality entrepreneur. The following proposition summarizes our findings.

Proposition 4. *We can show the following:*

i) When $b = 1/2$, $\Delta \leq 0$.

ii) When $q_H = q_L$, $\Delta \geq 0$; *for* $q_H \geq 2q_L$, $\Delta \leq 0$, *so there exists at least one* $\underline{q}_H (q_L < \underline{q}_H < 2q_L)$ *such that* $\Delta(\underline{q}_H) = 0$.

Two potential driving forces govern the efficiency of the signaling mechanisms. At the one extreme, when the market signal is uninformative, i.e., $b = 1/2$, Proposition 4 shows that the entrepreneur can signal more efficiently through price commitment; therefore, the high-quality entrepreneur prefers two-price signaling. At the other extreme, when there is no quality gap (i.e., $q_L = q_H$), as expected, one-price dominates two-price signaling. In the absence of any signaling cost, pricing flexibility of one-price signaling is valuable if the market signal is informative. The interplay of asymmetric information on the quality gap and informative market signals on consumer tastes in the selling season, determines the dominant signaling mechanism.

For a small gap in potential quality levels (i.e., $q_H < \underline{q}_H(q_L)$), one-price dominates two-price signaling due to the value of learning from the market signal and pricing flexibility (region I in Figure 5). As the gap in potential quality levels increases, the required downward distortion in the funding price in one-price signaling becomes so drastic that its cost exceeds the cost of commitment to future prices in the regular selling period prior to seeing the market signal. Therefore, two-price signaling dominates one-price signaling (region II in Figure 5). Figure 5 also demonstrates how the accuracy of the market signal affects the preferred signaling mechanism. In particular, we can show that $\underline{q}_H$ increases in b, i.e., the region under which two-price dominates one-price signaling (region II) shrinks as b increases. This is not surprising as the accuracy of the market signal only favors one-price signaling. Part (ii) of Proposition 4 also indicates that when the gap in quality levels exceeds the low-quality level itself (i.e., $q_H \geq 2q_L$), then two-price signaling dominates one-price signaling, independent of the accuracy of the market signal.

So far, we have characterized the high-quality entrepreneur's preference over the one- and two-price signaling mechanisms. We can also answer the question of what is the preferred pricing mechanism for the low-quality entrepreneur. Notice that in a separating equilibrium, the optimal strategy for the low-type entrepreneur is the same as his pricing strategy under full information. Given that under full information there is no signaling cost, the low-quality entrepreneur always prefers one-price signaling, due to the value of the market signal and pricing flexibility that the one-price mechanism provides (part (ii) of Proposition 4, when $q_L = q_H$).

7. Concluding Remarks

In this paper, we investigate whether entrepreneurs with high-quality products can signal their quality through pricing decisions in reward-based crowdfunding. In particular, we study two separate pricing mechanisms: One- and two-price signaling mechanisms. We characterize a threshold on financing target levels that allow a high-quality entrepreneur to signal his quality by charging a low price in the funding period (i.e., one-price signaling). This finding contrasts existing literature results on quality signaling in advance selling, which establishes that first period price cannot serve as a credible quality signaling tool (Chen and Jiang 2020). In crowdfunding setting, by reducing his price in the funding period (first period, in this setting), a high-quality entrepreneur increases the chance of surviving the funding period to reach the regular selling season (second period), a concern the advance selling model does not have (both periods will occur), as he expects high returns in the regular selling period due to his high quality. A low-quality entrepreneur is more interested in selling in the funding period before his quality level gets revealed to the market.

Since it may be costly for a high-quality entrepreneur to reduce his price in the funding period to signal his quality level, we propose an additional price commitment in the selling season to reduce the needed distortion in the funding price (i.e., two-price signaling). We show that whenever one-price signaling is possible, two-price signaling is also plausible; therefore, the following question arises: When is the selling season price commitment more efficient for the high-quality entrepreneur?

When both of the mechanisms are plausible, the gap in potential quality level and the accuracy of the market signal influence their relative performance. When the potential quality gap is small, the signaling cost due to price distortion is small, so one-price dominates two-price signaling. As the gap in quality levels increases or the accuracy of the market signal decreases, two-price signaling becomes preferable as signaling cost dominates the value of learning of consumer tastes and pricing flexibility. Supporting price commitment on crowdfunding platforms makes crowdfunding more attractive to high-quality entrepreneurs with high financing needs.

Further, we would like to highlight a couple of potential avenues for future research. In the current work, we overlook the potential strategic behavior of customers in the funding period, i.e., some customers may defer their purchase in the hope of lower prices in the regular selling period after a successful crowdfunding campaign, and it will be interesting to model and understand the effect of such behavior on crowdfunding design. Similarly, it would be interesting to investigate how an entrepreneur can use his crowdfunding campaign design as a marketing research tool to uncover potential market size or valuation of customers in the regular selling period.

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Appendix A:

A.1. Proofs of Main Results

Proof of Lemma 1 The expected payoff in the regular selling period given $s = G$ is

$$\pi_2(p_2) = \begin{cases} 2b(1-p_2/q)p_2 & q/2 \le p_2 \le q, \\ bp_2 + 2(1-b)(1/2 - p_2/q)p_2 & 0 < p_2 < q/2. \end{cases} \tag{A.1}$$

When $q/2 \le p_2 \le q$, the optimal price $p_2 = q/2$ and the optimal profit is $\frac{bq}{2}$; when $0 < p_2 < q/2$, the optimal $p_2 = \min\{\frac{q}{4-4b}, q/2\}$. As we assume $1/2 < b \le 1$, $\frac{q}{4-4b} > q/2$, thus the optimal $p_2 = q/2$ and the expected profit is $bq/2$. The expected payoff in regular selling period given $s = L$ is

$$\pi_2(p_2) = \begin{cases} 2(1-b)(1-p_2/q)p_2 & q/2 \le p_2 \le q, \\ (1-b)p_2 + 2b(1/2 - p_2/q)p_2 & 0 < p_2 < q/2. \end{cases} \tag{A.2}$$

When $q/2 \le p_2 \le q$, the optimal price $p_2 = q/2$ and the optimal profit is $\frac{(1-b)q}{2}$; when $0 < p_2 < q/2$, the optimal $p_2 = \min\{\frac{q}{4b}, q/2\}$. Since we assume $1/2 < b \le 1$, $\frac{q}{4b} < q/2$, thus the optimal $p_2 = \frac{q}{4b}$ and the expected profit is $\frac{q}{8b}$. As $\frac{q}{8b} > \frac{(1-b)q}{2}$ when $1/2 < b < 1$, the fund-raiser sets $p_2 = \frac{q}{4b}$, and the expected profit is $\frac{q}{8b}$.

Thus the expected payoff from the regular selling period is

$$\pi_2 = \frac{1}{2}\frac{bq}{2} + \frac{1}{2}\frac{q}{8b} = \frac{q}{4}(b + \frac{1}{4b}) \ge \frac{q}{4},$$

where $\frac{q}{4}$ is the expected profit with $\theta_2 \sim U[0,1]$. □

Proof of Lemma 2 When $T > \alpha q$, the optimal funding price is easy to get by optimizing (3) under the constraint of T.

When $T \le \alpha q$, it is straight forward to show that when $T \le p_1 < T/\alpha$ (charging low price), the local optimal funding price is $(T \vee \frac{q-\pi_2}{2}) \wedge \left(\frac{T}{\alpha}\right)^-$ and when $T/\alpha \le p_1 \le q$ (charging high price), the local optimal funding price is $(T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q$. When $T \ge \frac{q-\pi_2}{2}$, the local optimal funding price in the case of charging low prices is $p_1 = T$, which is dominated by the local optimal high price scenario, as

$$\pi(T) = (1 - \frac{T}{q})(T + \pi_2) < T + (1-\alpha)(1 - \frac{T}{\alpha q})\frac{T}{\alpha} + \pi_2 = \pi(T/\alpha) \le \pi((T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q).$$

When $T/\alpha \le \frac{q-\pi_2}{2}$, the local optimal funding price in the case of charging low prices is $p_1 \to \left(\frac{T}{\alpha}\right)^-$, which is dominated by the local optimal high price scenario, i.e., $\lim_{p_1 \to \left(\frac{T}{\alpha}\right)^-} \pi(p_1) < \pi((T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q)$, because

$$\begin{aligned} (1 - \frac{T}{\alpha q})(T/\alpha + \pi_2) &= (1-\alpha)(1 - \frac{T}{\alpha q})\frac{T}{\alpha} + \alpha(1 - \frac{T}{\alpha q})\frac{T}{\alpha} + (1 - \frac{T}{\alpha q})\pi_2 \\ &< T + (1-\alpha)(1 - \frac{T}{\alpha q})\frac{T}{\alpha} + \pi_2 = \pi(T/\alpha) \le \pi((T/\alpha \vee \frac{q}{2(1-\alpha)}) \wedge q) \end{aligned}$$

When $T \le \frac{q-\pi_2}{2} < T/\alpha$, the local optimal funding price in the case of charging low prices is $p_1 = \frac{q-\pi_2}{2}$. If the financing target level is low enough, i.e., $T/\alpha < \frac{q}{2(1-\alpha)}$, the local optimal funding price in the case of charging high price is $\frac{q}{2(1-\alpha)}$ or q. We can show that

$$\pi(\frac{q}{2(1-\alpha)}) = \frac{q}{4(1-\alpha)} + \pi_2 > \frac{(q+\pi_2)^2}{4q} = \pi(\frac{q-\pi_2}{2})$$

the inequality holds because $\frac{q}{4(1-\alpha)} + \pi_2 - \frac{(q+\pi_2)^2}{4q}$ increases in π_2 when $\frac{q}{4} \le \pi_2 \le \frac{5q}{16}$ and $\frac{q}{4(1-\alpha)} > q/4$.

$$\pi(q) = \alpha q + \pi_2 > \frac{(q+\pi_2)^2}{4q} = \pi(\frac{q-\pi_2}{2}),$$

the inequality holds because $\frac{q}{4} \le \pi_2 \le \frac{5q}{16}$ and $\frac{q}{2(1-\alpha)} > q$ (i.e., $\alpha > \frac{1}{2}$).

When $T/\alpha \ge \frac{q}{2(1-\alpha)}$, the local optimal funding price in the case of charging high price is $\frac{T}{\alpha}$, therefore, the entrepreneur charges the optimal low price in the funding period only if $\pi(\frac{q-\pi_2}{2}) > \pi(\frac{T}{\alpha})$, which is equivalent to $T > \overline{T}$ as $\pi(\frac{q-\pi_2}{2}) - \pi(\frac{T}{\alpha})$ increases in T when $T \ge \frac{\alpha q}{2(1-\alpha)} > \frac{\alpha(q-\pi_2)}{2}$. If $\alpha q > \frac{q-\pi_2}{2}$, we have $\pi(\frac{q-\pi_2}{2}) < \pi(\frac{T}{\alpha})$ when $T = \frac{q-\pi_2}{2}$, thus we need $\alpha q \le \frac{q-\pi_2}{2}$. Therefore, the condition is $\overline{T} < T \le \alpha q$ and $\alpha \le \frac{q-\pi_2}{2q}$ for $p_1^* = \frac{q-\pi_2}{2}$.
□

Proof of Lemma 3 We first prove the lemma when $T \le p_1^{HL*}$. In this case, $\pi^{HL*} = \pi^{HL}(p_1^{HL*})$ and $\pi^{L*} = \pi^L(p_1^{L*})$. From the definitions of $\pi^{LH}(p_1)$, p_1^{LH*} and π^{L*}, it is straightforward to see $\pi^{LH}(p_1^{LH*}) > \pi^{LH}(p_1^{L*}) > \pi^L(p_1^{L*})$. Given that $\pi^{LH}(p_1)$ is concave, there exists a unique $\overline{p}_1 < p_1^{LH*}$ that satisfies $\pi^{LH}(\overline{p}_1) = \pi^{L*}$, and a unique $\overline{p}_1' > p_1^{LH*}$ that satisfies $\pi^{LH}(\overline{p}_1') = \pi^{L*}$. A similar argument shows that there exist $\underline{p}_1 < p_1^{H*} < \underline{p}_1'$ that satisfy $\pi^{HL*} = \pi^H(\underline{p}_1) = \pi^H(\underline{p}_1')$.

In what follows, we show $\overline{p}_1 > \underline{p}_1$ by contradiction; $\overline{p}_1' > \underline{p}_1'$ can be shown similarly. Suppose $\overline{p}_1 \le \underline{p}_1$, then we have,

$$\begin{aligned}
\pi^H(\underline{p}_1) - \pi^{LH}(\overline{p}_1) &= (1 - \frac{\underline{p}_1}{q_H})(\underline{p}_1 + \pi_2^H) - (1 - \frac{\overline{p}_1}{q_H})(\overline{p}_1 + \pi_2^L) \\
&= \int_{\underline{p}_1/q_H}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1 - \int_{\overline{p}_1/q_H}^{\underline{p}_1/q_H} \left[2\theta_1 q_H - (q_H - \pi_2^L)\right] f(\theta_1)\, d\theta_1 \\
&> \int_{\underline{p}_1/q_H}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1.
\end{aligned}$$

The inequality holds because $\overline{p}_1 \le \underline{p}_1$ and $\underline{p}_1/q_H < p_1^{LH*}/q_H = \frac{q_H - \pi_2^L}{2q_H}$. Further, we can obtain

$$\begin{aligned}
\pi^{HL}(p_1^{HL*}) - \pi^L(p_1^{L*}) &= (1 - \frac{p_1^{HL*}}{q_L})(p_1^{HL*} + \pi_2^H) - (1 - \frac{p_1^{L*}}{q_L})(p_1^{L*} + \pi_2^L) \\
&= \int_{p_1^{HL*}/q_L}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1 + \int_{p_1^{HL*}/q_L}^{p_1^{L*}/q_L} \left[2\theta_1 q_L - (q_L - \pi_2^L)\right] f(\theta_1)\, d\theta_1 \\
&< \int_{p_1^{HL*}/q_L}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1. \qquad (A.3)
\end{aligned}$$

The inequality holds since $p_1^{L*}/q_L > p_1^{HL*}/q_L$ and $p_1^{L*}/q_L = \frac{q_L - \pi_2^L}{2q_L}$.

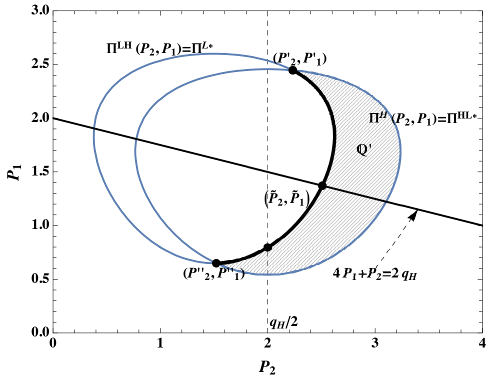
Notice that $\int_{\underline{p}_1/q_H}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1 > \int_{p_1^{HL*}/q_L}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1$, since $\underline{p}_1 < p_1^{HL*}$. Consequently, the above two inequalities lead to $\pi^{HL}(p_1^{HL*}) - \pi^L(p_1^{L*}) < \pi^H(\underline{p}_1) - \pi^{LH}(\overline{p}_1)$, which contradicts the definitions that $\pi^H(\underline{p}_1) = \pi^{HL}(p_1^{HL*})$ and $\pi^{LH}(\overline{p}_1) = \pi^L(p_1^{L*})$. Hence, we must have $\overline{p}_1 > \underline{p}_1$.

Next, we prove the lemma for $T \ge p_1^{L*}$. In this case $\pi^{HL*} = \pi^{HL}(T)$ and $\pi^{L*} = \pi^L(T)$. The proof follows the same way as the previous case except that (A.3) changes to

$$\begin{aligned}
\pi^{HL}(T) - \pi^L(T) &= (1 - \frac{T}{q_L})(T + \pi_2^H) - (1 - \frac{T}{q_L})(T + \pi_2^L) \\
&= \int_{T/q_L}^1 (\pi_2^H - \pi_2^L) f(\theta_1)\, d\theta_1.
\end{aligned}$$

Thus, we can establish the contradiction. When $p_1^{LH*} < T < p_1^{L*}$, the proof is the same, thus omitted. □

Figure A.1: Price pair in $\mathbb{Q}'$ maximizing $\Pi^H(P_1, P_2)$



Proof of Proposition 1 From Lemma 3, it is clear that if customers hold a belief as

$$j(p_1) = \begin{cases} H & \text{if } p_1 = \overline{p}_1, \\ L & \text{otherwise,} \end{cases}$$

where $\overline{p}_1$ is defined as in Lemma 3, then the entrepreneur's funding price is given by

$$p_1^{i*} = \begin{cases} \overline{p}_1 & \text{if } i = H, \\ p_1^{L*} & \text{if } i = L. \end{cases}$$

That is, under this consumer belief, when the entrepreneur is of low quality, he sets the fund-raising price at p_1^{L*} and has no incentive to set his price at $\overline{p}_1$ to mimic the high-quality entrepreneur's strategy; the entrepreneur also has no incentive to deviate from $\overline{p}_1$ if he is of high quality. The customers' belief is consistent with the entrepreneur's pricing strategies. Thus, a separating equilibrium exists and we can show that this is the unique equilibrium that survives the intuitive criterion in Appendix B.2. □

Proof of Lemma 4 Based on the formulation of $\mathbb{Q}'$ without campaign success threshold T by Lemma A.1 in subsection A.2, $(P_1, P_2) \in \mathbb{Q}'$ with $P_2 \geq q_H/2$ is dominated by the (P_1, P_2) on $(1 - P_1/q_H)(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}$, and $(P_1, P_2) \in \mathbb{Q}'$ with $P_2 < q_H/2$ is dominated by the Point $(P_1, q_H/2)$ on $(1 - P_1/q_H)(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}$. We are maximizing

$$\Pi^H(P_1, P_2) = (1 - P1/q_H)(P_1 + (1 - P_2/q_H)P_2), \tag{A.4}$$

with the constraint $(1 - P_1/q_H)(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}$, $\frac{q_H}{2} \leq P_2 \leq P_2'$. We have $\frac{\partial P_2}{\partial P_1} = \frac{-q_H q_L + P_2 q_L + 2P_1 q_L - P_2^2}{(P_1 - q_H)(2P_2 - q_L)}$, and

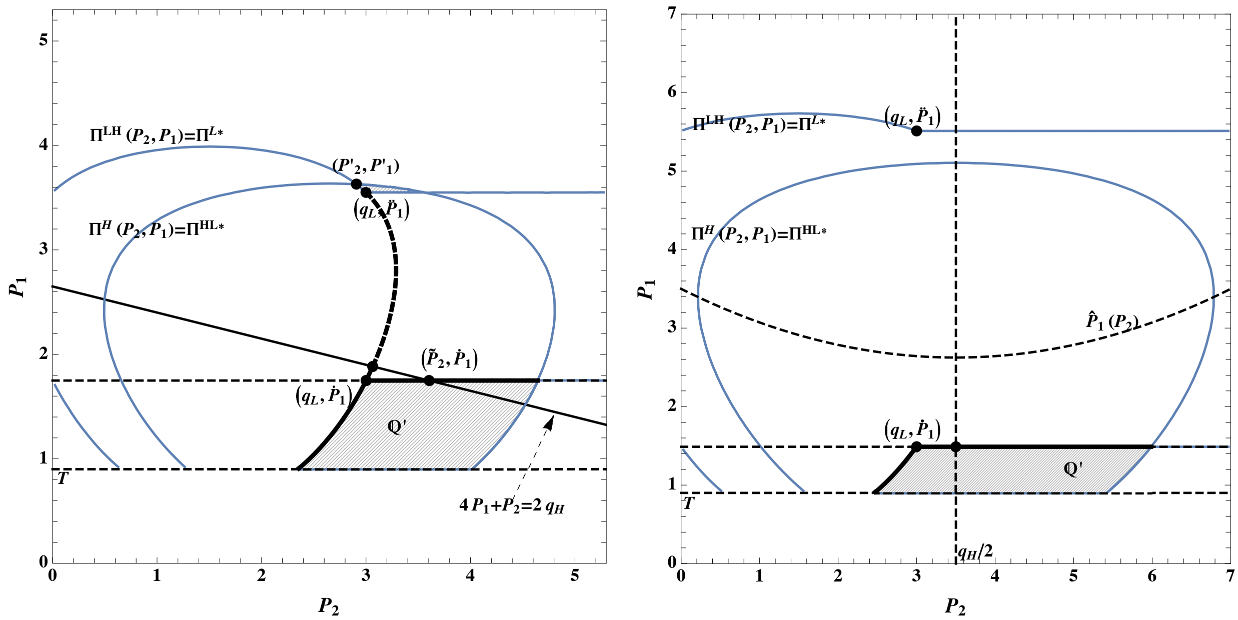
$$\frac{\partial \Pi^H(P_1, P_2)}{\partial P_1} = \frac{-(P_1 + (1 - P_2/q_H)P_2)}{q_H} + (1 - P_1/q_H)(1 + (1 - 2P_2/q_H)\frac{\partial P_2}{\partial P_1}) = \frac{-P_2\,(q_H - q_L)\,(4P_1 + P_2 - 2q_H)}{q_H^2\,(2P_2 - q_L)}. \tag{A.5}$$

When $4P_1 + P_2 - 2q_H = 0$, $\frac{\partial \Pi^H(P_1, P_2)}{\partial P_1} = 0$. Then we can get the optimal pair (P_1, P_2) by solving

$$4P_1 + P_2 - 2q_H = 0 \; \textit{and} \; (1 - P_1/q_H)(P_1 + (1 - P_2/q_L)P_2) = \Pi^{L*}, \tag{A.6}$$

simultaneously, and there are two solutions, one maximal pair and one minimal pair. As $\Pi^H(P_1', P_2') = \Pi^H(P_1'', P_2'') = \Pi^{HL*}$, there is only one optimal point on the iso-profit curve between (P_1', P_2') and (P_1'', P_2'') inside the iso-profit curve $\Pi^H(P_1, P_2) = \Pi^{HL*}$. Based on Equ (A.5), $\Pi^H(P_1, P_2)$ first increases then decreases when P_1 changes from P_1'' to P_1' (from low to high), thus $\tilde{P}_1$ is the maximal one as shown in Figure A.1. □

Figure A.2: Feasible range of separating equilibrium with Large gaps in potential quality level



(a) $q_L < q_H \leq 2q_L$ (b) $q_H > 2q_L$

Notes. $q_L = 3$, $q_H = 4$, $T = 0.9$ for (a) and $q_L = 3$, $q_H = 7$, $T = 0.9$ for (b).

Proof of Proposition 2 Based on Lemma 4, it is clear that if the consumers hold a belief as

$$j(P_1, P_2) = \begin{cases} H & \text{if } (P_1, P_2) = (P_{1se}^H, P_{2se}^H), \\ L & \textit{otherwise}, \end{cases}$$

where (P_{1se}^H, P_{2se}^H) is as shown in the proposition, then the fund-raiser's pricing strategy follows

$$(P_{1se}, P_{2se}) = \begin{cases} (P_{1se}^H, P_{2se}^H) & \text{if } i = H, \\ (P_1^{L*}, P_2^{L*}) & \text{if } i = L, \end{cases}$$

The consumer belief is consistent with the fund-raisers strategies. Thus, a separating equilibrium exists. It is the unique separating equilibrium survived with intuitive criterion as it is the one that maximizes $\Pi^H(P_1, P_2)$ with $(P_1, P_2) \in \mathbb{Q}'$, as Lemma 4 shows. □

Proof of Proposition 3 Same as proof of Proposition 2, the consumer belief is consistent with the fund-raisers strategies as $(P_{1se}^H, P_{2se}^H) \in \mathbb{Q}'$. Then we show it is the unique one that survives the intuitive criterion when $0 < T \leq \dot{P}_1$ and $\dot{P}_1 < T < P_1'$ respectively. Before we analyze these two cases, we characterize the property of $\Pi^H(P_1, P_2)$ first. Let $\hat{P}_1(P_2) = \frac{P_2^2 - q_H P_2 + q_H^2}{2q_H}$, and for a given P_2, we have $\Pi^H(P_1)$ increases in $[0, \hat{P}_1(P_2)]$ and decrease in $[\hat{P}_1(P_2), q_H]$. So region of (P_1, P_2) with $P_1 \geq q_H/2$ is always dominated by the region of (P_1, P_2) with $P_1 < q_H/2$

i) When $T \leq \dot{P}_1$, we show the feasible range in Figure A.2.

a) $q_L < q_H < 2q_L$. If $\tilde{P}_2 \leq q_L$, then it is the same as the proof in Lemma 4 and Proposition 2. If $\tilde{P}_2 > q_L$ (Figure A.2a), then $\tilde{P}_1 > \dot{P}_1$, and $(\dot{P}_1, q_L)$ is the optimal pricing pair, as $\Pi(P_1, P_2)$ increases in $P_1 \in [0, \dot{P}_1]$ and decreases in $P_2 \in [q_L, q_H]$.

b) $q_H \geq 2q_L$. We have $q_H/2 > q_L$ and $\dot{P}_1 < \hat{P}_1(q_H/2)$, so $\Pi^H(P_1)$ increase in $[0, \dot{P}_1]$ for $P_2 = q_H/2$. Therefore, $(P^H_{1se}, P^H_{2se}) = (\dot{P}_1, q_H/2)$ is the refined separating equilibrium (Figure A.2b), as it maximizes $\Pi^H(P_1, P_2)$.

ii) When $\dot{P}_1 < T < P'_1$, the feasible range $\mathbb{Q}'$ exists if and only if $P'_1 > \ddot{P}_1$, and the separating equilibrium follows the same logic as $T \leq \dot{P}_1$. □

Proof of Lemma 5 When $T \leq q_L < q_H < T/\alpha$, $\overline{p}_1$ is the smaller solution to $\pi^{LH}(p_1) = \pi^{L*}$, and $\dot{P}_1$ is the smaller solution to $\Pi^{LH}(P_1, q_L) = \Pi^{L*}$, i.e.,

$$(1 - \frac{\overline{p}_1}{q_H})(\overline{p}_1 + \pi^L_2) = \frac{(q_L + \pi^L_2)^2}{4q_L}, \ \textit{and} \ (1 - \frac{\dot{P}_1}{q_H})\dot{P}_1 = \frac{25q_L}{64},$$

with $\pi^L_2 \geq \frac{q_L}{4}$. When $\pi^L_2 = \frac{q_L}{4}$, the right hand side of the above two equations are the same, and we have $\dot{P}_1 > \overline{p}_1$ as $(1 - \frac{x}{q_H})x$ increases in $x \in [0, \frac{q_H}{2}]$. As

$$\frac{d\overline{p}_1}{d\pi^L_2} = \frac{1}{2}\left(\frac{(q_H - q_L)\pi^L_2}{\sqrt{q_L(q_H - q_L)(q_H q_L - (\pi^L_2)^2)}} - 1\right) < 0,$$

we have $\overline{p}_1 < \dot{P}_1 < \frac{q_H}{2} < P'_1$ for $\pi^L_2 \geq \frac{q_L}{4}$. □

Proof of Proposition 4 i) When $b = \frac{1}{2}$, $\pi^i_2 = \frac{q_i}{4}$, and $\Pi^{L*} = \pi^{L*}$, $\Pi^{HL*} = \pi^{HL*}$. As p^H_{1se} is the separating equilibrium price in one-price signaling, it satisfies

$$\pi^{L*} \geq \pi^{LH}(p^H_{1se}), \ \pi^{HL*} \leq \pi^H(p^H_{1se}).$$

Let $P_1 = p^H_{1se}$ and $P_2 = \frac{q_H}{2}$, then the pricing pair also satisfies

$$\Pi^{L*} \geq \Pi^{LH}(p^H_{1se}, \frac{q_H}{2}), \ \Pi^{HL*} \leq \Pi^H(p^H_{1se}, \frac{q_H}{2}).$$

Thus we have

$$\Pi^H(P^H_{1se}, P^H_{2se}) \geq \Pi^H(p^H_{1se}, \frac{q_H}{2}) = \pi^H(p^H_{1se}).$$

As (P^H_{1se}, P^H_{2se}) is the pricing pair survives the intuitive criterion and maximize $\Pi^H(P_1, P_2)$ in the feasible range, and we have $\overline{p}_1 < \dot{P}_1 < P'_1$ from Lemma 5.

ii) When $q_H = q_L$, $\tilde{P}_1 = \frac{3q_L}{8}$, $\tilde{P}_2 = \frac{q_L}{2}$, so

$$\Pi^H(P^H_{1se}, P^H_{2se}) \leq \Pi^H(\tilde{P}_1, \tilde{P}_2) = \pi^H(p^H_{1se})|_{b=\frac{1}{2}} \leq \pi^H(p^H_{1se}),$$

When $q_H = 2q_L$, $P^H_{1se} = \dot{P}_1$, $P^H_{2se} = q_L$, so

$$\pi^H(p^H_{1se}) \leq \pi^H(p^H_{1se})|_{b=1} = \frac{(626 + 5\sqrt{487})q_L}{1024} < \Pi^H(P^H_{1se}, P^H_{2se}) = \frac{(41 + 2\sqrt{14})q_L}{64}.$$

When $q_H > 2q_L$, $P^H_{1se} = \dot{P}_1$, $P^H_{2se} = q_H/2 > q_L$, and the result holds as $(1 - \frac{P_{2se}}{q_H})P_{2se}$ increases in q_H. □

A.2. The Feasible Range for the High Quality Entrepreneur in Two-Price Signaling

LEMMA A.1. *i)* $q_H < 4\Pi_L^*$. *The two iso-profit curves* $\mathcal{H}: \Pi^H(P_1, P_2) = \Pi^{HL*}$ *and* $\mathcal{G}: \Pi^{LH}(P_1, P_2) = \Pi^{L*}$ *cross once within* $P_2 < \frac{q_H}{2}$ *and* $P_2 \geq \frac{q_H}{2}$*, respectively, and when they cross,* $\mathcal{H}$ *crosses* $\mathcal{G}$ *from the above. The feasible range* $\mathbb{Q}'$ *is the area between these two intersection points, inside* $\mathcal{H}$ *and outside* $\mathcal{G}$*, as shown in Figure A.3a.*

ii) $q_H \geq 4\Pi_L^*$. *When* $P_2 \geq q_L$*, the iso-profit* $\mathcal{G}$ *crosses* $\mathcal{H}$ *from below; the properties of these two curves when* $P_2 < q_L$ *is the same as case i). The feasible range* $\mathbb{Q}'$ *is the area between these intersection points, inside* $\mathcal{H}$ *and outside* $\mathcal{G}$*, as shown in Figure A.3b.*

Proof of Lemma A.1

First, we show the single crossing property for $\mathcal{H}$ and $\mathcal{G}$ when $q_H < 4\Pi_L^*$. Let

$$F(x,y,z) = (1 - \frac{x}{q_H})[x + (1 - \frac{y}{z})y] - \frac{(z+4q_L)^2}{64q_L}, 0 \leq x \leq \frac{y^2 + q_H z - yz}{2z},$$

then $F(P_1, P_2, q_L) = 0$ is the iso-profit curve $\mathcal{G}$ and $F(P_1, P_2, q_H) = 0$ is the iso-profit curve $\mathcal{H}$. We have the partial derivative of x to y as

$$\frac{\partial x}{\partial y} = -\frac{F_y}{F_x} = \frac{(q_H - x)(2y - z)}{y^2 + (q_H - 2x)z - yz},$$

in which $q_H - x > 0$ and $y^2 + (q_H - 2x)z - yz > 0$, thus we have $\frac{\partial x}{\partial y} < 0$, i.e., x decreases in y when $y < \frac{z}{2}$; $\frac{\partial x}{\partial y} \geq 0$, i.e., x increases in y when $y \geq \frac{z}{2}$. Thus $y = \frac{z}{2}$ is the lowest point of $F(x,y,z) = 0$.

We show $F(x, y, q_L) = 0$ and $F(x, y, q_H) = 0$ cross once when $0 \leq x \leq \frac{y^2 + q_H z - yz}{2z}$ by contradiction. Assume that the two curves cross at two distinct points (x_1, y_1) and (x_2, y_2) with $y_1 < y_2$. By definition of the function, we get

$$(1 - \frac{x_1}{q_H})[x_1 + (1 - \frac{y_1}{q_L})y_1] = (1 - \frac{x_2}{q_H})[x_2 + (1 - \frac{y_2}{q_L})y_2] = \frac{25q_L}{64}, \tag{A.7}$$

$$(1 - \frac{x_1}{q_H})[x_1 + (1 - \frac{y_1}{q_H})y_1] = (1 - \frac{x_2}{q_H})[x_2 + (1 - \frac{y_2}{q_H})y_2] = \frac{(q_H + 4q_L)^2}{64q_L}. \tag{A.8}$$

subtracting (A.8) from (A.7), we get

$$(1 - \frac{x_1}{q_H})y_1^2 = (1 - \frac{x_2}{q_H})y_2^2$$

Let $f(x,y) = (1 - \frac{x}{q_H})y^2$; we have,

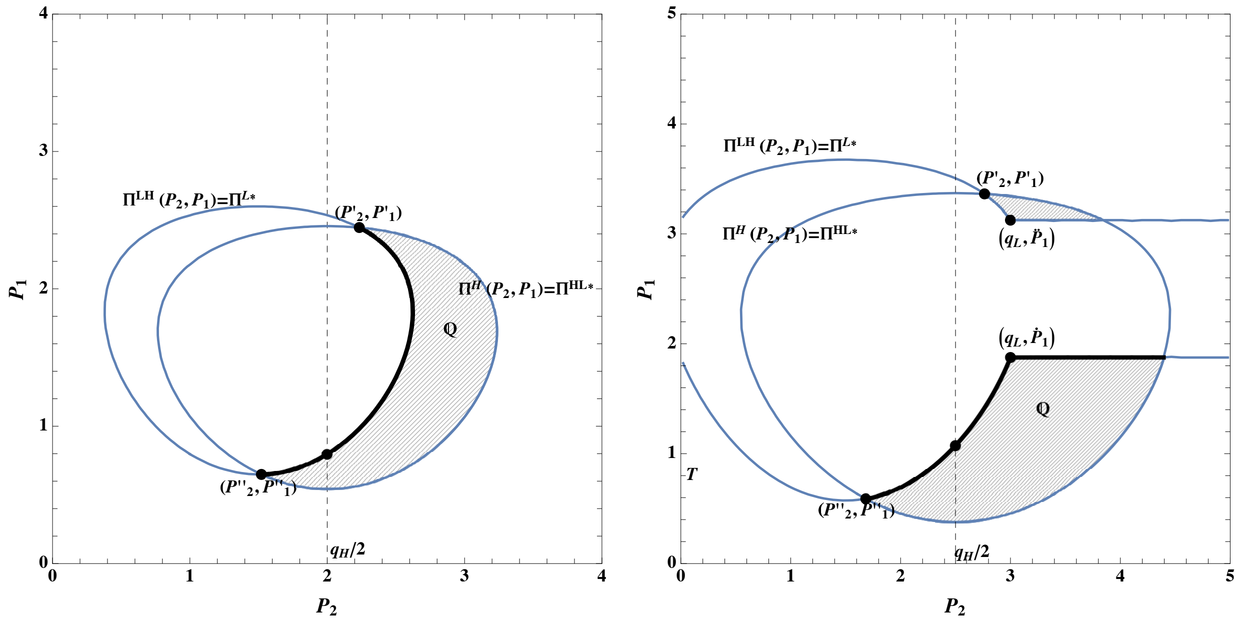
$$\frac{\partial f}{\partial y} = (1 - \frac{x}{q_H})2y + (-\frac{1}{q_H}\frac{\partial x}{\partial y})y^2.$$

As (x_1, y_1) and (x_2, y_2) both are on the curve $F(x, y, q_H) = 0$, $\frac{\partial x}{\partial y} = \frac{(q_H - x)(2y - q_H)}{y^2 + (q_H - 2x)q_H - yq_H}$, so

$$\frac{\partial f}{\partial y} = (1 - \frac{x}{q_H})y\frac{(2q_H - 4x - y)q_H}{y^2 + (q_H - 2x)q_H - yq_H} > 0,$$

as $2q_H - 4x - y \geq 0$ (when $z = 2y$, $y^2 + (q_H - 2x)z - yz = (2q_H - 4x - y)y \geq 0$). $\frac{\partial f}{\partial y} > 0$ implies that $f(x,y)$ monotonically increases in y. We immediately have $y_1 = y_2$ and $x_1 = x_2$ (there is a one-to-one correspondence between x and y in $F(x, y, q_H) = 0$ when $0 \leq x \leq \frac{y^2 + q_H z - yz}{2z}$). However, this contradicts the assumption that (x_1, y_1) and (x_2, y_2) are two distinct points, thus $F(x, y, q_H) = 0$ and $F(x, y, q_L) = 0$ intersect at most once when $0 \leq x \leq \frac{y^2 + q_H z - yz}{2z}$.

Figure A.3: Property of Two Iso-Profit Curves



(a) $q_H < 4\Pi_L^*$ (b) $q_H \geq 4\Pi_L^*$

Notes. $q_L = 3$ *and* $q_H = 4$ *for (a),* $q_H = 5$ *for (b)*

Similarly, we can show that $F(x, y, q_H) = 0$ and $F(x, y, q_L) = 0$ intersect at most once when $\frac{y^2 + q_H z - yz}{2z} \leq x \leq q_H$. $F(x, y, q_H) = 0$ and $F(x, y, q_L) = 0$ intersect exactly two times when $q_H < 4q_L$, so they intersect exactly once when $0 \leq x \leq \frac{y^2 + q_H z - yz}{2z}$ and once when $\frac{y^2 + q_H z - yz}{2z} \leq x \leq q_H$.

Let (x_1, y_1) be the intersection point. We have

$$\left.\frac{\partial x}{\partial y}\right|_{z=q_H} - \left.\frac{\partial x}{\partial y}\right|_{z=q_L} = \frac{-(q_H - q_L)(q_H - x_1)(2q_H - 4x_1 - y_1)y_1}{(q_H^2 + y_1^2 - q_H(2x_1 + y_1))(q_H q_L + y_1^2 - q_L(2x_1 + y_1))} \leq 0. \quad \text{(A.9)}$$

We show the intersection point (x_1, y_1) satisfies $y_1 \leq \frac{q_H}{2}$, by contradiction. Assume $y_1 > \frac{q_H}{2}$, then x increases in y when $y > \frac{q_H}{2}$ for both $F(x, y, q_H) = 0$ and $F(x, y, q_L) = 0$. When $y = \frac{q_H}{2}$, x that satisfies $F(x, y, q_H) = 0$ is the same as the x in $F(x, y, q_L) = 0$, so when $F(x, y, q_H) = 0$ and $F(x, y, q_L) = 0$ cross, $\left.\frac{\partial x}{\partial y}\right|_{z=q_H}$ should be greater than $\left.\frac{\partial x}{\partial y}\right|_{z=q_L}$, which contradicts (A.9). So when they cross, intersection point (x_1, y_1) satisfies $y_1 \leq \frac{q_H}{2}$, and iso-profit curve $F(x, y, q_H) = 0$ crosses $F(x, y, q_L) = 0$ from the above.

For any given P_2, $\Pi^{LH}(P_1, P_2)$ increases in P_1 for $P_1 < \frac{P_2^2 - P_2 q_L + q_H q_L}{2q_L}$ and decreases in P_1 for $P_1 \geq \frac{P_2^2 - P_2 q_L + q_H q_L}{2q_L}$, thus the area satisfying constraint $\Pi^{LH}(P_1, P_2) \leq \Pi^{L*}$ is outside of the iso-profit curve $\Pi^{LH}(P_1, P_2) = \Pi^{L*}$. Similarly, the area satisfying constraint $\Pi^{H}(P_1, P_2) \geq \Pi^{HL*}$ is inside the iso-profit curve $\Pi^{H}(P_1, P_2) = \Pi^{HL*}$. Based on the single-crossing property, the feasible range $\mathbb{Q}'$ lies between these two intersection points (P_1', P_2') and (P_1'', P_2'').

When $q_H \geq 4\Pi_L^*$, the properties of these two iso-profit curves with $P_2 < q_L$ is the same as the previous case. When $P_2 \geq q_L$, $\Pi^L(P_1^{L*}, P_2^{L*}) = \Pi^{LH}(P_1, P_2)$ is a line parallel to the P_2 axis and it is straightforward to establish that the feasible range $\mathbb{Q}'$ is the one(s) between the intersect points as Figure A.3b shows.