Transportation Research Part E 172 (2023) 103011

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

Crowdfunding or traditional mode? Strategy choices in product selling

Shengshuo Xu [a], Liuyi Ling [b,*], Shaofu Du [b], Lindong Liu [a]

[a] International Institute of Finance, School of Management, University of Science and Technology of China, Hefei 230026, China
[b] School of Management, University of Science and Technology of China, Hefei 230026, China

ARTICLE INFO

Keywords:
OR in marketing
Crowdfunding
Traditional selling
Opportunity cost

ABSTRACT

This study examines two selling strategies, namely, crowdfunding and traditional selling. Under traditional selling, the production behavior of the creator occurs *before* the purchases by consumers. In this case, the demand is uncertain, and the creator's production behavior is affected by the initial funding level. Under crowdfunding, the production behavior of the creator comes *after* the consumers have provided funding. In this case, consumers bear the opportunity cost, and the campaign succeeds (leading to production) only when the market demand exceeds a threshold value. In the basic model, we investigate the pricing strategy and the expected profit of the creator for each selling strategy. Our analysis reveals that crowdfunding dominates traditional selling when the creator's initial funding is low, or the unit production cost is high. We then generalize our models by considering product quality, providing main results consistent with those derived in the basic model but also revealing new and interesting insights. For example, in the case of endogenous product quality, the creator prefers a low production volume under traditional selling, and the opportunity cost has a large (small) impact on crowdfunding (traditional selling). Finally, we examine several extensions to our studies, including adopting Keep-It-All model for crowdfunding, the case involving multiple potential consumers, and the case where the consumer's valuation follows a normal distribution. Our paper highlights that crowdfunding, as a method of collecting finance, is also advantageous for creators with sufficient initial funding under certain conditions. Conclusions from these investigations can guide creators during their sales planning.

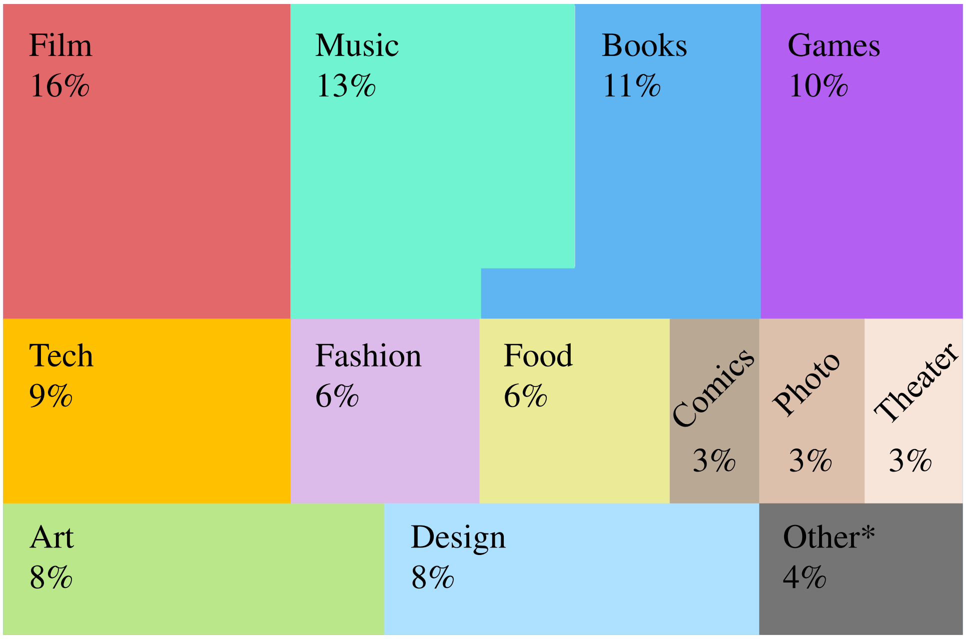
1. Introduction

To begin entrepreneurial initiatives, some creators have started to rely on the Internet to seek direct financial help from the general public instead of approaching financial investors such as angel investors, banks, or venture capital funds. This allows creators to attract outside capital and respond to financing constraints (Cosh et al., 2009; Lambert and Schwienbacher, 2010; Kumar et al., 2020). This relatively new way of financing, called "crowdfunding", has allowed creators to seek capital for project-specific investments and new ventures (Larralde and Schwienbacher, 2010; Mollick and Kuppuswamy, 2014).

In reward-based crowdfunding (referred to hereafter as "crowdfunding"), a creator first states the project information (i.e., the financial goal for raising capital, detailed product information, and runtime of the campaign), and backers (consumers) are offered a product that is eventually to be produced by the creator with the money raised during the campaign (Cumming et al., 2020; Ellman and Hurkens, 2019). By the definition of crowdfunding, it is not difficult to see that crowdfunding includes the production and sale

* Corresponding author.
E-mail address: lyling@ustc.edu.cn (L. Ling).

https://doi.org/10.1016/j.tre.2022.103011
Received 25 April 2022; Received in revised form 4 November 2022; Accepted 29 December 2022
Available online 6 March 2023
1366-5545/



* Other includes Crafts (2%), Dance (1%), and Journalism (1%).

Fig. 1. A breakdown of Kickstarter projects (2009–2019).

of commodities, making it similar to retailing (referred to hereafter as "traditional selling"), where the product is first produced, and then the consumer decides whether to buy. From this point of view, crowdfunding is not only a way to help creators raise funds but also can be understood as a selling strategy.

As the largest, most popular, and longest-standing crowdfunding platform, Kickstarter reached $5.4 billion in total funding with $875 million worth of projects in 2020.[1] Kickstarter aims to "democratize fundraising": any creator can post a project (e.g., a technology product, book, or film) to the platform, set a monetary goal, and raise money from the general public (backers) to pursue an opportunity. Since its inception to 2019, the site has hosted 433,207 projects. Fig. 1 shows how these projects break down by category.[2] Fig. 1 shows crowdfunded efforts in many product categories. These products were created using crowdfunding, but they could also have been brought to market using the traditional selling model. For example, Amazon.com has a catalog of 12 million products across all categories and services. Factoring in the Amazon marketplace, there are 353 million products available on Amazon.[3]

Naturally, a question arises: *When a creator creates an original product, should they choose crowdfunding or the traditional selling format to sell the product*? For example, when a research and development (R&D) group has designed a highly precise 3D scanner with fast, light and full-color advantages over other products in the current market, which selling format should it choose? When a writer/illustrator finishes a new comic book, how can its first bucket of gold be maximized? Since the innovative product has unique features, for example, the horizontal or vertical differences distinguished from the product on current market, it always can attract a specific consumer group with an idiosyncratic taste for the product. How can a creator choose the best selling strategy according to the specific product type?

Although the economic performance of crowdfunding has been widely studied, there has been little research studying its implications on the choices of the creator as a selling strategy. In view of this gap in the literature, this paper investigates the following questions *(1) What are the critical differences between crowdfunding and traditional selling from the perspectives of the creator and consumer? (2) For a particular product, are there conditions under which one strategy dominates the other? If such conditions exist, which factors influence the dominance, and how can the dominance of either strategy be influenced? (3) How can the product quality be determined under different selling strategies when the quality decision is endogenized? How does the quality decision influence creators' selling strategies?*

In-depth analysis finds that crowdfunding and traditional selling have diametrically opposite characteristics. In crowdfunding selling, creators can get financial support from a crowd of individual consumers, which reduces the difficulty of launching a project. This source of funding is vital because using traditional financing channels (e.g., angel investors, banks, and venture capital), creators

1 https://stockapps.com/?s=kickstar
2 https://thehustle.co/kickstarter-a-data-analysis/
3 https://www.repricerexpress.com/amazon-statistics/

face many difficulties in obtaining financial support (Kuppuswamy and Bayus, 2018). Moreover, only at the end of the crowdfunding campaign do the creators begin to produce products. Thus, creators can determine the product quantity according to the market demand, which has sharply reduced the effective cost of capital for creators because they effectively contract with their future consumers before investments are sunk (Strausz, 2017; Ellman and Hurkens, 2019). However, crowdfunding selling still has several disadvantages. First, under the commonly used All-Or-Nothing model[4] (used by Kickstarter and other platforms), creators first set a fixed funding target. The project proceeds only if the total money pledged exceeds the target at the end of the campaign; otherwise, all pledges are canceled, and the creator does not receive any funding. Therefore, the profit in crowdfunding is affected by the threshold amount of pledged money. Second, consumers are required to lock in their investment until the project either succeeds or fails (Kim et al., 2020). Therefore, consumers are subject to the opportunity cost of the deposited investments, which may impair their utility and reduce the market demand.

In contrast to the above characteristics, traditional selling can overcome the shortcomings of crowdfunding. In traditional selling, creators first invest in production, after which consumers decide whether to buy the product. In this case, whether the purchasing is online or offline, consumers do not have to wait a long time before getting their product. Therefore, some or all of the opportunity cost for consumers can be avoided. In addition, because the number of sales is not limited by a preproduction investment value (i.e., an AON target in crowdfunding), products can be sold whenever there is a demand in the market.

However, traditional selling still has certain disadvantages compared with crowdfunding. First, different from the crowdfunding model in which creators learn the demand according to the order quantity from consumers in crowdfunding, in traditional selling, creators need to determine the product quantity before observing the consumers' buying behavior. Therefore, creators bear the risk of underproduction or overproduction. Second, unable to seek financial contributions from consumers interested in the project, in traditional selling, a creator's production capacity is limited by its initial capital. The requirement for startup capital prevents many underfunded creators from adopting traditional selling.

Motivated by the above practical observations, we investigate crowdfunding and traditional selling analytically and subsequently guide creators in their strategic choices. We summarize the main contributions as follows.

First, our work enriches the limited literature on the strategic choices between crowdfunding and traditional selling. In the investigation, we first use a basic model to describe these two strategies, wherein the threshold value is considered in crowdfunding, and both the production volume decision and initial funding level are considered in traditional selling. In addition, we use the opportunity cost coefficient to characterize the potential loss borne by the party who invests first under the two selling strategies. We obtain the optimal prices and optimal profits under the two strategies and analyze the influence of the opportunity cost coefficient and unit cost on the optimal profits. By comparing the expected profit derived from each strategy, we provide the creators with an optimal selling strategy. The main results show that crowdfunding is preferable when the startup capital is low or the unit production cost is high, and traditional selling is more profitable otherwise.

Second, we take the product quality into consideration and subsequently analyze the optimal decision under different quality levels. We consider two cases for product quality: exogenous and endogenous. We show that the main results in the exogenous case are consistent with those in the basic model. In the endogenous case, we find that the creator will always determine a low production volume to control the risk of demand uncertainty under traditional selling. Additionally, for the creator with a mid-range level of initial funding, crowdfunding dominates traditional selling when the opportunity cost coefficient is low, and traditional selling is more profitable otherwise.

Third, we extended our studies by integrating the Keep-It-All (KIA) model in crowdfunding, considering multiple potential consumers in the two sale models, thus investigating the problem with a more complicated distribution of consumer valuations of the product. Besides the mathematical analyses, we also provide several interesting business insights resulting from the extensions. For example, KIA is preferred when consumers hold a high level of trust towards the product, the profit advantage under crowdfunding is increasing in the potential market and decreasing in the threshold value, and the influence of opportunity cost and startup capital on the choice of optimal strategy greatly increases when consumer's valuation follows the normal distribution.

The remainder of this paper is organized as follows. We provide the related literature review in Section 2. Section 3 describes the main problem and the basic model. Section 4 introduces product quality to the basic model in both the exogenous and endogenous cases. Section 5 examines several extensions. Section 6 concludes this study and provides several directions for future research.

2. Literature review

In this section, we provide a review related to our paper and show how the previous studies relate to our work. Our paper is mainly related to crowdfunding, strategy choices, and product quality of the project, which we summarize in Table 1.

First, it enriches the growing literature on crowdfunding. Most research in this stream has focused on the underlying dynamics of success among crowdfunding projects (Mollick, 2012), such as social connections (Mollick, 2012; Gerber et al., 2012; Bayus, 2013; Zheng et al., 2014; Bi et al., 2017), geographic distance (Agrawal et al., 2011; Kang et al., 2017), product category (Chen et al., 2016; Chan et al., 2018), signals of quality (Bi et al., 2017; Chan et al., 2018; Wang and Yang, 2019), the size and time of the most recent pledge (Burtch et al., 2013; Astebro et al., 2019), and other economic factors (Agrawal et al., 2015). Kunz et al. (2017) explore how the interaction between creators and customers, investment presentation, and rewards influence the success of a crowdfunding campaign. Chen et al. (2016) study the appeal modes, product type, message frames, and presentation

[4] We also consider the Keep-It-All model in the extension section. In this case, consumer valuation is affected by the trust level.

Table 1
Summary of relevant literature.

Related streams	Sub-streams	Relevant literature	Research gap
Crowdfunding	Social connections	Mollick (2012), Gerber et al. (2012)	Our paper mainly focuses on the essential characteristics of crowdfunding: how the opportunity cost being borne by the consumer, the crowdfunding target, and the potential market all affect the pricing decision, expected profit, and eventually the strategy selection of the creator.
	Recent pledge	Burtch et al. (2013), Astebro et al. (2019)	
	Signals of quality	Bi et al. (2017), Chan et al. (2018), Wang and Yang (2019)	
	Creator's strategy	Hu et al. (2015), Yang et al. (2020), Peng et al. (2020)	
Strategy choices	Pre ordering vs. profit sharing	Belleflamme et al. (2014)	Our work focuses on the differences between crowdfunding and traditional selling strategies. Contrary to the conventional wisdom, we find traditional selling has certain advantages under certain conditions, aiming to guide the creator in their strategy choices under different financial abilities and market conditions.
	All-Or-Nothing (AON) vs. Keep-It-All (KIA)	Cumming et al. (2020), Nie et al. (2020), Bi et al. (2019), Xu and Zhang (2022)	
	Crowdfunding vs. traditional selling	Xu et al. (2021)	
Product quality	Traditional selling	Jing (2007), Valenzuela et al. (2009), Bala et al. (2014), Lu et al. (2019), Zhang et al. (2019)	Our paper investigates how the opportunity cost and creator's initial funding affect the product quality decision and, thereby, the strategy choice for the creator.
	Crowdfunding	Kumar et al. (2020), Hu et al. (2015), Gao et al. (2022), Liu et al. (2021)	

characteristics. Yang et al. (2020) investigate the design of appropriate profit allocation mechanisms to enhance the success rate of investment-based crowdfunding projects. Less attention has been given to the pricing strategy in crowdfunding. Hu et al. (2015) establish a dynamic model and stress the dominance of different pricing strategies (i.e., volume, margin, intertemporal, and menu pricing) in the context of crowdfunding. Peng et al. (2020) study how package size decisions influence pricing strategies in reward-based crowdfunding projects. Our paper mainly focuses on the essential characteristics of crowdfunding: how the opportunity cost being borne by the consumer, the crowdfunding target, and the potential market all affect the pricing decision, expected profit, and eventually the strategy selection of the creator.

Second, we explore the choice of selling strategies for the creator. Most research has focused on the model selection in a crowdfunding campaign (Belleflamme et al., 2014; Cumming et al., 2020; Nie et al., 2020; Bi et al., 2019; Xu and Zhang, 2022). Belleflamme et al. (2014) compare two forms of crowdfunding: pre-ordering and profit sharing. They find that entrepreneurs prefer pre-ordering when the initial capital requirement is relatively small, and profit sharing is preferred otherwise. Cumming et al. (2020) specifically describe two types of reward-based crowdfunding models: All-Or-Nothing (AON) and Keep-It-All (KIA). They find that small, scalable projects are more likely to be funded through the KIA model, whereas large and non-scalable projects are more likely to be funded through the AON model. Theoretical research also examines the advantages of the AON and KIA models (Nie et al., 2020; Bi et al., 2019; Xu and Zhang, 2022). Nie et al. (2020) consider a static game of incomplete information when consumers hold heterogeneous valuations towards the product quality. Bi et al. (2019) regard the uncertainty generated in KIA as consumer distrust of the project. Xu and Zhang (2022) build a two-stage model and study how the strategic behavior of informed consumers affects the model selection for the creator. Less attention has been given to studying the conditions under which crowdfunding is the creator's optimal choice. Xu et al. (2021) demonstrate that crowdfunding dominates traditional selling in all three aspects: financing, ex-post production, and point provision. Our work also focuses on the differences between crowdfunding and traditional selling strategies. Contrary to the conventional wisdom, we find traditional selling has certain advantages under certain conditions, aiming to guide the creator in their strategy choices under different financial abilities and market conditions.

Third, this paper contributes to the product quality stream in the marketing literature. Various studies have addressed product quality under traditional selling by considering network externality (Jing, 2007), customization (Valenzuela et al., 2009), distribution (Bala et al., 2014), co-products (Lu et al., 2019), and platform contracts (Zhang et al., 2019). Other studies investigate product quality under crowdfunding. For example, Cornelius and Gokpinar (2020) find that consumers' involvement in product development increases the funding success. Kumar et al. (2020) show that the cost of external financing affects crowdfunding production. Hu et al. (2015) investigate the optimal quality gap between two vertically differentiated products. Bi et al. (2019) study product quality under the AON and KIA models. Xu et al. (2021) explore the motivation of product design difference between crowdfunding and traditional selling. Gao et al. (2022) analyze and compare the quality commitment and no-commitment strategies in crowdfunding. Liu et al. (2021) study the optimal product menu with product quality under crowdfunding and traditional selling. Consistent with this body of literature, our paper provides new insights into product quality in both crowdfunding and traditional selling. We investigate how the opportunity cost and creator's initial funding affect the product quality decision and, thereby, the strategy choice for the creator.

In this paper, we consider whether differences in product types give rise to differences in the types of creators that select a particular strategy while furthermore considering their eventual likelihood of success. From a managerial perspective, these issues are crucial to understanding how creators can obtain necessary resources and transform innovative ideas into products.

3. Basic model

In this section, we start with a basic model to study consumer behavior and analyze the optimal selling strategy for the creator. Our objective is to first use a parsimonious model to illustrate the basic economic force behind the crowdfunding and traditional selling strategies.

3.1. Assumptions

Consumer behavior. To strengthen our focus on the comparisons between the two selling strategies, in the basic model, we assume the following: (i) there are only two potential consumers in the market (Bi et al., 2019; Xu and Zhang, 2022),[5] (ii) the valuation of each consumer for product, V, is uniformly distributed in the interval [0,1] to imply the heterogeneity of the consumers, and the distribution is known by the creator (Belleflamme et al., 2014; Bi et al., 2019; Xu and Zhang, 2022), (iii) consumers arrive and make decisions at the same time (Nie et al., 2020; Bi et al., 2019), and (iv) each consumer cannot buy more than one unit product (Belleflamme et al., 2014; Nie et al., 2020). We also assess the robustness of our model by relaxing the first assumption to multiple potential consumers in Section 5.4 and replacing the uniform distribution with normal distribution in Section 5.5.

Creator behavior. Consider a risk-neutral creator who has initial funding $K(K \geq 0)$. The creator needs to determine a selling strategy (i.e., crowdfunding or traditional selling) and the price p for the product before selling it. The unit production cost is c.

An important difference between the crowdfunding and traditional selling is the investment sources. Using the former strategy, the consumer first pledges, which means they invest in the project before production stars. Using the latter strategy, the creator invests all that is needed for production. In this case, we capture the cost of waiting (risk-free rate) during the production process by an opportunity cost coefficient α, which is assumed to be the same for both the consumer and creator. Specifically, the opportunity cost coefficient is related to the time duration of the campaign. Since this time duration is not very long (usually less than 90 days), we assume the extra cost for any agent is not too large (i.e., $\alpha \leq 1/2$) (Xu and Zhang, 2022). A larger opportunity cost coefficient α corresponds to a higher potential loss for the consumer or the creator who invests in production.

Next, we will study the expected profits in crowdfunding and traditional selling strategies, exploring their eventual probability of reaching the target (PRT) from the creator's perspective. Now, we formally introduce the crowdfunding and traditional selling strategies as follows.

3.2. Crowdfunding selling

In crowdfunding selling (CS), the creator first releases detailed product information. After the announcement, consumers arrive and decide whether to buy the product according to their valuation. We consider perfect information in the crowdfunding setting. That is, the product information is symmetric between the creator and consumer. For example, creators can present specific product information through detailed text, pictures, or videos. In this case, the consumer can accurately value the crowdfunding product, and thus the valuations of the product under the crowdfunding and traditional selling strategies are consistent. The crowdfunding model we analyze here is All-Or-Nothing;[6] that is, the project can succeed only if both consumers pledge (recall that our model has only two consumers); otherwise, the raised funds are returned to the consumers (Bi et al., 2019; Xu and Zhang, 2022). The sequence of events in crowdfunding selling is shown in Fig. 2. Subsequently, the pledging utility of a consumer can be denoted as $u_{CS} = V - (1+\alpha)p$. We consider that a consumer pledging under CS incurs an opportunity cost αp. Given the waiting time under CS, consumers could have invested the same amount elsewhere (Bi et al., 2019; Kim et al., 2020). Thus, the parameter α measures the impact of the unit price on the consumer's losses (Xu and Zhang, 2022). In this case, each consumer will pledge if and only if $u_{CS} \geq 0$, that is, $V \in [(1+\alpha)p, 1]$. By noting that V follows a uniform distribution in [0,1], we have that the pledging probability of each consumer is $[1-(1+\alpha)p]$ and the PRT of the crowdfunding project is $[1-(1+\alpha)p]^2$. Since the unit profit of a product is $(p-c)$, the expected profit of the creator can be expressed as

$$\pi_{CS}(p) = 2(p-c)[1-(1+\alpha)p]^2. \tag{3.1}$$

The creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{CS}(p) \\ \text{s.t.} \quad & c \leq p \leq \frac{1}{1+\alpha}. \end{aligned} \tag{3.2}$$

The following Lemma 1 summarizes the optimal solution under crowdfunding selling. (See the appendix for the proofs of all lemmas, propositions and corollaries presented in this paper.)

[5] The two-consumer model where the crowdfunding can succeed only when both buyers sign up highlights the characteristics of "crowd" in CS. The reason is that, in practice, all crowdfunding projects require many buyers, and so it is necessary to model the coordination between buyers (Hu et al., 2015).

[6] The All-Or-Nothing model is widely used in reality, such as by Kickstarter, TaoBao, and JD.com. This setting is also commonly used in the crowdfunding literature (Belleflamme et al., 2014; Hu et al., 2015).

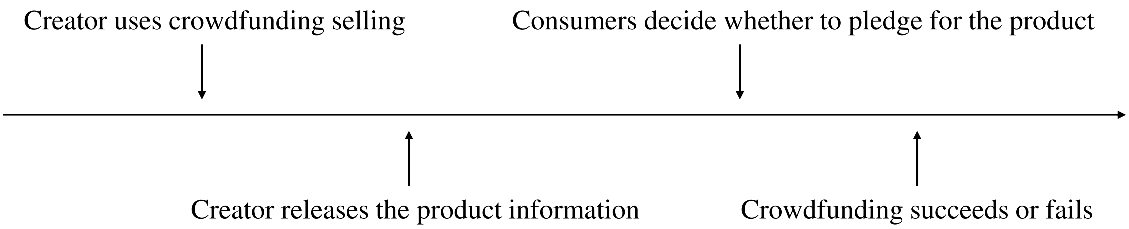


Fig. 2. Sequence of events in crowdfunding selling.

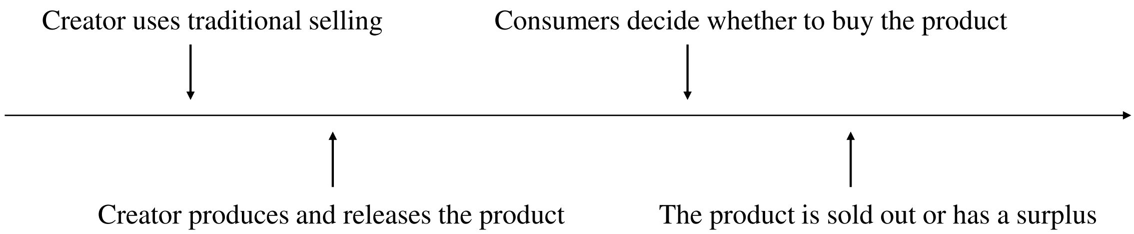


Fig. 3. Sequence of events in traditional selling.

Lemma 1 (*Optimal Solution for Crowdfunding Selling: The Basic Model*)**.** *In crowdfunding selling, the optimal price and profit are*

$$p^*_{CS} = \frac{1+2(1+\alpha)c}{3(1+\alpha)} \text{ and } \pi^*_{CS} = \frac{8[1-(1+\alpha)c]^3}{27(1+\alpha)}.$$

Lemma 1 illustrates the condition and solution under CS. In CS, the optimal price and expected profit are jointly decided by the unit cost c and opportunity cost coefficient α. First, the optimal pledging price is increasing, and the optimal profit is decreasing in the unit cost c (i.e., $\partial p^*_{CS}/\partial c \geq 0$ and $\partial \pi^*_{CS}/\partial c \leq 0$). Second, the optimal profit is convex in c (i.e., $\partial^2 \pi^*_{CS}/\partial c^2 \geq 0$). Third, the upper limit of unit cost $\hat{c}$ is determined by the opportunity cost coefficient α. When the consumers' return on investing in other products is increasing, the upper limit of the unit cost $\hat{c}$, optimal price, and profit are decreasing (i.e., $\partial \hat{c}/\partial \alpha < 0$, $\partial p^*_{CS}/\partial \alpha < 0$, and $\partial \pi^*_{CS}/\partial \alpha \leq 0$). These results are intuitive: under CS, when the unit cost of the product increases, the creator should set a higher corresponding price, and the corresponding profit decreases (because the success rate decreases). Moreover, higher opportunity cost also decreases the profit of CS since the consumer suffers more losses.

3.3. Traditional selling

In traditional selling (TS), the creator first produces the product and offers it for sale at price p. Then, consumers arrive and decide whether to buy the product according to their valuation. The sequence of events in traditional selling is shown in Fig. 3.

TS and CS have two fundamental differences. First, under TS, the production decision of the creator is made before the purchasing decision of consumers (i.e., the creator needs to determine the product quantity before consumers start buying, and the product may not be sold out). Under CS, the creator's production starts after the consumers' pledges are received (i.e., the product quantity is determined when the funding target is achieved). Second, under CS, the creator can invest the consumers' funding in production (i.e., consumers bear the opportunity cost). Under TS, the creator must invest first (i.e., the creator bears the opportunity cost) and is financially constrained by the initial funding K.

In reality, the creator who uses TS could also borrow money from the traditional financing channels, but doing so does not have any great effects on our results. The reason is as follows: the main purpose of this paper is to investigate the profitability of CS and TS, while also analyzing how the product cost and the opportunity cost of different agents affect the strategy choice of the creator. In this case, different levels of initial capital can be recognized as the eventual capability of the different types of creators, except that the final profit is reduced when creators pay a borrowing cost. Thus, we choose the fixed initial capital level.

In TS, the utility of a consumer is $u_{TS} = V - p$. In this case, each consumer will buy if and only if $u_{TS} \geq 0$, that is, $V \in [p, 1]$. As in the crowdfunding case, each consumer will buy with probability $(1-p)$ and will decline with probability p.

Because the creator cannot use consumer money to produce under TS, the actual unit cost of each product (considering the risk-free rate during the production time) is $(1+\alpha)c$. In the basic model, we consider the salvage value s as $s = 0$, but in Section 5.1, we consider a positive salvage value. Next, we analyze the relationship between the unit cost c and initial funding K to determine product quantity Q.

When $K < c$, the creator cannot produce the product, and the profit is 0.

When $c \leq K < 2c$, the creator can decide to produce quantity 0 or 1. When $Q = 0$, the profit is 0. When $Q = 1$, the product will be sold out with probability $(1-p^2)$ (it happens when at least one consumer purchases the product), and the probability of

Table 2
Optimal solution for traditional selling: The basic model.

Condition	Quantity	Price	Profit
$K < c$ or $c > \frac{2\sqrt{3}}{9(1+\alpha)}$	0	0	0
$c \le K < 2c$ and $c \le \frac{2\sqrt{3}}{9(1+\alpha)}$	1	$p^*_{TS1} = \frac{\sqrt{3}}{3}$	$\pi^*_{TS1} = \frac{2\sqrt{3}}{9} - (1+\alpha)c$
$K \ge 2c$ and $c \le \frac{9-4\sqrt{3}}{18(1+\alpha)}$	2	$p^*_{TS2} = \frac{1}{2}$	$\pi^*_{TS2} = \frac{1}{2} - 2(1+\alpha)c$
$K \ge 2c$ and $\frac{9-4\sqrt{3}}{18(1+\alpha)} < c \le \frac{2\sqrt{3}}{9(1+\alpha)}$	1	$p^*_{TS1} = \frac{\sqrt{3}}{3}$	$\pi^*_{TS1} = \frac{2\sqrt{3}}{9} - (1+\alpha)c$

one surplus product remaining is p^2 (it happens when both consumers decline to purchase the product). Subsequently, the expected profit is

$$\pi_{TS1}(p) = [(1-p^2)p - (1+\alpha)c]^+. \tag{3.3}$$

The creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{TS1}(p) \\ \text{s.t.} \quad & p \le 1, c \le K < 2c. \end{aligned} \tag{3.4}$$

When $K \ge 2c$, the creator can decide to produce 0, 1 or 2. When $Q = 0$, the profit is 0. When $Q = 1$, the profit is $\pi_{TS1}(p)$. When $Q = 2$, the probability of selling out is $(1-p)^2$ (it happens when both consumers purchase the product), that of having one surplus product is $2(1-p)p$ (it happens when one consumer buys while the other declines to purchase the product), and that of having two surplus products is p^2. The expected profit is

$$\pi_{TS2}(p) = [2(1-p)^2 p + 2(1-p)p^2 - 2(1+\alpha)c]^+. \tag{3.5}$$

Given $\pi_{TS}(p) = \max\{\pi_{TS1}(p), \pi_{TS2}(p)\}$, the creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{TS}(p) \\ \text{s.t.} \quad & p \le 1, K \ge 2c. \end{aligned} \tag{3.6}$$

The following Lemma 2 summarizes the optimal production quantity, price, and corresponding expected profit under TS.

Lemma 2 (*Optimal Solution for Traditional Selling: The Basic Model*). *The optimal solution for traditional selling is given in Table 2.*

Lemma 2 states that the optimal production quantity, price, and expected profit of the creator are decided by the initial funding K, unit production cost c, and opportunity cost coefficient α. First, the creator cannot produce when K is very small. When K is not very small and c is very high, the creator still cannot use TS because the expected profit is negative. Second, when K is in a medium range ($c \le K < 2c$), the creator can only choose to produce one unit when c is low. Third, when K is sufficiently large ($K \ge 2c$), the creator should determine the production quantity according to c. When c is low, the creator should produce more products to satisfy all market demand along with setting a lower price ($p^*_{TS2} < p^*_{TS1}$). The reason is that even if the products are unmarketable, the creator's loss is very small. When c is in a medium range, the creator should increase both the profit margin and the probability (producing one unit) that the product will be sold out in order to control the loss due to the unsold products. Moreover, under each condition, the optimal price is irrelevant to the actual unit cost. Since the investment has already been sunk, the creator's goal is to maximize the profit.

3.4. Crowdfunding vs. Traditional selling

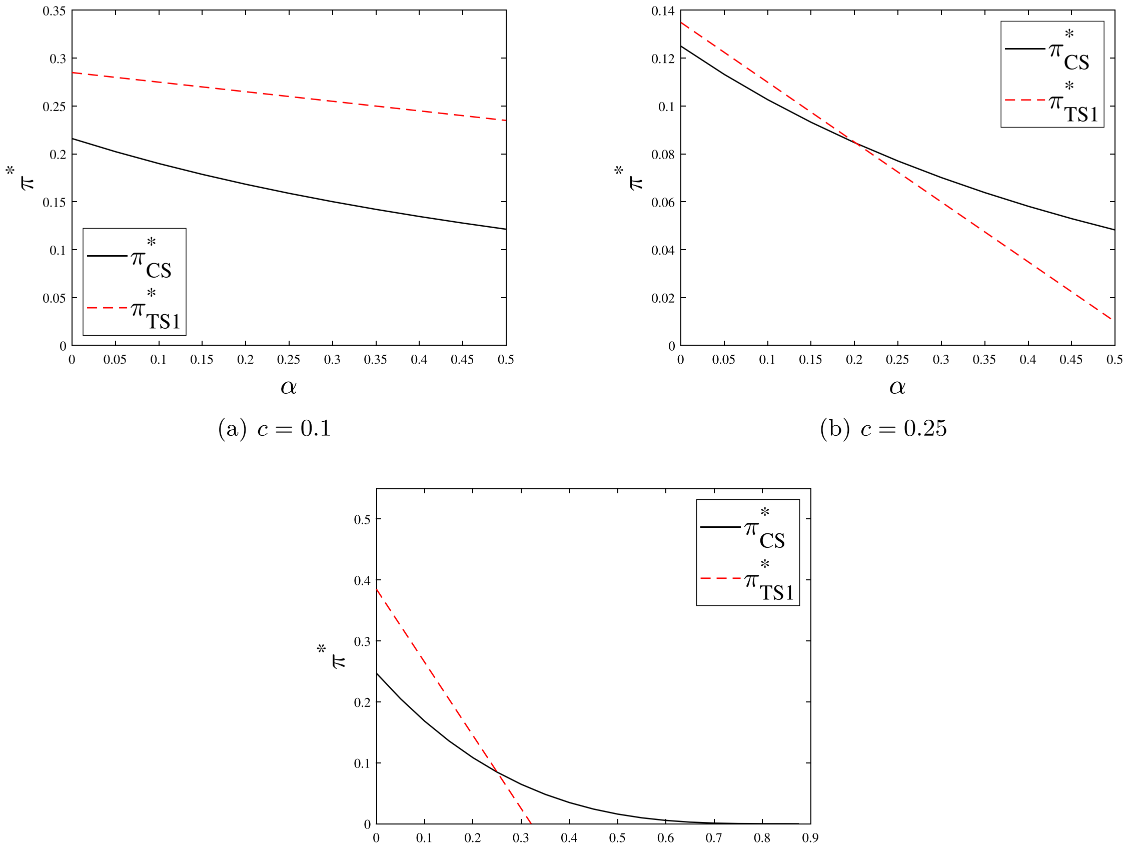
Earlier in this study, we show how to obtain the optimal profits under CS and TS. Next, we formally compare the two selling strategies and analyze the advantages of each strategy for different types of products.

According to Lemma 2, when $c \le K < 2c$, the creator can only produce one unit. When $K \ge c$, the creator should produce more products when the cost is high. Therefore, for creators with a certain amount of funds (i.e., $K \ge c$), producing one unit is a necessary option under TS. In addition, because α and c both affect the profits π^*_{CS} and π^*_{TS1}, we first analyze and compare the impact of different parameters on the optimal profits π^*_{CS} and π^*_{TS1}, which can help us better understand the impact of different parameter changes on strategy choice. We show the main result in Lemma 3.

Lemma 3 (*Parameter Influence Comparisons: The Basic Model*). *The following conclusions result from comparing the effects of α and c on the optimal profits, where c_1 is defined in the appendix.*

(i) $|\frac{\partial \pi^*_{TS1}}{\partial \alpha}| \le |\frac{\partial \pi^*_{CS}}{\partial \alpha}|$ *when* $c \le c_1$ *and* $|\frac{\partial \pi^*_{TS1}}{\partial \alpha}| > |\frac{\partial \pi^*_{CS}}{\partial \alpha}|$ *when* $c_1 < c \le \frac{2\sqrt{3}}{9(1+\alpha)}$.

(ii) $|\frac{\partial \pi^*_{TS1}}{\partial c}| > |\frac{\partial \pi^*_{CS}}{\partial c}|$ *when* $c \le \frac{2\sqrt{3}}{9(1+\alpha)}$.



(a) $c = 0.1$ (b) $c = 0.25$ (c) $\alpha = 0.2$

Fig. 4. Parameter influence comparisons: The basic model.

Lemma 3 is graphically illustrated in Fig. 4. The vertical axis represents the optimal profits π^*. Because c must satisfy $c \leq 2\sqrt{3}/[9(1+\alpha)]$ under TS, and the optimal profits are decreasing in α and c, we respectively analyze the impact of changes in α and c on the optimal profits.

The first conclusion of Lemma 3 is illustrated in Fig. 4(a) and (b), where the horizontal axis represents the opportunity cost coefficient α. We find that α has a greater influence on TS (CS) when c is large (small). This is because in crowdfunding, when the price is low (corresponding to low-cost products), the market demand is high. In this case, the price change caused by the opportunity cost change has a great impact on market demand and thereby, the profit. When the price is high (corresponding to high-cost products), although an increase in opportunity cost reduces market demand, the impact is less than when the cost is low. Moreover, under TS, the opportunity cost increases monotonically with c. Thus, the influence of α on TS (CS) is increasing (decreasing) in c. The second conclusion of Lemma 3 is illustrated in Fig. 4(c), where the horizontal axis represents unit cost c. We find that when α is fixed, c always has a greater influence on TS.

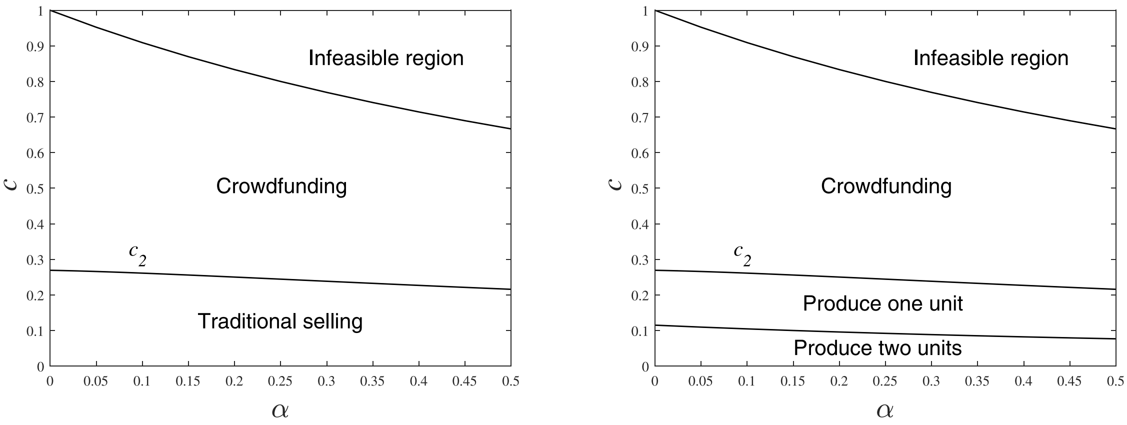
Our findings have the following implications. First, under CS, creators should carefully analyze the production time and cost of the product in advance to determine the optimal choices. For low-cost products, creators should shorten the time from consumer payment to obtaining the product as much as possible; for high-cost products, creators can appropriately increase this time horizon since the revenue is less sensitive to varying costs. In addition, creators should pay more attention to the cost of products under TS than under CS. The reason is, without building a relationship with consumers, and facing uncertainty ex ante for the creator, the cost changes more greatly impact the profit under TS.

Based on the optimal profits (in Lemmas 1 and 2) and the parameter influence comparison (in Lemma 3), a formal comparison of the two optimal profits leads to Proposition 1, which states the conditions under which one strategy dominates the other.

Proposition 1 (*Profit Comparison: The Basic Model*). *The optimal selling strategy is jointly determined by initial funding K, unit cost c, and opportunity cost coefficient α. Specifically, the optimal strategy is*

(i) *crowdfunding when $K < c$ or when $K \geq c$ and $c_2 < c \leq 1/(1+\alpha)$,*

(ii) *traditional selling when $K \geq c$ and $c \leq c_2$ (c_2 is defined in the appendix).*



(a) $c \leq K < 2c$ (b) $K \geq 2c$

Fig. 5. Crowdfunding vs. traditional selling: The basic model.

First, Proposition 1 states that CS is more suitable for creators who lack startup capital ($K < c$). In CS, creators can take advantage of consumers' funds without first investing large amounts of their own money. In TS, creators must first invest the capital to produce, which puts forward different requirements for their capital ability.

Second, for creators with a certain amount of startup capital (i.e., $K \geq c$), Proposition 1 is graphically illustrated in Fig. 5 , where the horizontal axis represents opportunity cost coefficient α, and the vertical axis represents the unit cost c. We find TS is more profitable than CS when the unit cost is small, and CS yields more profit otherwise. The reason is that CS emphasizes the scale of participating consumers. In other words, crowdfunding products can be sold only if many consumers participate; otherwise, the campaign fails, and the product cannot be produced. In this case, when the cost is low ($c \leq c_2$), although CS is more likely to succeed with a low price, TS can achieve a higher profit margin with a lower risk ($p^*_{CS} < p^*_{TS2} < p^*_{TS1}$). When the unit cost is high ($c > c_2$), although the PRT under CS is low, crowdfunding can transfer the risk of demand uncertainty to consumers. Under TS, creators bear a higher risk of having unsold products, so their potential loss is higher. This makes CS is more advantageous.

The indifference line of cost, c_2, is decreasing in the opportunity cost coefficient α ($\partial c_2/\partial \alpha < 0$). In Fig. 5, with the increase of α, the advantages of TS is decreasing, and the creator can use TS only when the unit cost is low. The reason is that although c_2 is not large, α does have a greater impact on TS (i.e., $c_2 > c_1$). In other words, the opportunity cost has a greater impact on CS than TS only when the product cost is very small (proven in Lemma 3), but in this case, TS always dominates CS. Therefore, in the high cost range, opportunity cost has a greater impact on TS.

Proposition 1 obtains the optimal strategy under different cost ranges based on comparing the optimal profits. We also want to further explore the probability of reaching the target (PRT) under each strategy, which can help us completely understand the characteristics and advantages of each strategy. Specifically, under CS, PRT is success rate, that is, the probability of both consumers signing up in the campaign, which is also the probability of selling two products. Under TS, PRT is sell-out rate, which depends on the creator's output decision (i.e., 1 or 2), that is, the probability of selling the established production objective that maximizes profits. Using the optimal solutions in different cost ranges expressed in Proposition 1, Corollary 1 compares the eventual PRT under the two selling strategies in the basic model.

Corollary 1 (*PRT Comparison: The Basic Model*)**.** *In the basic model, denote the PRT of CS and of producing one and two units in TS as PRT_{CS}, PRT_{TS1}, and PRT_{TS2}, respectively. When $K \geq c$, we obtain that*

(i) *producing one unit under TS always has a higher PRT than CS (i.e., $PRT_{CS} < PRT_{TS1}$ when $c \leq c_2$),*

(ii) *producing two units under TS always has a lower PRT than CS (i.e., $PRT_{TS2} < PRT_{CS}$ when $K \geq 2c$ and $c \leq (9-4\sqrt{3})/[18(1+\alpha)]$).*

Consider the region where both CS and TS can be launched (i.e., the profits are positive). In the region where producing one unit under TS is optimal (when $K \geq c$ and $c \leq c_2$), producing one unit under TS always has a higher PRT than CS. In the region where producing two units under TS is optimal (when $K \geq 2c$ and $c \leq (9-4\sqrt{3})/[18(1+\alpha)]$), producing two units under TS always has a lower PRT than CS.

It should be noted that the PRT under CS is decreasing in the unit cost, while the PRT under TS is irrelevant to the unit cost. This is because the price of the crowdfunding product is increasing in the unit cost, while the price under TS does not change with respect to the unit (sunk) cost. When we compare the PRT of CS and TS, Corollary 1 first states that producing fewer products in TS is always more likely to reach the target than CS. That is to say, in this case, a higher PRT under TS compensates for the profit loss due to a higher price and corresponding higher utility loss per consumer. Second, although consumers bear the opportunity cost under CS, the PRT under CS is still higher than that under TS with producing more products. The reason is that creators pursue maximizing revenue under TS, whereas they balance both PRT and profit under CS. Therefore, when the unit cost is low, compared with TS, reducing the price and pursuing a higher PRT impair the profit under CS. From another aspect, Corollary 1 also explains that TS is more advantageous when the unit cost is low, and CS is preferred otherwise.

These findings have significant practical implications. Our results suggest that the creators of low-cost products should adopt TS. Such low-cost products include toys, electronic accessories, video games, books, home and kitchen products, and applications for Android smartphones; these are all top-selling product categories on Amazon.[7] Although the music category (typically comprising smaller campaigns with a raising target between $1,000 and $9,999) has seen the largest share of successful campaigns with 31,688 successfully funded projects on Kickstarter,[8] it may still perform well under TS. The same data shows that only 0.08% of campaigns have reached the million dollar threshold on Kickstarter. Of these, 92% involve games, design, and technology, with those categories having 133, 122, and 95 projects that raised $1 million or more, respectively. While the PRT of these high-cost projects is low under CS, the creators actually face greater risks under TS.

Our results also show that although opportunity cost adversely affects both strategies, it does have a greater impact on TS. For example, under TS, a higher interest or a longer production time means a greater potential loss for the creator. Therefore, in addition to the cost of the product, the creator should also pay attention to factors such as the enforceability of the production plan and the economic environment, especially creators who require financial help from banks or other institutions.

4. Model with product quality

In this section, we extend the basic model to allow the creator to decide the product quality during production and explore how the product quality may alter the optimal selling strategy. In Section 4.1, we focus on the case of exogenous quality, while in Section 4.2, we shift our focus to the endogenous case.

4.1. Exogenous quality

Suppose that the creator offers a product with an exogenous quality q. Here, to fairly assess the advantages under each strategy, we suppose that the information about product quality is symmetric between the creator and consumer (Liu et al., 2021). The consumers' valuations depend on the quality of the products. Specifically, for a quality level q, we assume that consumers' product valuation is qV. The basic model is a special case, with the quality level fixed at $q = 1$. We assume that the unit production cost with quality q is $q^2/2$, which means the creator pays more if it decides to offer products with higher qualities (Hu et al., 2015; Bi et al., 2019; Liu et al., 2021).

We formally introduce crowdfunding and traditional selling strategies with exogenous product quality as follows.

4.1.1. Crowdfunding vs. Traditional selling

In CS, similar to the basic case studied in Section 3, the pledging utility of a consumer can be denoted as $u_{CEX} = qV - (1+\alpha)p$. Given the quality q, consumer's valuation for the product is qV (Bala et al., 2014; Hu et al., 2015; Bi et al., 2019). Since V is uniformly distributed on [0,1], we have that the pledging probability of each consumer is $(1-(1+\alpha)p/q)$ and the PRT of the project is $(1-(1+\alpha)p/q)^2$. By noting that the unit profit is $(p - q^2/2)$, we can express the expected profit of the creator under CS with exogenous product quality as

$$\pi_{CEX}(p) = 2\left(p - \frac{q^2}{2}\right)\left[1 - \frac{(1+\alpha)p}{q}\right]^2. \tag{4.1}$$

The creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{CEX}(p) \\ \text{s.t.} \quad & \frac{q^2}{2} \le p \le \frac{q}{1+\alpha}. \end{aligned} \tag{4.2}$$

The following Lemma 4 summarizes the optimal price and the corresponding expected profit of the creator under CS.

Lemma 4 (*Optimal Solution in Crowdfunding Selling: Exogenous Quality*). *In crowdfunding selling, the optimal price and profit are*

$$p^*_{CEX} = \frac{[1+(1+\alpha)q]q}{3(1+\alpha)} \text{ and } \pi^*_{CEX} = \frac{q[2-(1+\alpha)q]^3}{27(1+\alpha)}.$$

Lemma 4 states that the optimal price and expected profit are jointly decided by the product quality q and opportunity cost coefficient α. First, the optimal price is increasing in product quality q ($\partial p^*_{CEX}/\partial q > 0$), and the expected profit is concave in q ($\partial^2 \pi^*_{CEX}/\partial q^2 < 0$). Second, the optimal price and profit are decreasing with the opportunity cost coefficient α ($\partial p^*_{CEX}/\partial \alpha < 0$ and $\partial \pi^*_{CEX}/\partial \alpha < 0$).

In TS, we can express the pledging utility of each consumer as $u_{TEX} = qV - p$. In this case, each consumer will buy if and only if $u_{TEX} \ge 0$, that is, $V \in [p/q, 1]$. Thus, each consumer will buy with probability $(1 - p/q)$ and decline with probability p/q.

---

[7] https://www.x-cart.com/blog/top-selling-items-on-amazon.html

[8] https://www.crowdcrux.com/kickstarter-statistics-in-2020/

Table 3
Optimal solution for traditional selling: Exogenous quality.

Condition	Quantity	Price	Profit
$K < \frac{q^2}{2}$ or $q > \frac{4\sqrt{3}}{9(1+\alpha)}$	0	0	0
$\frac{q^2}{2} \le K < q^2$ and $q \le \frac{4\sqrt{3}}{9(1+\alpha)}$	1	$p^*_{TEX1} = \frac{\sqrt{3}q}{3}$	$\pi^*_{TEX1} = \frac{2\sqrt{3}q}{9} - \frac{(1+\alpha)q^2}{2}$
$K \ge q^2$ and $q \le \frac{9-4\sqrt{3}}{9(1+\alpha)}$	2	$p^*_{TEX2} = \frac{q}{2}$	$\pi^*_{TEX2} = \frac{q}{2} - (1+\alpha)q^2$
$K \ge q^2$ and $\frac{9-4\sqrt{3}}{9(1+\alpha)} < q \le \frac{4\sqrt{3}}{9(1+\alpha)}$	1	$p^*_{TEX1} = \frac{\sqrt{3}q}{3}$	$\pi^*_{TEX1} = \frac{2\sqrt{3}q}{9} - \frac{(1+\alpha)q^2}{2}$

Next, we analyze the relationship between the exogenous quality q and initial funding K to determine product quantity Q.

When $K < q^2/2$, the creator cannot produce the product, and the profit is 0.

When $q^2/2 \le K < q^2$, the creator can decide to produce quantity 0 or 1. When $Q = 0$, the profit is 0. When $Q = 1$, the product will be sold out with probability $(1 - (p/q)^2)$, and one surplus product occurs with probability $(p/q)^2$. The expected profit is

$$\pi_{TEX1}(p) = \left[\left(1 - \frac{p^2}{q^2}\right)p - \frac{(1+\alpha)q^2}{2}\right]^+. \tag{4.3}$$

The creator's decision objective is given by

$$\begin{aligned} &\max_p \quad \pi_{TEX1}(p) \\ &\text{s.t.} \quad p \le q, \frac{q^2}{2} \le K < q^2. \end{aligned} \tag{4.4}$$

When $K \ge q^2$, the creator can decide to produce 0, 1, or 2 products. When $Q = 0$, the profit is 0. When $Q = 1$, the profit is $\pi_{TEX1}(p)$. When $Q = 2$, the product will be sold out with probability $(1 - p/q)^2$, and one surplus product remains with probability $2(1 - p/q)p/q$, and two surplus products remain with probability $(p/q)^2$. The expected profit is

$$\pi_{TEX2}(p) = \left[2p\left(1 - \frac{p}{q}\right)^2 + 2\left(1 - \frac{p}{q}\right)\frac{p^2}{q} - (1+\alpha)q^2\right]^+. \tag{4.5}$$

Given $\pi_{TEX}(p) = \max\{\pi_{TEX1}(p), \pi_{TEX2}(p)\}$, the creator's decision objective is given by

$$\begin{aligned} &\max_p \quad \pi_{TEX}(p) \\ &\text{s.t.} \quad p \le q, K \ge q^2. \end{aligned} \tag{4.6}$$

The following Lemma 5 summarizes the optimal quantity, price, and corresponding expected profit under TS.

Lemma 5 (*Optimal solution for traditional selling: Exogenous quality*)**.** *The optimal solution of traditional selling is given in Table 3.*

Lemma 5 states that the optimal solutions are jointly decided by the initial funding K, product quality q, and opportunity cost coefficient α. We find the optimal price is increasing with q ($\partial p^*_{TEX}/\partial q \ge 0$), and the expected profit is concave in q ($\partial^2 \pi^*_{TEX}/\partial q^2 \le 0$). When the creator's initial funding is sufficient ($K \ge q^2$), producing more products can still yield higher profit when the product quality is low. The reason is that the creator takes less risk of unmarketability when producing low-quality products at low cost. Unlike the finding in the basic model, the quality of the product directly affects the price because the consumer valuation for the product is closely related to the quality. In this case, compared with the basic case, the creator can make production quantity decisions in a higher cost (quality) range.

From Lemma 5, when K is large (i.e., $K \ge q^2/2$), it is necessary to produce one unit under TS. We first use the results in Lemmas 4 and 5 to analyze and compare the influence of different parameters on the optimal profits under CS and producing one unit under TS. The main results are shown in Lemma 6.

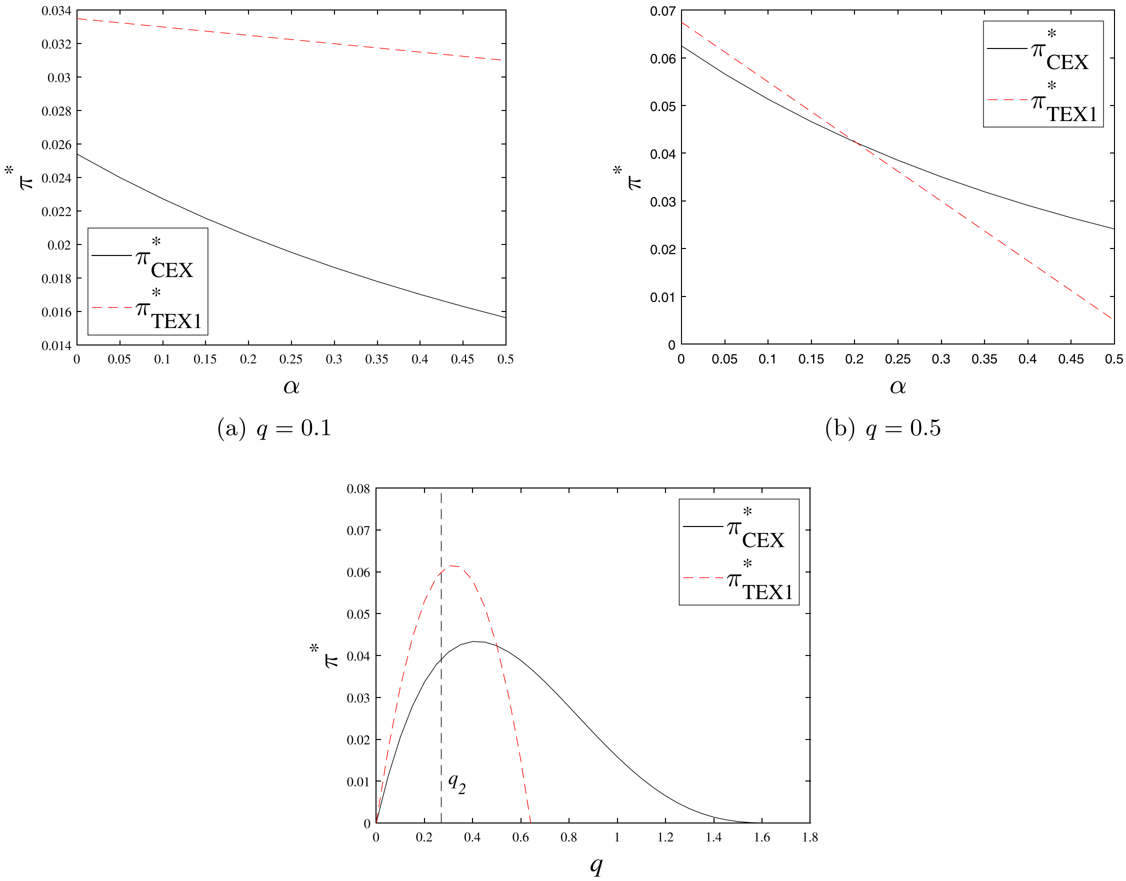
Lemma 6 (*Parameter Influence Comparisons: Exogenous Quality*)**.** *The following conclusions result from comparing the effects of α and c on the optimal profits, where q_1 and q_2 are defined in the appendix.*

(i) $|\frac{\partial \pi^*_{TEX1}}{\partial \alpha}| \le |\frac{\partial \pi^*_{CEX}}{\partial \alpha}|$ *when* $q \le q_1$ *and* $|\frac{\partial \pi^*_{TEX1}}{\partial \alpha}| > |\frac{\partial \pi^*_{CEX}}{\partial \alpha}|$ *when* $q_1 < q \le \frac{4\sqrt{3}}{9(1+\alpha)}$,

(ii) $\frac{\partial \pi^*_{CEX}}{\partial q} \le \frac{\partial \pi^*_{TEX1}}{\partial q}$ *when* $q \le q_2$ *and* $\frac{\partial \pi^*_{CEX}}{\partial q} > \frac{\partial \pi^*_{TEX1}}{\partial q}$ *when* $q_2 < q \le \frac{4\sqrt{3}}{9(1+\alpha)}$,

(iii) $|\frac{\partial^2 \pi^*_{CEX}}{\partial q^2}| < |\frac{\partial^2 \pi^*_{TEX1}}{\partial q^2}|$ *when* $q \le \frac{4\sqrt{3}}{9(1+\alpha)}$.

Lemma 6 is graphically illustrated in Fig. 6. The vertical axis represents the optimal profits π^*. The first conclusion in Lemma 6 is illustrated in Fig. 6(a) and (b). We find that α has a greater influence on TS (CS) when q is large (small). The second and third conclusions in Lemma 6 are illustrated in Fig. 6(c). Because π^*_{CEX} and π^*_{TEX1} are concave in q, we compare the actual value of the partial derivatives of the optimal profits with respect to q. When $q \le q_2$, the profits increase in q, and the profit under TS changes greatly. When $q > q_2$, the profits decrease in q in most areas, and the profit under TS still has a large change. Thus, in summary, q has a greater (smaller) impact on TS (CS), and the above conclusions are consistent with the findings in the basic model.



(a) $q = 0.1$ (b) $q = 0.5$

(c) $\alpha = 0.2$

Fig. 6. Parameter influence comparisons: Exogenous quality.

Based on the optimal profits (in Lemmas 4 and 5) and correlation analysis (in Lemma 6), the following Proposition 2 compares the optimal profits under the two selling strategies.

Proposition 2 (*Profit Comparison: Exogenous Quality*). *The optimal selling strategy is jointly determined by initial funding K, product quality q, and opportunity cost coefficient α. Specifically, the optimal strategy is*

(i) *crowdfunding when $K < q^2/2$ or when $K \geq q^2/2$ and $q_3 < q \leq 2/(1+\alpha)$,*

(ii) *traditional selling when $K \geq q^2/2$ and $q \leq q_3$ (q_3 is defined in the appendix).*

When $K \geq q^2/2$, Proposition 2 is graphically illustrated in Fig. 7. The horizontal axis represents the opportunity cost coefficient α, and the vertical axis represents the product quality q. Fig. 7 shows that TS is more profitable than CS when the product quality is low, and CS yields higher profit otherwise. Moreover, with an increasing opportunity cost coefficient, the advantage of TS is decreasing ($\partial q_3/\partial \alpha < 0$). These findings are consistent with Proposition 1 in the basic model. The difference is that because product quality has a positive effect on consumer valuation, the creator can make decisions within a higher cost range.

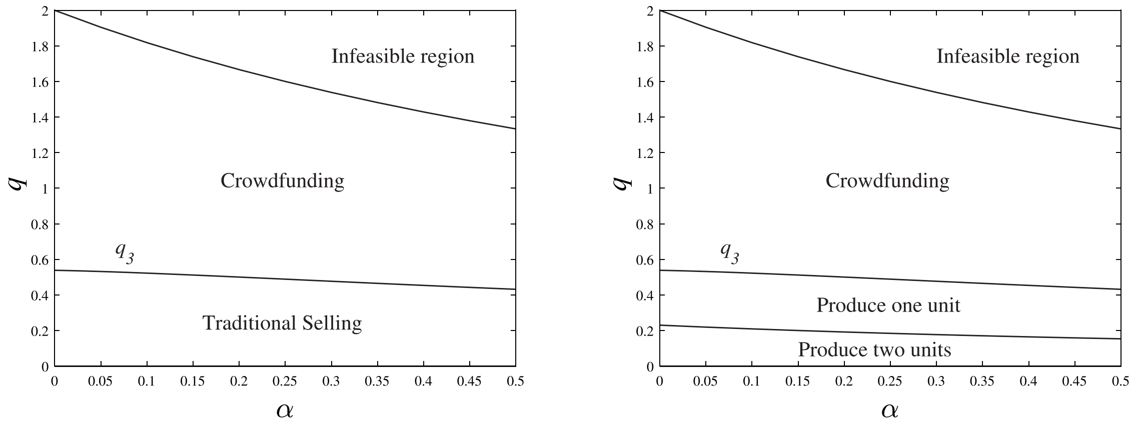
Using the optimal solutions in different quality ranges expressed in Proposition 2, Corollary 2 compares the eventual PRT under the two selling strategies in the exogenous quality case.

Corollary 2 (*PRT Comparison: Exogenous Quality*). *In the exogenous case, denote the PRT of CS, and of producing one and two units in TS as PRT_{CEX}, PRT_{TEX1}, and PRT_{TEX2}, respectively. When $K \geq q^2/2$, we obtain that*

(i) *producing one unit under TS always has a higher PRT than CS (i.e., $PRT_{CEX} < PRT_{TEX1}$ when $q \leq q_3$),*

(ii) *producing two units under TS always has a lower PRT than CS (i.e., $PRT_{TEX2} < PRT_{CEX}$ when $K \geq (1+\alpha)q^2$ and $q \leq (9-4\sqrt{3})/[9(1+\alpha)]$).*

The results in Corollary 2 are consistent with Corollary 1. When the product quality is exogenous, producing one unit in TS has the highest PRT. When the initial capital is sufficient, the PRT under CS is still higher than producing two units under TS when the quality is in the region where the latter is more profitable. Therefore, considering exogenous product quality does not affect the conclusions obtained in the basic model.



(a) $q^2/2 \leq K < q^2$ (b) $K \geq q^2$

Fig. 7. Crowdfunding vs. traditional selling: Exogenous quality.

Table 4
Optimal solutions: Endogenous quality.

Strategy	Condition	Quality	Price	Profit
CS	\	$q^*_{CEN} = \frac{1}{2(1+\alpha)}$	$p^*_{CEN} = \frac{1}{4(1+\alpha)^2}$	$\pi^*_{CEN} = \frac{1}{16(1+\alpha)^2}$
TS	$K < \frac{2}{27(1+\alpha)}$	$q^*_{TEN1} = \sqrt{\frac{2K}{1+\alpha}}$	$p^*_{TEN1} = \sqrt{\frac{2K}{3(1+\alpha)}}$	$\pi^*_{TEN1} = \frac{2}{9} \cdot \sqrt{\frac{6K}{1+\alpha}} - K$
	$K \geq \frac{2}{27(1+\alpha)}$	$q^*_{TEN1} = \frac{2\sqrt{3}}{9(1+\alpha)}$	$p^*_{TEN1} = \frac{2}{9(1+\alpha)}$	$\pi^*_{TEN1} = \frac{2}{27(1+\alpha)}$

4.2. Endogenous quality

Typically, the creator can decide the product quality during production (Hu et al., 2015; Bi et al., 2019). In this section, we treat the product quality as an endogenous decision to explore how the product line design may alter the optimal selling strategy.

From Section 4.1, we know the respective expected profits under crowdfunding and traditional selling strategies for any given product quality level q. Since the quality level is endogenous, the creator would decide the product quality and the price in order to maximize the expected profit. We summarize the main results in Lemma 7.

Lemma 7 (*Optimal Solutions: Endogenous Quality*). *The optimal solutions under crowdfunding and traditional selling strategies are given in Table 4.*

Lemma 7 first states that the optimal qualities, prices, and profits under two selling strategies are decreasing in the opportunity cost coefficient α. Second, the optimal production quantity under TS is always obtained at 1. The reason is that regardless of the initial funding K, the creator can always make more profit by producing fewer products with higher production quality ($q^*_{TEN2} < q^*_{TEN1}$), since doing so reduces the risk of demand uncertainty. Third, when the initial capital is small ($K < 2/[27(1+\alpha)]$), the profit is increasing in the initial capital ($d\pi^*_{TEN1}/dK > 0$). In this case, the optimal profit is obtained by producing a low-quality product because of capital constraints (corner solution). When the initial capital reaches a certain level ($K \geq 2/[27(1+\alpha)]$), the capital can cover the cost of optimal quality, and the optimal profit is no longer increasing in K (interior solution).

Using Lemma 7, we can compare the crowdfunding and traditional selling strategies adopted by the creator. The analytical results are shown in Proposition 3.

Proposition 3 (*Profit Comparison: Endogenous Quality*). *The optimal strategy is jointly determined by initial funding K and opportunity cost coefficient α. Specifically, the optimal strategy is crowdfunding when $K \leq K_1$, and traditional selling when $K > K_1$ (K_1 is defined in the appendix).*

Proposition 3 is graphically illustrated in Fig. 8. The horizontal axis represents the opportunity cost coefficient α, and the vertical axis represents the initial funding K. Proposition 3 and Fig. 8 show that when the product quality is endogenous, TS is more suitable for creators with sufficient initial funds, and CS yields higher profit otherwise. The advantage of TS is that the creator can obtain the optimal profit by producing a small quantity of high-quality products, and the small quantity minimizes the risk of demand uncertainty. When the capital is small, the revenue from TS decreases with less money invested. In this case, compared with TS, although there is a requirement for the threshold value under CS, the advantage of using consumers' money for production gradually appears. In this case, CS can help creators obtain sufficient funds to improve product quality, thereby obtaining higher profits.

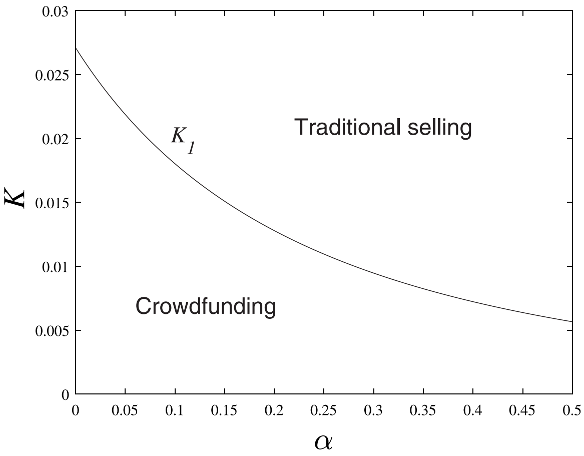


Fig. 8. Crowdfunding vs. traditional selling: Endogenous quality.

The indifference line of capital, K_1, is decreasing in the opportunity cost coefficient α ($dK_1/d\alpha < 0$). When the initial funding is medium-level, CS becomes a profitable selling strategy when the opportunity cost coefficient is small, and TS yields more profit otherwise. Different from the basic model and the exogenous case of product quality, when the quality is endogenous, the advantages of TS (CS) increase (decrease) as the opportunity cost coefficient increases. The reason is that, in this case, the optimal quality of the product is lower, and the opportunity cost coefficient has a small (large) impact on TS (CS) (proven in Lemma 6).

These findings have practical implications. Our results suggest that, in the case of endogenous product quality, creators should determine an appropriate selling strategy according to both the initial funding level and the opportunity cost coefficient. Under TS, the profit is closely related to the initial funding. Specifically, the profit decreases when initial capital is low. However, this relationship does not mean that the more initial capital creator has, the more profit it will make. For a market of a certain size, after the initial capital reaches a certain amount, the profit will not increase with further increases of the initial capital. Moreover, under TS, the startup funds should be used to improve product quality and thus improve product reputation, rather than blindly expanding the scale of production.

It is certain that CS is more suitable for creators who do not have much money. In this case, the creator should investigate the consumer's tolerance for the waiting time of a campaign (i.e., the opportunity cost incurred by the waiting). Kim et al. (2020) find that crowdfunding platforms can increase the investment demand by 21.7% and reduce the length of the fundraising period by 164 days by identifying and targeting the consumers who perceive smaller risk, opportunity cost and satiation.

Using the optimal solutions in Proposition 3, Corollary 3 compares the eventual PRT under two selling strategies in the endogenous quality case.

Corollary 3 (*PRT Comparison: Endogenous Quality*)**.** *In the endogenous case, denote the PRT of CS and producing one unit in TS as PRT_{CEN} and PRT_{TEN1}, respectively. Then $PRT_{CEN} < PRT_{TEN1}$ always holds.*

Since producing two units is not the optimal decision in the endogenous case under TS, Corollary 3 only compares the PRT of CS and producing one unit in TS. First, we find that in the endogenous case, PRT_{CEN} and PRT_{TEN1} are unrelated to the unit cost and opportunity cost coefficient. Second, regardless of the startup capital level, compared with CS, producing one unit in TS still has a higher PRT, which is consistent with the above conclusions.

5. Model extensions

The basic model discussed above helps to understand the conditions under which one selling strategy dominates the other. In this section, we discuss several extensions to our models to get a deeper understanding of the differences between the crowdfunding and traditional selling strategies. To strengthen our focus on each extension, in the rest of this section, we analyze the impacts of different factors and consider more general settings based on the model studied in Section 4.1 wherein the product quality is exogenous.

5.1. Salvage value

In this section, we extend our model by considering the salvage value $s > 0$ under TS. In this case, the leftover units can be sold in an exogenous salvage market at s per unit, where s satisfies $0 < s \leq q^2/2$. To focus on the derived results followed by introducing s, we postulate (1) the opportunity cost for either agent is $\alpha = 0$, and (2) the creator's initial funding is insufficient (i.e., $q^2/2 \leq K < q^2$).

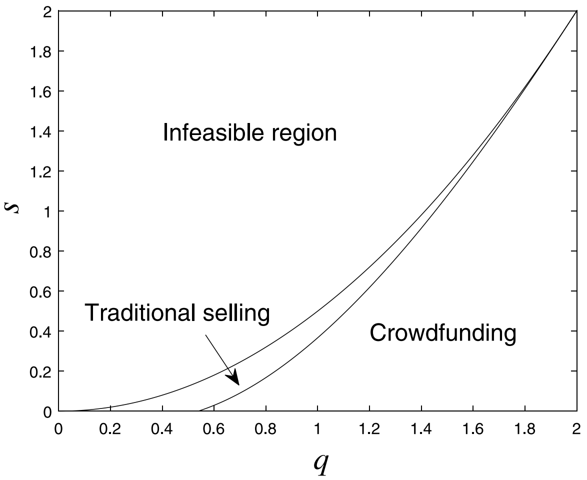


Fig. 9. Crowdfunding vs. traditional selling: Salvage value.

In this case, the creator can decide to produce quantity 0 or 1. When $Q = 1$, the expected profit is

$$\pi_S(p) = \left[\left(1 - \frac{p^2}{q^2}\right) p + \frac{sp^2}{q^2} - \frac{q^2}{2}\right]^+. \tag{5.1}$$

The second part above is the additional profit that the creator obtains in the salvage market. Then, the creator's decision objective is given by

$$\begin{aligned} \max_p \quad & \pi_S(p) \\ \text{s.t.} \quad & p \le q, \frac{q^2}{2} \le K < q^2. \end{aligned} \tag{5.2}$$

Since the demand always matches the supply under CS, the salvage value only influences TS. By solving for the optimal price decision in function (5.2), Proposition 4 describes how the optimal strategy varies with the product quality q and salvage value s.

Proposition 4 (*Profit comparison: Salvage value*)**.** *Define $\hat{s}$ as the salvage value equating the profits under the two selling strategies. By introducing the salvage value s in TS, we find*

(i) *the optimal price and profit are increasing in salvage value s under TS,*
(ii) *TS dominates CS when $q \le 0.54$ or when $q > 0.54$ and $\hat{s} < s \le q^2/2$, and CS is more profitable otherwise.*

Proposition 4 first states that the salvage value increases the advantage of TS (recall that TS dominates CS only when $q \le 0.54$ in the exogenous quality case). Second, when the product quality is large ($q > 0.54$), TS is preferable for a product with high salvage value. The reason is that the PRT is decreasing in the product quality ($\partial({p_S^*}^2/q^2)/\partial q < 0$) (because the valuation is first-power while the cost is quadratic with quality q), thus a higher salvage value is needed to compensate for the potential loss under TS.

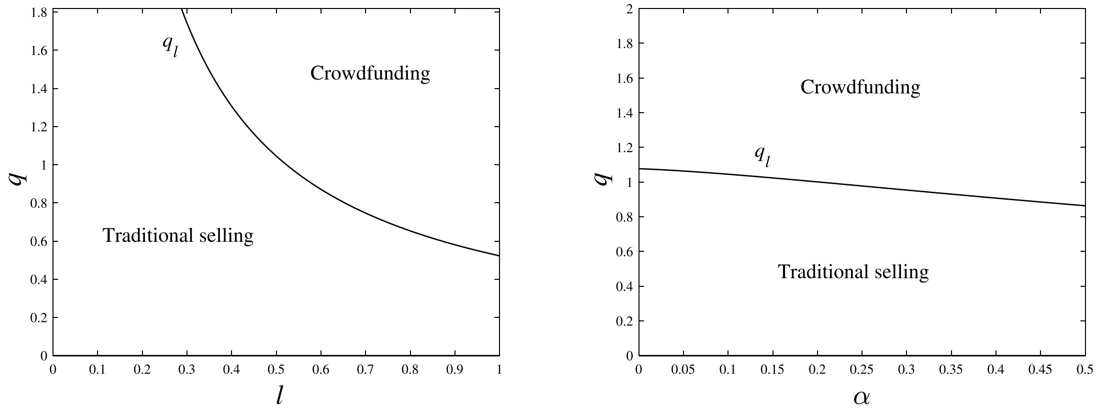
Proposition 4 is graphically illustrated in Fig. 9. The horizontal axis represents the product quality q, and the vertical axis represents the salvage value s. An intriguing phenomenon is seen: as s increases, the advantage of TS decreases. The reason is that a higher salvage value indicates a higher quality, which means the PRT under TS is lower. In this case, creators are better off transferring the risk of failure from themself to consumers. From another perspective, our finding also supports the previous conclusion that CS (TS) is preferable for projects with higher (lower) product quality (corresponding to higher (lower) cost).

5.2. Product quality coefficient

We posit that the quality cost is $q^2/2$ in the previous section. What will happen if we introduce the coefficient l on product quality? The following proposition investigates how the equilibrium varies with unit cost $lq^2/2$.

Proposition 5 (*Profit Comparison: Product Quality Coefficient*)**.** *Define q_l as the threshold value equating the profits under the two selling strategies. By introducing the product quality coefficient l, we find*

(i) *TS dominates CS if $l < \underline{l}$ or $l \ge \underline{l}$ and $q < q_l$, and CS outperforms TS otherwise ($\underline{l}$ is defined in the appendix);*
(ii) *the threshold value q_l is decreasing in product quality coefficient l and opportunity cost coefficient α. Formally, $\partial q_l/\partial l < 0$ and $\partial q_l/\partial \alpha < 0$ if $l \ge \underline{l}$.*



(a) $\alpha = 0.1$ (b) $l = 0.5$

Fig. 10. Crowdfunding vs. traditional selling: Product quality coefficient.

As shown in Fig. 10, Proposition 5 states that if l is sufficiently small ($l < \underline{l}$), TS always performs well. If l is large ($l \geq \underline{l}$), the equilibrium depends on the quality of the product: CS is more profitable if the quality is large, and TS is profitable otherwise. Furthermore, CS becomes more advantageous with increasing l and α since it can test the market environment ex ante. Those observations are consistent with the primary conclusions in our basic model.

5.3. Keep-It-All in crowdfunding

In practice, most existing crowdfunding platforms, including JD Finance and Kickstarter, adopt the All-Or-Nothing (AON) model, but a few platforms, such as Lendingclub.com and Kiva.org, do adopt the Keep-It-All (KIA) model. In this part, we compare the crowdfunding and traditional selling strategies in the situation where either of the two models could be adopted in crowdfunding.

In the KIA model, creators keep the entire pledged amount, regardless of whether the stated funding target is reached. If the target is reached, creators produce high-quality products as is done using the AON model. If the goal is not reached, creators can scale the project (e.g., perhaps a portion of the planned product is feasible) at a level that individuals still obtain utility from the reward (Cumming et al., 2020). In this case, owing to the creator's incentive to abandon the project and escape with the consumer's pledges, consumers' valuation of the product would be lower (Bi et al., 2019). By denoting the trust level as $\beta (0 < \beta \leq 1)$, we can express the pledging utility of a consumer as

$$u_{KIA} = \beta q V - (1+\alpha)p. \tag{5.3}$$

In this case, each consumer will pledge if and only if $u_{KIA} \geq 0$, that is, $V \in [(1+\alpha)p/\beta q, 1]$, and the pledging probability of each consumer is $(1 - (1+\alpha)p/\beta q)$. Therefore, the expected profit under KIA with exogenous product quality is

$$\pi_{KIA}(p) = 2\left(p - \frac{q^2}{2}\right)\left[1 - \frac{(1+\alpha)p}{\beta q}\right]^2 + 2\left[1 - \frac{(1+\alpha)p}{\beta q}\right]\frac{(1+\alpha)p}{\beta q}\left(p - \frac{q^2}{2}\right). \tag{5.4}$$

The first term describes the expected profit when two consumers sign up, and the second term describes the expected profit when only one consumer signs up. The creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{KIA}(p) \\ \text{s.t.} \quad & \frac{q^2}{2} \leq p \leq \frac{\beta q}{1+\alpha}. \end{aligned} \tag{5.5}$$

We first compare the expected profits under AON and KIA, and summarize the main results in Lemma 8.

Lemma 8 (*Profit Comparison: AON vs. KIA*)**.** *The optimal crowdfunding model is jointly determined by product quality q, trust level β, and opportunity cost coefficient α. Specifically, the optimal model is AON when $\beta \leq \beta_1$ and KIA when $\beta > \beta_1$ (β_1 is defined in the appendix).*

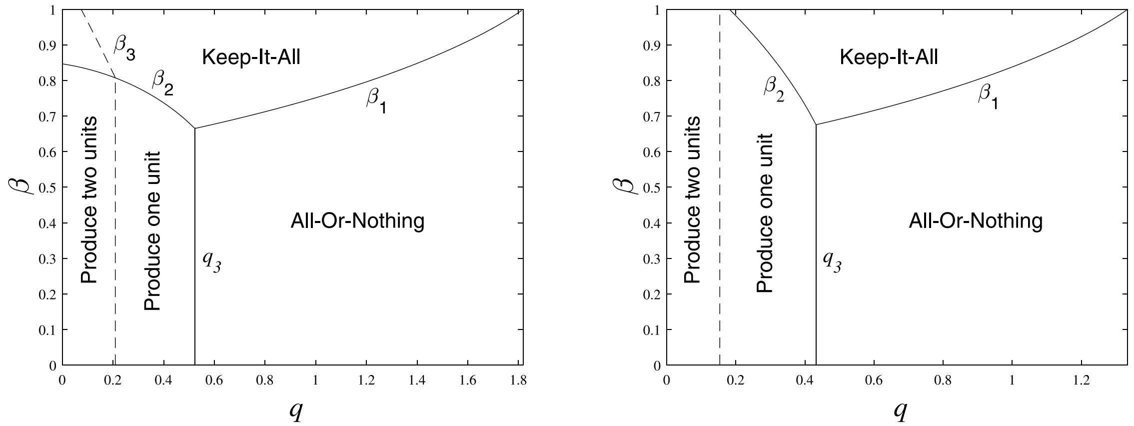
Lemma 8 states that KIA is more profitable when β is large, and AON yields more profit otherwise. We also find that β_1 is increasing in α and q ($\partial\beta_1/\partial q > 0$ and $\partial\beta_1/\partial\alpha > 0$). This happens because when α or q is increasing, consumers suffer more losses under KIA, so a high level of trust is required to compensate for the profit loss under KIA.

A formal comparison of the three optimal profits in Lemmas 5 and 8 leads to Proposition 6, which states the conditions under which each strategy dominates the others.

Table 5
Optimal strategy: Two crowdfunding models vs. traditional selling.

Optimal strategy	Required conditions		
	K	q	β
All-Or-Nothing	\	$q > q_3$	$\beta \leq \beta_1$
Keep-It-All	\	$q > q_3$	$\beta > \beta_1$
	$\frac{q^2}{2} \leq K < q^2$	$q \leq q_3$	$\beta_2 < \beta \leq 1$
	$K \geq q^2$	$\frac{9-4\sqrt{3}}{9(1+\alpha)} < q \leq q_3$	$\beta_2 < \beta \leq 1$
	$K \geq q^2$	$q \leq \frac{9-4\sqrt{3}}{9(1+\alpha)}$	$\beta_3 < \beta \leq 1$
Traditional selling	$\frac{q^2}{2} \leq K < q^2$	$q \leq q_3$	$\beta \leq \min\{\beta_2, 1\}$
	$K \geq q^2$	$\frac{9-4\sqrt{3}}{9(1+\alpha)} < q \leq q_3$	$\beta \leq \min\{\beta_2, 1\}$
	$K \geq q^2$	$q \leq \frac{9-4\sqrt{3}}{9(1+\alpha)}$	$\beta \leq \min\{\beta_3, 1\}$

Note. β_2 and β_3 are defined in the appendix.



(a) $\alpha = 0.1$ (b) $\alpha = 0.5$

Fig. 11. Two crowdfunding models vs. traditional selling.

Proposition 6 (*Profit Comparison: Two Crowdfunding Models vs. Traditional Selling*)**.** *The optimal selling strategy is jointly determined by the initial funding K, product quality q, trust level β, and opportunity cost coefficient α. Specifically, the optimal strategy is shown in Table 5.*

Proposition 6 is graphically illustrated in Fig. 11. The horizontal axis represents the product quality q, and the vertical axis represents the trust level β. Fig. 11 shows that, when q is large ($q > q_3$), KIA dominates AON when β is large, and AON is more profitable otherwise.

Next, we compare TS and the KIA model. First, for creators with sufficient funds ($K \geq q^2$), producing two units under TS (to the left of the dashed line) is more profitable when the product quality is low. Second, for creators with insufficient funds ($q^2/2 \leq K < q^2$), when the opportunity cost coefficient is low (in Fig. 11(a)), producing one unit under TS can yield more profit when the trust level and product quality are low. This is because TS has a higher PRT at a lower level of trust. When the opportunity cost coefficient is high (in Fig. 11(b)), compared with Fig. 11(a), the creator can profitably adopt TS with a higher level of trust. We find that as the opportunity cost coefficient increases, the advantage of TS (the KIA model) increases (decreases). This is consistent with the finding in the exogenous quality case; that is, compared with crowdfunding, TS is less affected by opportunity cost when the product quality (cost) is small.

5.4. *Case with multiple consumers*

We now consider the case wherein there are $n(n \geq 2)$ potential consumers in the market. In CS, a project will succeed only if $m(2 \leq m \leq n)$ consumers choose to pledge, where m denotes the threshold value. Therefore, the expected profit of creator is

$$\pi_{CM}(p) = \sum_{i=m}^{n} C_n^i \left[1 - \frac{(1+\alpha)p}{q}\right]^i \left[\frac{(1+\alpha)p}{q}\right]^{n-i} i\left(p - \frac{q^2}{2}\right), i = m, m+1, \ldots, n. \tag{5.6}$$

In function (5.6), the probability that the creator can sell at least $i(m \leq i \leq n)$ products follows a binomial distribution. We consider the effects of the fund-raising goal on the profitability in different market sizes. In other words, for a certain target, we study the effects of different market sizes on the profit under CS. The creator's decision objective is given by

$$\begin{aligned} \max_{p} \quad & \pi_{CM}(p) \\ \text{s.t.} \quad & \frac{q^2}{2} \le p \le \frac{q}{1+\alpha}. \end{aligned} \tag{5.7}$$

Based on the expressions of π_{CM}, Proposition 7 shows how the number of potential consumers affects the optimal pledging price and profit under certain conditions.

Proposition 7. *In crowdfunding selling, $\pi_{CM}(p)$ is decreasing in m. When $m = n$, we obtain that*
(i) *p^*_{CM} and π^*_{CM} are decreasing in α,*
(ii) *p^*_{CM} is increasing in q, and decreasing in n,*
(iii) *π^*_{CM} is concave in q, and the optimal quality q^*_{CM} is decreasing in α and n,*
(iv) *π^*_{CM} is decreasing in n when $q \ge \hat{q}_{CM}$, and concave in n when $q < \hat{q}_{CM}$, and the optimal n_{CM} is given by the equality*

$$2e^{-\frac{1}{n_{CM}}}\left(1+\frac{1}{n_{CM}}\right) = 2-(1+\alpha)q,$$

where

$$q^*_{CM} = \frac{2}{(1+\alpha)(n+2)},\ p^*_{CM} = \frac{[2+n(1+\alpha)q]q}{2(n+1)(1+\alpha)},$$
$$\pi^*_{CM} = \frac{q}{(1+\alpha)}\cdot\left[\frac{n[2-(1+\alpha)q]}{2(n+1)}\right]^{n+1},\ \text{and}\ \hat{q}_{CM} = \frac{2-3e^{-2}}{1+\alpha}.$$

Proposition 7 first states that the expected profit is decreasing in the funding target. For projects with a higher fund-raising goal, in the same market environment, the threshold value is higher, so the PRT declines. When the funding target is high or the potential market is small ($n = m$), the price increases in the product quality q and the profit is concave in q; also, the optimal price and profit are negatively correlated with the opportunity cost coefficient α. These findings are consistent with the previous conclusions. We also analyzed the correlation between the optimal profit and the potential consumer count n. When the product quality is high ($q > \hat{q}_{CM}$), the more potential consumers there are, the less the profit. When the product quality is low ($q \le \hat{q}_{CM}$), the optimal profit increases when there are fewer participants and decreases when there are more.

In TS, the creator needs to determine the production quantity $Q(0 \le Q \le n)$ that maximizes its profit. Therefore, we can derive the expected profit as follow:

$$\pi_{TM}(p,Q) = \begin{cases} \left[\left(1-\frac{p^n}{q^n}\right)p - \frac{(1+\alpha)q^2}{2}\right]^+ & Q = 1 \\ \left[\sum_{j=1}^{Q} C_n^j\left(1-\frac{p}{q}\right)^j\left(\frac{p}{q}\right)^{n-j} jp - \frac{(1+\alpha)Qq^2}{2}\right]^+ & j \le Q, Q = 2,3,\dots,n. \end{cases} \tag{5.8}$$

In function (5.8), the creator should determine the optimal quantity Q and price p according to the quality q and initial funding K. First, the expected profit must be positive. Second, when $Q = 1$, the probability that the product cannot be sold is $(p/q)^n$. When $2 \le Q \le n$, the probability that the creator can sell $j(j \le Q)$ products follows a binomial distribution. The creator's decision objective is given by

$$\begin{aligned} \max_{p,Q} \quad & \pi_{TM}(p,Q) \\ \text{s.t.} \quad & p \le q, K \ge \frac{Qq^2}{2}. \end{aligned} \tag{5.9}$$

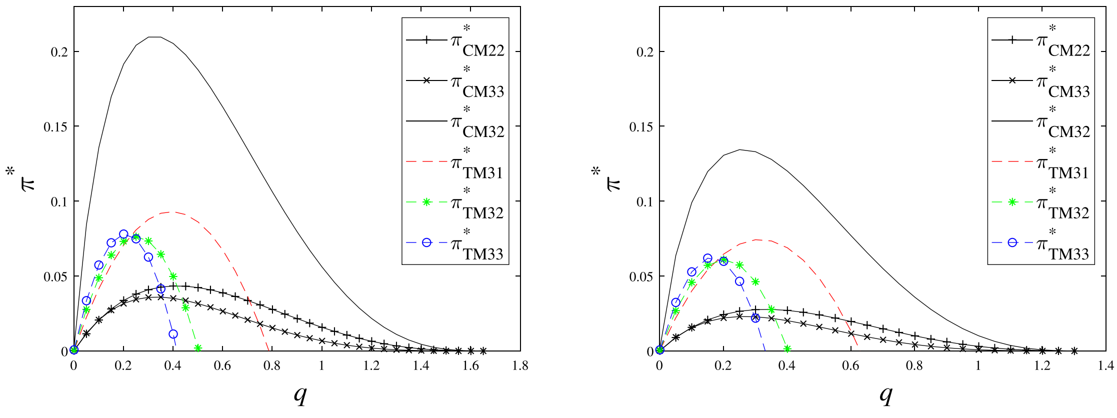
We now investigate the case that the creator's initial capital is limited. We show the results in Proposition 8.

Proposition 8. *In traditional selling, when $q^2/2 \le K < q^2$, the optimal solution of producing one unit in TS is given by:*
(i) *$\pi^*_{TM1} \ge 0$ when $q \le \bar{q}_{TM1}$,*
(ii) *p^*_{TM1}, π^*_{TM1}, and $\bar{q}_{TM1}$ are increasing in n,*
(iii) *p^*_{TM1} is increasing in q, and π^*_{TM1} is concave in q, where*

$$p^*_{TM1} = \frac{q}{(1+n)^{\frac{1}{n}}}, \pi^*_{TM1} = \left[\frac{qn}{(n+1)^{\frac{1+n}{n}}} - \frac{(1+\alpha)q^2}{2}\right]^+,\ \text{and}\ \bar{q}_{TM1} = \frac{2n}{(1+\alpha)(n+1)^{\frac{1+n}{n}}}.$$

Proposition 8 states that if just one product is produced, then we have both that the optimal price is increasing in the product quality q and the profit is concave in q. Moreover, the optimal price, profit, and the upper limit of product quality are all increasing in the number of potential consumers n. The reason is that, for any given production quantity, the more likely the product is to be sold, the greater the potential for profit margin improvement.

We obtain the optimal selling strategy based on the above conditions and summarize the main results in Proposition 9.



(a) $\alpha = 0.2$ (b) $\alpha = 0.5$

Fig. 12. Crowdfunding vs. traditional selling: Multiple consumers.

Proposition 9. *When $q^2/2 \leq K < q^2$ and $m = n$, the optimal strategy is*
(i) *crowdfunding selling when $n \leq n_M$ and $q > q_M$,*
(ii) *traditional selling when $n \leq n_M$ and $q \leq q_M$ or when $n > n_M$, (n_M and q_M are defined in the appendix).*

Proposition 9 reveals that when the potential market n is small ($n \leq n_M$), CS is more profitable when the product quality q is large, and TS yields more profit otherwise. These findings are consistent with the conclusions in Proposition 2. Moreover, because the profit under TS is increasing in n, while the profit under CS is decreasing in n, when n is large ($n > n_M$), TS always dominates CS. It should be noted that Proposition 9 only analyzes the special case of insufficient funding under TS and a higher funding target (or smaller market) under CS. In other cases, it is hard to directly compare the optimal strategy. We now consider a numerical study of the expected profits; the numerical results are shown in Fig. 12.

In Fig. 12, for the sake of simplicity and clarity, we take the size of the potential market as $n = 2, 3$ under CS. In this case, we can observe the trend of optimal profit as n increases while considering the potential loss of consumers. The solid line denotes the optimal profit under CS, and π^*_{CMnm} denotes the profit with potential consumers n and threshold value m. First, we find that the profit under CS is decreasing in m ($\pi^*_{CM33} \leq \pi^*_{CM32}$) and decreasing in n when $n = m$ and $n > n_{CM}$ ($\pi^*_{CM33} \leq \pi^*_{CM22}$). These conclusions have been proved in Proposition 7. Second, we find that the profit under CS is increasing in n when $m < n$ ($\pi^*_{CM22} \leq \pi^*_{CM32}$). That is to say, when the threshold value is determined, the profit under CS increases with the market size.

The dashed line denotes the optimal profit under TS, and π^*_{TMnQ} denotes the profit with n potential consumers and production quantity Q. We find that for well-funded creators, producing more products yields higher profit when the product quality is lower. Moreover, higher product quality requires creators to produce fewer products. These findings are consistent with our previous conclusions. Next, we compare the optimal profits under TS and CS. Considering that CS and TS may face different markets,[9] we consider two values of n in CS. When the markets for the two sale models are the same size, the smaller the threshold value, the higher the CS profit. When the market in TS is large, CS yields more profit for products with higher quality, and TS is more profitable otherwise. Moreover, when the potential market and threshold are equal under CS (i.e., for profits π^*_{CM22} and π^*_{CM33}), as the opportunity cost coefficient increases, the advantage of TS (CS) decreases (increases) (compare Fig. 12(a) and (b)). This finding is consistent with the above conclusion when only two potential consumers are in the market.

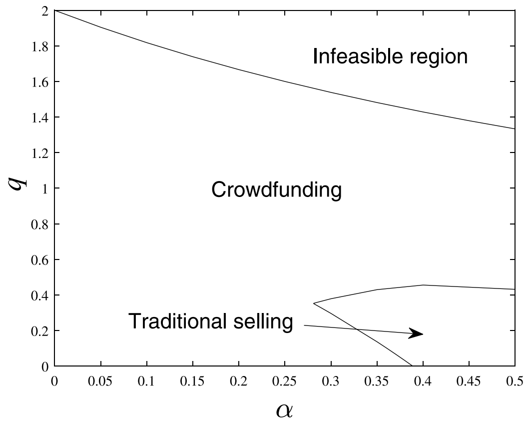
5.5. Normally distributed consumer valuation

In previous sections, we assume that the consumer valuation is uniformly distributed over the interval $[0, 1]$. To assess the robustness of our results, we now implement some numerical experiments by replacing the assumption of uniform distribution with the normal distribution $N(1/2, 0.12)$ over $[0, 1]$, and the cumulative distribution function denoted by Φ.[10] For simplification, under the assumption of normally distributed valuations, we only show the numerical results in Section 4.1 where the exogenous quality is considered.

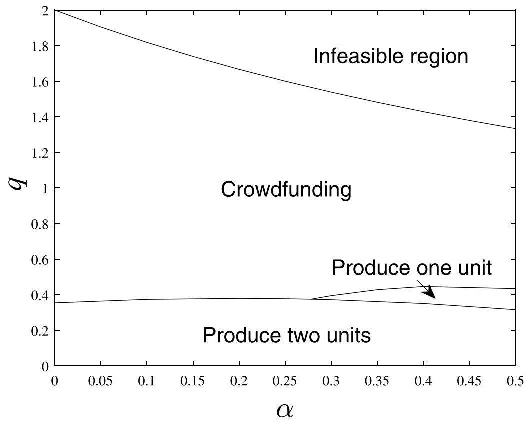
In CS, we can denote the pledging utility of a consumer by $u_{CN} = qV - (1+\alpha)p$. Hence, the pledging probability of each consumer is $[1 - \Phi((1+\alpha)p/q)]$, and the PRT of the project is $[1 - \Phi((1+\alpha)p/q)]^2$. Then, we can express the expected profit of the creator under

[9] For example, young people show a stronger desire to support crowdfunding projects because they are more willing to explore and accept new things (Wang and Yang, 2019). The elderly tend to have a higher aversion at the same level of risk, so they may prefer traditional selling based on paying cash on delivery, instead of paying first and waiting to obtain the product (Xu and Zhang, 2022).

[10] In this case, the market can be fully covered (i.e., $\Phi(1) = 1$).



(a) $q^2/2 \le K < q^2$



(b) $K \ge q^2$

Fig. 13. Crowdfunding vs. traditional selling: Normal distribution.

CS with exogenous product quality as

$$\pi_{CN}(p) = 2\left(p - \frac{q^2}{2}\right)\left[1 - \Phi\left(\frac{(1+\alpha)p}{q}\right)\right]^2. \tag{5.10}$$

The creator's decision objective is given by

$$\begin{aligned} \max_p \quad & \pi_{CN}(p) \\ \text{s.t.} \quad & \frac{q^2}{2} \le p \le \frac{q}{1+\alpha}. \end{aligned} \tag{5.11}$$

In TS, we denote the pledging utility of each consumer by $u_{TN} = qV - p$. In this case, each consumer will buy if and only if $u_{TN} \ge 0$. Thus, each consumer will pledge with probability $[1 - \Phi(p/q)]$ and decline with probability $\Phi(p/q)$. When $q^2/2 \le K < q^2$, the expected profit is

$$\pi_{TN1}(p) = \left[\left(1 - \Phi^2\left(\frac{p}{q}\right)\right)p - \frac{(1+\alpha)q^2}{2}\right]^+. \tag{5.12}$$

The creator's decision objective is given by

$$\begin{aligned} \max_p \quad & \pi_{TN1}(p) \\ \text{s.t.} \quad & p \le q, \frac{q^2}{2} \le K < q^2. \end{aligned} \tag{5.13}$$

When $K \ge q^2$ and $Q = 2$, the product will sell out with probability $[1 - \Phi(p/q)]^2$, one surplus product remains with probability $2[1 - \Phi(p/q)]\Phi(p/q)$, and two surplus products remain with probability $\Phi^2(p/q)$. The expected profit is

$$\pi_{TN2}(p) = \left[2p\left(1 - \Phi\left(\frac{p}{q}\right)\right)^2 + 2p\left(1 - \Phi\left(\frac{p}{q}\right)\right)\Phi\left(\frac{p}{q}\right) - (1+\alpha)q^2\right]^+. \tag{5.14}$$

Given $\pi_{TN}(p) = \max\{\pi_{TN1}(p), \pi_{TN2}(p)\}$, the creator's decision objective is given by

$$\begin{aligned} \max_p \quad & \pi_{TN}(p) \\ \text{s.t.} \quad & p \le q, K \ge q^2. \end{aligned} \tag{5.15}$$

The creator can choose either of the strategies to launch their project and decide the optimal price to maximize the expected profit.

In the normal distribution case for valuation V, it is hard to directly solve the optimal expected profits as we did in Section 4.1. We now numerically study the optimal expected profit; the numerical results are shown in Fig. 13.

Under consumer valuation following a normal distribution, the advantages of producing one unit under TS no longer exist when the opportunity cost coefficient is low. Specifically, for creators with insufficient funding (i.e., Fig. 13 (a)), TS dominates CS when the product quality is low and the opportunity cost coefficient is high, and CS yields more profit otherwise. For well-funded creators (i.e., Fig. 13 (b)), producing two units under TS is more profitable when the product quality is low. This result is consistent with Section 4.1. However, producing one unit under TS is more profitable only when the product quality is low and the opportunity cost is high. In summary, under the assumption of a normally distributed valuation V, the initial capital and opportunity cost coefficient greatly affect the optimal choice of strategy, so creators should decide the optimal strategy considering their specific economic conditions, the production time, and the current interest rate.

6. Conclusion

In this work, we study two types of selling strategies – crowdfunding and traditional selling – subsequently analyze the strategy choice and the corresponding operational decisions of the creator under different conditions. Specifically, under crowdfunding, we stress that the creator can utilize the funds from the consumers for production costs, so the opportunity cost is borne by the consumer. Under traditional selling, the creator must first invest, so the creator bears the opportunity cost and the risk of demand uncertainty.

Our theoretical analysis contributes several novel insights. First, the analyses of the basic model suggest that crowdfunding always dominates traditional selling when the creator's startup capital is limited. For the well-funded creator, crowdfunding yields more profit when the unit production cost is high, and traditional selling is more profitable otherwise. Our model explains that the advantages of crowdfunding are lower barriers to entry and lower demand risk, while traditional selling can reduce the creator's demand risk when producing a low-cost product. Second, when we generalize our basic model by considering the product quality decision, we show that, under traditional selling, the creator should determine the product quality according to its financial ability and always produce fewer products than the market demand. To be more specific, in the endogenous quality case, crowdfunding dominates traditional selling when the initial capital is small, and traditional selling is more profitable otherwise. Third, this study also offers implications for the creator in the extension section. For example, the Keep-It-All model might be a better choice when the consumer has a high level of trust in the crowdfunding project. When traditional selling has more potential consumers, crowdfunding might be more advantageous when the threshold number is small. The effects of startup capital and the opportunity cost coefficient on the strategy choice are more obvious under the normal distribution for consumer valuation.

This study offers insights into the two selling strategies, but it leaves interesting issues for future research. First, further theoretical and empirical analysis is needed to investigate project design elements such as a fixed time horizon and the herding effect. Second, the crowd, containing both informed and uninformed consumers, may arrive sequentially and rationally choose whether and how much to pledge. Therefore, the dynamics of consumer behavior would be another interesting direction for deeper research. Last, we suggest that crowdfunding and traditional selling be compared with many other selling strategies, including group buying and advance selling, to examine their impacts on market competition and channel relationships.

Acknowledgments

The work is supported by the National Natural Science Foundation of China (NSFC) [Grants 71971205, 72171220].

Appendix A. Supplementary data

Supplemental material to this paper is available at https://doi.org/10.1016/j.tre.2022.103011.

References

Agrawal, Ajay K., Catalini, Christian, Goldfarb, Avi, 2011. The Geography of Crowdfunding. National bureau of economic research.
Agrawal, Ajay, Catalini, Christian, Goldfarb, Avi, 2015. Crowdfunding: Geography, social networks, and the timing of investment decisions. J. Econ. Manag. Strategy 24 (2), 253–274.
Astebro, Thomas B, Fernández Sierra, Manuel, Lovo, Stefano, Vulkan, Nir, 2019. Herding in equity crowdfunding. In: Paris December 2018 Finance Meeting Eurofidai-AFFI.
Bala, Ram, Krishnan, V., Zhu, Wenge, 2014. Distributed development and product line decisions. Prod. Oper. Manage. 23 (6), 1057–1066.
Bayus, Barry L., 2013. Crowdsourcing new product ideas over time: An analysis of the Dell IdeaStorm community. Manage. Sci. 59 (1), 226–244.
Belleflamme, Paul, Lambert, Thomas, Schwienbacher, Armin, 2014. Crowdfunding: Tapping the right crowd. J. Bus. Ventur. 29 (5), 585–609.
Bi, Gongbing, Geng, Botao, Liu, Lindong, 2019. On the fixed and the flexible funding mechanisms in reward-based crowdfunding. European J. Oper. Res. 279 (3), 168–183.
Bi, Sheng, Liu, Zhiying, Usman, Khalid, 2017. The influence of online information on investing decisions of reward-based crowdfunding. J. Bus. Res. 71, 10–18.
Burtch, Gordon, Ghose, Anindya, Wattal, Sunil, 2013. An empirical examination of the antecedents and consequences of contribution patterns in crowd-funded markets. Inf. Syst. Res. 24 (3), 499–519.
Chan, C S Richard, Park, Haemin Dennis, Patel, Pankaj C, Gomulya, David M, 2018. Reward-based crowdfunding success: decomposition of the project, product category, entrepreneur, and location effects. Ventur. Cap. Int. J. Entrepreneurial Financ. 20 (3), 285–307.
Chen, Steven, Thomas, Sunil, Kohli, Chiranjeev, 2016. What really makes a promotional campaign succeed on a crowdfunding platform?: Guilt, utilitarian products, emotional messaging, and fewer but meaningful rewards drive donations. J. Advert. Res. 56 (1), 81–94.
Cornelius, Philipp Benjamin, Gokpinar, Bilal, 2020. The role of customer investor involvement in crowdfunding success. Manage. Sci. 66 (1), 452–472.
Cosh, Andy, Cumming, Douglas, Hughes, Alan, 2009. Outside enterpreneurial capital. Econ. J. 119 (540), 1494–1533.
Cumming, Douglas J., Leboeuf, Gaël, Schwienbacher, Armin, 2020. Crowdfunding models: Keep-it-all vs. all-or-nothing. Financ. Manage. 49 (2), 331–360.
Ellman, Matthew, Hurkens, Sjaak, 2019. Optimal crowdfunding design. J. Econom. Theory 184, 104939.
Gao, Qian, Guo, Xiaolong, Yang, Feng, Yu, Yugang, 2022. Commitment or not? Creator's quality strategies with uncertain market in reward-based crowdfunding. Int. J. Prod. Res. 60 (17), 5307–5331.
Gerber, Elizabeth M., Hui, Julie S., Kuo, Pei-Yi, et al., 2012. Crowdfunding: Why people are motivated to post and fund projects on crowdfunding platforms. In: Proceedings of the International Workshop on Design, Influence, and Social Technologies: Techniques, Impacts and Ethics, Vol. 2, No. 11. Northwestern University Evanston, IL, p. 10.
Hu, Ming, Li, Xi, Shi, Mengze, 2015. Product and pricing decisions in crowdfunding. Mark. Sci. 34 (3), 331–345.
Jing, Bing, 2007. Network externalities and market segmentation in a monopoly. Econom. Lett. 95 (1), 7–13.
Kang, Lele, Jiang, Qiqi, Tan, Chuan-Hoo, 2017. Remarkable advocates: An investigation of geographic distance and social capital for crowdfunding. Inf. Manage. 54 (3), 336–348.
Kim, Chul, Kannan, P.K., Trusov, Michael, Ordanini, Andrea, 2020. Modeling dynamics in crowdfunding. Mark. Sci. 39 (2), 339–365.
Kumar, Praveen, Langberg, Nisan, Zvilichovsky, David, 2020. Crowdfunding, financing constraints, and real effects. Manage. Sci. 66 (8), 3561–3580.

Kunz, Michael, Bretschneider, Ulrich, Erler, Max, Leimeister, Jan Marco, 2017. An empirical investigation of signaling in reward-based crowdfunding. Electron. Commer. Res. 17 (3), 425–461.
Kuppuswamy, Venkat, Bayus, Barry L., 2018. Crowdfunding creative ideas: The dynamics of project backers. In: The Economics of Crowdfunding. Springer, pp. 151–182.
Lambert, Thomas, Schwienbacher, Armin, 2010. An empirical analysis of crowdfunding. Soc. Sci. Res. Netw. 1578175, 1–23.
Larralde, Benjamin, Schwienbacher, Armin, 2010. Crowdfunding of small entrepreneurial ventures. Handbook of Entrepreneurial Finance, Vol. 1699183. Oxford University Press
Liu, Qiang, Liu, Xiaofeng, Balachander, Subramanian, 2021. Crowdfunding project design: optimal product menu and funding target. Prod. Oper. Manage. 30 (10), 3800–3811.
Lu, Tao, Chen, Ying-Ju, Tomlin, Brian, Wang, Yimin, 2019. Selling co-products through a distributor: The impact on product line design. Prod. Oper. Manage. 28 (4), 1010–1032.
Mollick, Ethan, 2012. The dynamics of crowdfunding: Determinants of success and failure. J. Bus. Ventur. 29 (1), 1–16.
Mollick, Ethan R., Kuppuswamy, Venkat, 2014. After the campaign: Outcomes of crowdfunding. UNC Kenan-Flagler Research Paper, No. 2376997.
Nie, Tengfei, Wang, Xinxiu, Zhu, Yangguang, Du, Shaofu, 2020. Crowdfunding mechanism comparison when product quality is uncertain. Int. Trans. Oper. Res. 27 (5), 2616–2657.
Peng, Jing, Zhang, Jianghua, Nie, Tengfei, Zhu, Yangguang, Du, Shaofu, 2020. Pricing and package size decisions in crowdfunding. Transp. Res. E 143, 102091.
Strausz, Roland, 2017. A theory of crowdfunding: A mechanism design approach with demand uncertainty and moral hazard. Amer. Econ. Rev. 107 (6), 1430–1476.
Valenzuela, Ana, Dhar, Ravi, Zettelmeyer, Florian, 2009. Contingent response to self-customization procedures: Implications for decision satisfaction and choice. J. Mar. Res. 46 (6), 754–763.
Wang, Zhengpei, Yang, Xue, 2019. Understanding backers' funding intention in reward crowdfunding: An elaboration likelihood perspective. Technol. Soc. 58, 101–149.
Xu, Yang, Song, Wen, Bi, Gong-bing, 2021. The roles of crowdfunding: financing, point provision and ex-post production. Int. J. Prod. Res. 59 (23), 7037–7056.
Xu, Shengshuo, Zhang, Zihao, 2022. Choosing a crowdfunding model considering strategic customer behaviour. Total Qual. Manag. Bus. Excell. 33 (7–8), 862–883.
Yang, Yunshen, Bi, Gongbing, Liu, Lindong, 2020. Profit allocation in investment-based crowdfunding with investors of dynamic entry times. European J. Oper. Res. 280 (1), 323–337.
Zhang, Jianqiang, Cao, Qingning, He, Xiuli, 2019. Contract and product quality in platform selling. European J. Oper. Res. 272 (3), 928–944.
Zheng, Haichao, Li, Dahui, Jing, Wu, Yun, Xu, 2014. The role of multidimensional social capital in crowdfunding: A comparative study in China and US. Inf. Manage. 51 (4), 488–496.