Crowdfunding Pricing Strategy of Innovative Products Considering Consumer Social Learning

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Abstract. Consumers are deliberate. When a product of unknown quality is launched on a crowdfunding platform, they may choose to postpone the purchase in order to observe the content of consumer reviews on the online platform, constantly update their beliefs about the product's quality, and make a more rational purchase decision. In the meantime, the reference price of crowdfunded products has a significant impact on consumer purchasing decisions. In this paper, we consider consumers' social learning behavior, develop a two-stage crowdfunding model with reference price influence, and investigate the optimal decision problem of crowdfunding promoters and consumers, providing theoretical references and managerial suggestions for crowdfunding promoters' two-stage pricing decisions.

Keywords: Crowdfunding · Pricing strategy · Social learning · Reference price

1 Introduction

Innovative products are especially popular on crowdfunding sites [1]. While innovative products avoid competition from other products, they also make it difficult for consumers to form an opinion about the quality of crowdfunded products. Consumers are unable to effectively identify information about product quality due to a lack of reference products on the market and an unclear information environment [2]. Consumers tend to observe other people's buying behavior and online reviews in the market and make judgments about the quality of products before deciding whether to buy them in this context of information asymmetry, resulting in a herding phenomenon. As a result, crowdfunding promoters can use the reference price effect to reduce the free-rider phenomenon caused by consumers' social learning behavior, thereby increasing crowdfunding success rates [3]. As a result, the purpose of this paper is to investigate the effects of social learning and reference price effects on crowdfunding pricing mechanisms [4].

M. F. b. Sedon et al. (Eds.): SSHA 2023, ASSEHR 752, pp. 322–328, 2023.
https://doi.org/10.2991/978-2-38476-062-6_40

Table 1. Related parameters

Symbols	Description
p_1, p_2	Crowdfunding stage price, Retail stage price
q	Consumers' perceptions of quality after participating in crowdfunding
q_m, q_n	A priori perception posteriori awareness of product quality
x	Consumer valuations on [0, 1] that follow a uniform distribution.
π	Expected profit
α	The activity of consumer reviews, $\alpha \in (0, 1)$
μ	Strength of the reference price effect, $\mu \in (0, 1)$
δ	Strategic consumer level, $\delta \in (0, 1)$
c	Cost of production per unit, $c \in (0, 1)$

2 A Crowdfunding Model that Considers Social Learning

2.1 Model Assumptions and Parameter Descriptions

Because the quality of innovative products is unknown, consumers can only perceive the quality of the products after they arrive, using $\overline{q}$ to denote consumer quality perceptions after purchasing the products, and consumers' perceptions of product quality follow a normal distribution $\overline{q} \sim N\left(q, \sigma^2\right)$.

The first group of consumers enters the crowdfunding market, and consumers form an a priori perception $\overline{q}_m$ of product quality q, $\overline{q}_m$ follows the normal distribution $\overline{q}_m \sim N\left(q_m, \sigma_m^2\right)$. Assume that some α consumers write product reviews and reveal their perception of quality q after purchasing the product on the platform.

In the retail phase, consumers update the a priori quality perception $\overline{q}_m$ to the a posteriori quality perception $\overline{q}_n \sim N\left(q_n, \sigma_n^2\right)$ according to Bayes' law. Customers who enter the crowdfunding market during the crowdfunding phase are n. The number of online reviews in the retail phase is αn, with an average rating of R. According to the literature [5], consumers' a posteriori product quality perceptions can be further expressed as $q_n = \frac{n\alpha\gamma}{n\alpha\gamma+1}R$ and $\sigma_n^2 = \frac{\sigma_\varepsilon^2}{n\alpha\gamma+1}$, and $\gamma = \sigma_\varepsilon^2/\sigma^2$ is the ratio of ex-ante quality uncertainty to review noise. Because consumers must form rational beliefs about q_n in order to predict the expected utility of the retail stage in the crowdfunding stage, q_n is treated as a random variable in the crowdfunding stage, with a mean of 0 and a variance of $\sigma_m^2 \frac{n\alpha\gamma}{n\alpha\gamma+1}$. The expected posterior distribution of q_n is denoted by $f(\cdot; z)$ as a probability density function with mean 0 and standard deviation σ_z, where $\sigma_z = \sigma_m\sqrt{(1-z)\alpha\gamma/\left[(1-z)\alpha\gamma+1\right]}$. As show in Table 1.

2.2 Foundational Model of Unsocial Learning

At the start of the crowdfunding period, the promoter announces the crowdfunding price and the retail price, when the retail price is the reference price in the eyes of the consumers and the crowdfunding price is the most recent price.

2.2.1 Consumer Decision Making

When $\alpha = 0$, $E[q_n] = q_m = 0$, there is no valid information about the crowdfunded product and no social learning process exists. At this time, the consumer's expected utility for the crowdfunding stage retail stage are $U_1 = x - p_1 + \mu(p_2 - p_1)$ and $U_2 = \delta(x - p_2)$. The consumer selects the crowdfunding stage purchase when $x \geq \tau(p_1, p_2)$, $U_1 \geq U_2 \geq 0$. Where:

$$\tau(p_1, p_2) = \begin{cases} p_1, & p_1 \leq p_2, \\ \frac{p_1(1+\mu) - p_2(\delta+\mu)}{1-\delta}, & p_1 > p_2, p_1(1+\mu) - p_2(\delta+\mu) \leq 1-\delta, \\ 1, & p_1 > p_2, p_1(1+\mu) - p_2(\delta+\mu) > 1-\delta. \end{cases}$$

(i) When $p_1 \leq p_2$, i.e., when the penetration pricing method is used, consumers with positive expected utility will buy the product during the crowdfunding stage.
(ii) Even if the skimming pricing method is used when $p_1 > p_2$ and $p_1(1+\mu) - p_2(\delta+\mu) \leq 1-\delta$, there will still be highly valued consumers who purchase the product at the crowdfunding stage in advance due to the small price difference between the different stages and considering the consumers' product preferences.
(iii) When $p_1 > p_2, p_1(1+\mu) - p_2(\delta+\mu) > 1-\delta$, i.e., when the skimming pricing method is used and the price difference between the crowdfunding stage and the retail stage is large, consumers will not choose to buy at the crowdfunding stage.

2.2.2 Decisions on Product Design

The profit function of the crowdfunding promoter is: $\pi = (p_1 - c)[1 - \tau(p_1, p_2) + \mu(p_2 - p_1)]^+ + (p_2 - c)[\tau(p_1, p_2) - p_2]^+$, where $[r]^+$ is defined as $\begin{cases} r, r \geq 0 \\ 0, r < 0 \end{cases}$. Substituting each of the three different expressions for $\tau(p_1, p_2)$ into the promoter's profit function.

Proposition 1. When $p_1 \leq p_2$, $p_1^* = \frac{1+c}{2}$, $p_2^* = 1$, $p_1^* = \frac{1+c}{2}$, $p_2^* = 1$, p_1^* and p_2^* are independent of μ, and π^* increases with μ.

Proposition 1 demonstrates that the promoter's pricing decision is independent of μ at this time, whereas the promoter's profit increases as μ increases. Because the crowdfunding price is lower than the retail price, the reference price at this time has a positive impact on consumers and increases their willingness to buy, and some consumers with low expected utility will choose to purchase the product sooner due to the reference price effect, increasing the crowdfunding promoter's profit.

Proposition 2. $P_1^* = \frac{c(1+\delta)+2\mu(1+c)+2}{\delta+4\mu+3}$, $p_2^* = \frac{2c+\delta+2\mu(1+c)+1}{\delta+4\mu+3}$, $\pi^* = \frac{\mu+(1-c)^2+2}{\delta+4\mu+3}$, and p_1^* decreases as δ and μ increase, p_2^* increases as δ and μ increase, and π^* decreases as μ increases when $p_1 > p_2$ and $p_1(1+\mu) - p_2(\delta+\mu) \leq 1-\delta$.

Proposition 2 demonstrates that the stronger the reference price effect, the greater the price difference between the crowdfunding and retail stages, demonstrating a phenomenon in which p_1^* decreases and p_2^* increases. Although the success rate of crowdfunding is higher at this time, and consumers are more inclined to buy the product

during the crowdfunding stage due to the reference price, the lower price at which most consumers buy reduces the promoter's profit.

Proposition 3. The optimal price is $p_1 > p_2$ and $p_1(1+\mu) - p_2(\delta+\mu) > 1-\delta$ when the price path satisfies $p_2^* = \frac{1+c}{2}$ and $\pi^* = \frac{(1-c)^2}{4}$. However, due to the crowdfunding mechanism's configuration, the crowdfunding fails at this time.

2.3 Models of Crowdfunding in the Presence of Social Learning

The consumer game's equilibrium then exhibits opposing forces: on the one hand, consumers expect a higher number of reviews at the retail stage and a higher number of consumers who delay their participation in the crowdfunding decision; on the other hand, the higher the number of consumers who delay their participation in the crowdfunding decision, the lower the number of reviews provided at the retail stage.

2.3.1 Consumer Decision Making

When $x \geq \theta(p_1, p_2)$, consumers will participate in crowdfunding, where:

$$\theta(p_1, p_2) = \begin{cases} y, \ p_1(1+\mu) - p_2(\delta+\mu) \leq 1-\delta \\ 1, \ p_1(1+\mu) - p_2(\delta+\mu) > 1-\delta \end{cases}$$

The only solution to the implicit equation $y - p_1 + \mu(p_2 - p_1) = \delta \int_{p_2-y}^{\infty}(y + q_n - p_2) f(q_n; y) dq_n$ is $y \in [p_1, 1]$. The left side of the equation represents consumers' expected utility to purchase at the crowdfunding stage, while the right side of the equation represents consumers' expected utility at the retail stage (delayed purchase), with the lower bound of the integral taken as $p_2 - y$ indicating that consumers will purchase at the retail stage when their expected utility is positive.

2.3.2 Decisions on Product Design

According to the above analysis of consumer purchasing strategies, the demand for the product during the crowdfunding stage is $D_1 = 1 - \theta + \mu(p_2 - p_1)$. Because q_n is random in the crowdfunding stage, the retail demand is:

$$D_2 = \begin{cases} 0 & q_n \leq p_2 - \theta, \\ \theta + q_n - p_2 & q_n - \theta < q_n \leq p_2, \\ \theta & q_n > p_2. \end{cases}$$

The crowdfunding sponsor's profit function is then $\pi = (p_1 - c)\left[1 - \theta + \mu(p_2 - p_1)\right] + (p_2 - c)\left(\int_{p_2-\theta}^{p_2}(\theta + q_n - p_2) f(q_n; \theta) dq_n + \int_{p_2}^{+\infty} \theta f(q_n; \theta) dq_n\right)$. Because the analytical expression for $\{p_1^*, p_2^*\}$ in the above profit function is difficult to find, the main properties of the optimal price are given below.

Proposition 4. There exists a threshold $\Delta(\gamma) \in [0, 1]$ such that if $\delta \geq \Delta(\gamma)$, the optimal price satisfies $p_1^* < p_2^*$.

According to Proposition 4, the presence of social learning causes the initiator's price path to shift from skimming pricing to penetration pricing. The reason for this is that, on the one hand, by mitigating the impact of the change in retail valuation caused by consumers' online reviews, which exacerbates consumers' strategy and essentially causes δ to increase, that δ increases, resulting in lower crowdfunding prices and higher retail prices. Charging consumers an information premium at the retail stage raises the price even further at the retail stage.

To calculate the optimal price under different reference price effect strengths, set the parameters and maximize the profit function. As shown in Fig. 1, increasing the reference price effect reduces p_1 and p_2, while decreasing p_1 even more. As shown in Fig. 2, μ at higher levels, when consumer strategy δ is low to medium, the initiator uses skimming pricing optimally; when δ is high, the firm uses penetration pricing optimally, i.e., pre-announcing the information premium at the retail stage. As μ increases, the threshold $\Delta(\gamma)$ rises, indicating that the reference price effect reduces p_1 to a greater extent, allowing penetration pricing to be used more widely.

The combined effect of social learning and the reference price effect on pricing strategy demonstrates that social learning causes a delay in consumers' pricing strategy, resulting in a decrease in p_1. The reference price effect reduces p_1 and encourages customers to buy the product sooner. In contrast to the absence of both social learning and reference price effects, the increase or decrease in p_2 is determined by the magnitude of these two effects. Finally, the promoter's profit changes are discussed. Because analytic

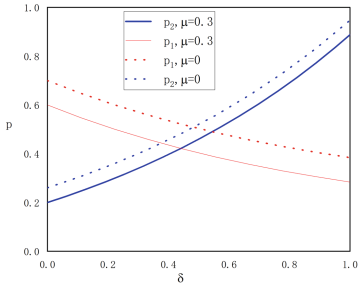

Fig. 1. Optimal price variation with $\delta(\alpha = 0.6, \gamma = 0.6, \sigma_n = 1, c = 0.2)$

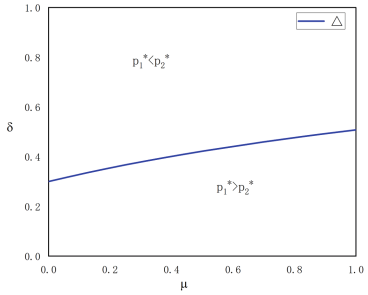

Fig. 2. Price path area map $(\alpha = 0.6, \gamma = 0.6, \sigma_n = 1, c = 0.2)$

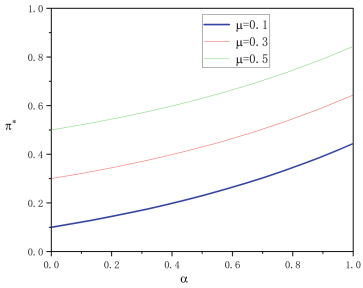

Fig. 3. Optimal profit variation with $\alpha(\gamma = 0.6, \sigma_n = 1, c = 0.2, \delta = 0.7)$

expressions for profit are difficult to obtain, the results of the numerical arithmetic example show (as shown in Fig. 3) that the promoter profit always increases as the review activity increases, implying that social learning is beneficial to the firm's profitability and that improving the reference price effect leads to an increase in the promoter optimal profit.

3 Conclusion

Although the Internet boom has aided in the development of crowdfunding models, existing literature typically treats consumer decisions as individual independent behaviors, ignoring the effects of social learning and reference price effects. Online reviews, product valuation, reference price, and patience level all influence consumer purchasing behavior. Social learning increases the number of strategic consumers while decreasing consumers' willingness to purchase products at the crowdfunding stage, whereas the reference price effect increases consumers' willingness to purchase products at the crowdfunding stage, resulting in a shift in crowdfunding sponsors' pricing strategy from skimming to penetration pricing. Even if consumers' strategic behavior has a negative impact, promoters can still benefit from it. This also provides crowdfunding promoters with some insights into announcing two-stage prices and developing penetration pricing strategies after entering the crowdfunding market, while also creating a good communication environment for consumers, disclosing more effective information about product quality, increasing consumer review activity, and bringing a positive impact on consumer social learning through information premiums to motivate consumers to participate in crowdfunding in advance.

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