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Information disclosure in hotelling competition: advertisement vs. blockchain

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Advertising is a widely used tool for (e-commerce) firms to disclose information, while blockchain has emerged as another choice in recent years. Under the framework of the Hotelling model, this paper studies (e-commerce) firms' selection of information disclosure tools and pricing strategy in a competitive market. We begin with the scenario where only advertising or blockchain is available to firms. Our analysis shows that excessive advertising may occur under advertising while there may exist multiple equilibria under blockchain. We then study the interplay between these two tools, and some interesting results are obtained. First, there may be a unique equilibrium, no equilibrium, or multiple equilibria of the game when choosing an information disclosure tool. Second, in the equilibrium where firms use different tools, the level of excessive advertising may be higher than in the scenario without blockchain. Third, counterintuitively, an increase in the advertising cost may discourage blockchain adoption but encourage advertisement. Finally, using the situation where both firms use advertising as a benchmark, we show that while the industry profit and social welfare can be either higher or lower, consumers are always worse off with blockchain adoption.

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Introduction

Consumers often struggle to assess key product attributes, such as safety and freshness, before purchase, creating a significant information asymmetry problem (Gupta, 2023; Zhang et al., 2022). Advertising has traditionally served as a primary tool for firms to communicate product features and shape brand image (Choi and Mela, 2019; Long and Amaldoss, 2024). However, firms possess a clear incentive to overstate product quality, a practice known as *deceptive advertising*. This issue is prevalent across industries. In the food sector, for instance, freshness labels can be manipulated by altering expiration dates, as seen in the Hema Fresh incident of 2018, and health benefits are often exaggerated. A notable case is Vitaminwater, which was marketed as a healthy alternative to soda despite containing nearly as much sugar per bottle. [1] Similarly, in the pharmaceutical industry, the efficacy of drugs is frequently overstated (Liao et al., 2025; Spigset, 1998; Wu et al., 2023). The unreliability of such firm-controlled information highlights a persistent credibility gap in marketing communications.

In response to this credibility gap, blockchain technology has emerged as a powerful tool for information disclosure. The proliferation of e-commerce and consumer demand for traceability has expanded blockchain's role beyond post-purchase verification into a pre-purchase marketing instrument. Firms can now embed product information, such as provenance and quality specifications, onto a tamper-proof, decentralized ledger. During the pre-purchase phase, consumers can instantly access this on-chain data, often by scanning a simple QR code, to authenticate claims before committing to a purchase (Wang et al., 2024; Zhou et al., 2022). This mechanism provides verifiable information at virtually no cost to the consumer, directly competing with the persuasive, yet often unsubstantiated, claims of traditional advertising (Wang et al., 2022). Major corporations like Walmart and Tyson Foods, for instance, already leverage this technology to grant consumers unprecedented transparency. [2] However, this credibility is not without its price, as blockchain adoption incurs significant fixed and variable operational costs for the firm (Wang et al., 2022).

Advertising and blockchain differ fundamentally as information signals. Advertising provides a flexible signal, allowing a firm to strategically position itself in the market. This flexibility, however, comes at the risk of high mismatch costs for consumers. In contrast, blockchain reveals a firm's true attribute, which minimizes these mismatch costs but sacrifices the firm's strategic flexibility. Firms, therefore, face a critical trade-off between the signaling flexibility of advertising and the signaling veracity of blockchain. For example, while Nestlé uses blockchain for product traceability, its competitor Mead Johnson relies on traditional advertising. Our paper explores this trade-off using a Hotelling model, where a firm's attribute is its location. We investigate when firms should choose advertising over blockchain and how these two tools interact in competition. Finally, we analyze the impact of these strategies on firm profits, consumer surplus, and social welfare.

We find some interesting conclusions. First, when a firm adopts blockchain for information disclosure, it will induce the other firm adopting advertising to choose an advertising level further from its true attribute, i.e., aggravating excessive or deficient advertising. The interpretation of these results is as follows. If the firms choose to disclose information through advertising, when the cost of advertising is low (high) enough, the firm conducts excessive (deficient) advertising. In the case with excessive advertising, if a firm switches to use blockchain, its disclosed attribute is reduced. Thus, the firm will lose competitive advantage in disclosing product information, thereby encouraging the other to advertise. That is, the advertising level of the other firm (which continues using advertising) is increased in equilibrium, thus being substantially higher than its true level. In contrast, in the case with deficient advertising, the firm switching to use blockchain gains competitive advantage in disclosing product information, thereby discouraging the other (which continues to advertise) from advertising.

Second, the decrease in the advertising cost may encourage a firm to switch from advertisement to blockchain for information disclosure. This counterintuitive result occurs when a firm's actual position/attribute is sufficiently high, in which case it will conduct excessive advertising. In this situation, the competition between firms is intensive, and blockchain adoption would ease the competition and become an equilibrium. Moreover, it is noteworthy that there may be no equilibrium in the information disclosure tool choice game.

Third, blockchain adoption by one or both firms may bring to a win-win situation for the whole industry and society, while it never benefits consumers. This seemingly paradoxical harm to consumers arises because one firm's adoption of blockchain can intensify competitive pressures, potentially leading the rival firm to engage in more extreme advertising. This behavior can result in greater market obfuscation and higher prices, which outweigh the transparency benefits for consumers. Finally, to ensure the applicability of our analytical results, we conduct a numerical study to check the robustness of our conclusion under different advertising and blockchain cost functions. The details are provided in Appendix B.

Our research contributes to the fields of information disclosure and blockchain operations. Our primary contribution is to reveal the potential downsides of blockchain adoption in competitive environments. We are the first to show that one firm's strategic move toward transparency can paradoxically exacerbate its rival's excessive advertising, offering a critical counterpoint to the generally positive view of the technology's impact on information environments. Furthermore, we derive managerial insights for introducing and regulating blockchain adoption by comparing blockchain adoption with advertising in a supply chain. We identify the conditions for implementing blockchain as a disclosure tool, providing guidance on when and how firms should implement and manage blockchain applications in the supply chain. Finally, our research contributes a nuanced welfare analysis by disentangling the technology's impact on different stakeholders. We reveal a critical conflict, showing that while blockchain adoption can create a win-win situation for firms and society, this outcome may come at the expense of consumer surplus. This highlights the importance of a stakeholder-level perspective when evaluating the societal value of new information technologies.

The remainder of this paper is structured as follows. "Literature review" introduces the correlation between the existing research and our research. "The basic model: no information disclosure" provides the main assumptions, model setting, and basic model without information disclosure. "Information disclosure via advertisement" considers the optimal decision of information disclosure through advertising. In "Information disclosure via blockchain," we discuss the optimal decision when firms disclose information via blockchain and discuss the scenario in which both advertising and blockchain are available to the firms. "The impact of blockchain on stakeholders" analyzes the influence of blockchain on industry profits, social welfare and consumer surplus. In "Model extension," we verify the robustness of the cost function of advertising and blockchain. "Conclusion" discusses the primary findings, management significance, and future research direction. The proofs of lemmas and propositions are provided in the Appendix.

Literature review

This study primarily involves three streams of research, namely blockchain, advertising, and information disclosure.

More and more research has focused on the effect of blockchain technology on operations management and business models (Kumar et al., 2018; Mithas et al., 2022; Morkunas et al., 2019). In this stream, the blockchain's characteristic as a guarantor of veracity is highlighted. For instance, applying blockchain technology to the supply chain can help customers to truly and completely understand the source, production, and custody of products (Montecchi et al., 2019). Chod et al. (2020) focus on the verifiability of supply chain information, claiming that blockchain is more effective than traditional oversight mechanisms in making the supply chain transparent. Moreover, blockchain technology can combat copycats in the supply chain (Pun et al., 2021; Shen et al., 2022). Many studies have demonstrated that blockchain improves the authenticity of product information and explored its value for the supply chain. For example, in a two-level supply chain, Cao et al. (2022) find that the quantity produced and the total profit of the supply chain increase in the presence of blockchain. Niu et al. (2022) consider the use of blockchain technology to disclose real-time component information of remanufactured products to risk-averse consumers, thus eliminating consumers' risk aversion and distrust about the quality of remanufactured goods. Zhong et al. (2023) compare whether manufacturers adopt blockchain technology in two competing channels and discover that when the cost of blockchain is lower, the level of blockchain adoption by manufacturers is higher. Through a comparative analysis of whether two platforms should adopt blockchain technology to disclose quality information, Wang et al. (2022) find that the use of blockchain technology ultimately depends on cost-effectiveness. In essence, this stream of literature establishes blockchain as a powerful tool for guaranteeing information veracity. However, firms possess other, more flexible tools for market communication, with advertising being the most prominent.

Advertisement can help enterprises gain more market share in a competitive environment. Some studies focus on deceptive advertising (Gupta, 2023), while others consider advertising cooperation strategies in supply chains; see, e.g., Aust and Buscher (2012); Bass et al. (2005); Karray (2015). In recent years, with the booming development of digital media, online advertising is becoming more popular than traditional advertising (Singal et al., 2022). Some digital platforms offer skippable advertising, sponsored content advertising, and targeted advertising to viewers (Chatterjee and Zhou, 2021; Dukes et al., 2022). As noted by De Giovanni (2011), improving the level of advertising and product quality are both beneficial strategies for companies. However, Piccolo et al. (2018); Zhang and Huang (2020) point out that creators/firms will use deceptive ads to exaggerate the quality of their products, and study how deceptive ads affect consumers' purchasing decisions. Rhodes and Wilson (2018) hypothesizes that a monopoly with product quality information can make false claims about the product quality and show that firms with low quality may choose to advertise falsely and that lower penalties for firms benefit consumers. Wu and Geylani (2020) examines the effect of penalizing deceptive claims on firms' deceptive advertising decisions when consumers are skeptical. The above literatures suggest that firms have incentives to publish false advertisements despite facing ex post penalties. The literature most relevant to our work from this stream is Moorthy and Shahrokhi Tehrani (2023), which examines targeting strategies for advertising and prices under a Hotelling model. While these studies thoroughly explore comparisons between different advertising models, they do not consider the competitive disruption posed by an entirely new class of verifiable disclosure technology, such as blockchain.

Product attribute information is an indispensable index for supply chain members to make decisions. Quality information is mostly disclosed by the manufacturer (Hotz and Xiao, 2013), and there are two common disclosure mechanisms: voluntary disclosure and compulsory disclosure (Cao et al., 2020). Generally, only enterprises with high-quality products will disclose quality information. However, in a competitive environment, less quality information is disclosed under voluntary disclosure (Guo and Zhao, 2009). Mandatory disclosure can promote competition, improve consumer surplus, and possibly improve market efficiency (Board, 2009). Some research in this field discusses which supply chain member should take responsibility for information disclosure. For instance, when the information between the supply chain members and consumers is asymmetrical, the supply chain members choose whether to disclose the real product information to consumers according to their own profits (Guan and Chen, 2015; Guo, 2009). In a fiercely competitive setting, Guan and Wang (2022) investigate whether firms disclose more quality information when consumers have prior expectations about product quality compared to perfectly rational consumers in a monopolistic environment and in an environment where quality information is shared or not between firms. Guo and Zhao (2009) examine the impact of different markets (competitive and monopolistic) and disclosure sequences on corporate quality disclosure. Wang et al. (2023) consider that e-tailers offer variable levels of product disclosure depending on the differences in experience and searchable attributes of the product. While our work shares the common goal of investigating the impact of information disclosure on social welfare and consumer surplus, it is fundamentally distinguished from prior studies. The existing literature largely examines voluntary versus mandatory disclosure mechanisms or the strategic choices of supply chain members, but does not consider the unique trade-offs presented by the choice between a flexible, non-verifiable signal like advertising and a rigid, verifiable one like blockchain.

The most proximate study to ours is Wang et al. (2022), which also examines blockchain adoption in a duopoly. Our findings diverge significantly due to a critical difference in the modeled strategic space. In Wang et al. (2022) the alternative to adopting verifiable technology is simply information asymmetry. In our framework, firms have an active alternative: non-verifiable, flexible advertising. This crucial distinction leads to contrasting conclusions. While they find blockchain adoption hinges on its cost-effectiveness, we uncover a more complex dynamic: a firm's adoption of truthful blockchain can paradoxically incentivize its rival to engage in more extreme deceptive advertising. Our core theoretical contribution, therefore, is the identification of this negative competitive externality, which challenges the prevailing view that verifiable technologies unilaterally improve the market's information environment.

The basic model: no information disclosure

In this paper, we consider a duopoly model with (e-commerce) firm 1 and (e-commerce) firm 2 in the market. In the following, we will refer to them as firm 1 and firm 2. They sell homogeneous products to consumers at price p_i ($i = 1, 2$); see, e.g., Zhou et al. (2023). For example, Coca-Cola and Pepsi are similar in function in terms of providing a refreshing and thirst-quenching experience to the consumers. However, they differ significantly in terms of taste, sweetness and brand image. We define c as the marginal cost of production and $R^j > 0$ ($j = n,\ a,\ b$) as the consumer's valuation of the product in scenario j, where $j = n, a, b$ refers to the scenario without information disclosure and with information via advertising or blockchain, respectively. The impact of advertising and blockchain on consumer utility is mainly in valuation

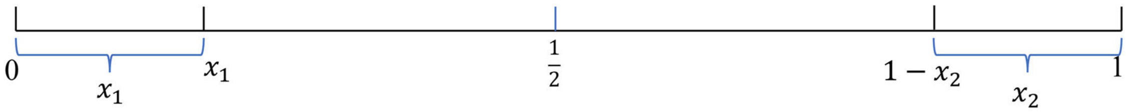

Fig. 1 Illustration of the firms' true position in the Hotelling line. Shows the relationship between the positions of the two symmetric firms at [0,1].

Table 1 Notations.

Notation	Definition
p_i	The product price of firm i ($i = 1, 2$)
c	The marginal cost of production
$R^j = R$	The consumer's valuation of the product ($j = n, a, b$)
x	Consumer taste; $x \in [0, 1]$
$x_1(1 - x_2)$	True position/product attribute of firm 1 (2); $x_1 = x_2 = l \in [0, 1/2]$
t	Consumer's unit disutility caused by buying undesired product, $t > 0$
s	Advertising level
k	Advertising cost rate
F	The setup cost of blockchain
f	The unit cost of blockchain

R^j and mismatch cost. According to business practices, consumers have higher product valuation R^b under blockchain disclosure because consumers have more trust in the information disclosed by blockchain due to its transparency and non-tamperability. On the contrary, consumers are suspicious of the information disclosed by advertising because of excessive advertising. Thus, in general, the product valuation of consumers is smaller under the disclosure via advertising than under the disclosure via blockchain, i.e., $R^a < R^b$. However, the analysis for such valuation change is straightforward. For the convenience of our analysis and to highlight the impact of information disclosure on mismatch cost, we assume that $R^n = R^a = R^b = R$, which has no effect on our main findings.

We use the linear Hotelling model as the analysis framework; that is, consumers are uniformly distributed on a [0,1] line segment representing a linear market and choose whether to buy the product from firm 1 or firm 2 (Hotelling1929). Without loss of generality, we normalize the consumer population N to 1 (Liu and Shum, 2013). The linear Hotelling model is not complicated, but can be used to simulate consumer heterogeneity. Since each consumer has their own ideal product (attribute), we can use the horizontal distribution of consumers in the Hotelling model to represent the taste differences between consumers. That is, consumers have different net valuations of the products from the two firms. Furthermore, the firms are heterogeneous in their ability to satisfy consumers' heterogeneous tastes in the sense that their true position, denoted by x_1 (for firm 1) and $1 - x_2$ (for firm 2), is predetermined at $0 \le x_1 \le 1/2 \le 1 - x_2 \le 1$, as shown in Fig. 1. Note that the location represents the attribute information of the product sold by the firm. As the position changes, the mismatch cost of some consumers decreases while the others' increases. The ideal position refers to the position that minimizes the total mismatch cost for the firm, and it is not hard to see that the ideal position for a monopoly firm is 1/2. Thus, as x_1 (resp., x_2) increases, the ability of firm 1 (resp., firm 2) to satisfy consumers' heterogeneous tastes increases as the firm becomes closer to the ideal position. For the sake of illustration, we assume that the two firms' positions are symmetric with respect to 1/2, i.e., $x_1 = x_2 = l \in [0, 1/2]$. The notations and definitions used in this paper are summarized in Table 1.

Without adopting any means of information disclosure, the firms' true position information is not disclosed to consumers, so consumers, as a group, undervalue the product. That is, the two firms are considered to be located somewhere less than l of the linear city by consumers. For convenience, we assume that the two firms are considered to be located at the extreme points of the linear city in the absence of information disclosure. This assumption increases the significance of information disclosure, which affects how consumers perceive the firms' positions. firm 1 is positioned at point 0, while firm 2 is situated at point 1. We use the superscript "n" to indicate the scenario in which the firm does not disclose its position. When neither firms discloses its position, the "net" utility that a consumer at [0,1] can get from firm 1 or firm 2, respectively, is

$$\begin{aligned} U_1^{nn}(p_1) &= R - p_1 - tx, \\ U_2^{nn}(p_2) &= R - p_2 - t(1 - x), \end{aligned} \qquad (1)$$

where $t > 0$ is the unit disutility caused by the firm not providing the desired product to the consumer, which we refer to as *mismatch sensitivity*. In order to focus on competition between firms and clearly demonstrate the main conclusions of our paper, we assume that every consumer will purchase products, which means that the market is fully covered. This assumption can be satisfied, for instance, when the consumer's valuation R of the product is large enough; see, e.g., Andritsos and Aflaki (2015); Huang et al. (2020b).

Assumption 1: *The product value is sufficiently large,* i.e., $R > c + 3t/2$.

Assumption 1 guarantees that all consumers buy products. Because higher costs of the product correspond to higher prices, the minimum product value that guarantees positive consumer utility becomes larger as costs increase. In addition, the high unit mismatch disutility reduces the consumer's net utility, so that the minimum product value that guarantees a positive consumer utility becomes larger as the unit mismatch disutility increases.

Let $x^{nn}(p_1, p_2)$ solve $U_1^{nn}(p_1) = U_2^{nn}(p_2)$ with respect to x. It is obvious that consumers in positions larger than $x^{nn}(p_1, p_2)$ will buy from firm 2, otherwise they will buy from firm 1. Therefore, the demands for firms 1 and 2 are $x^{nn}(p_1, p_2)$ and $1 - x^{nn}(p_1, p_2)$, respectively. Hence, the two firms' profits are given by $\pi_1^{nn}(p_1, p_2) = (p_1 - c)x^{nn}(p_1, p_2)$ and $\pi_2^{nn}(p_1, p_2) = (p_2 - c)(1 - x^{nn}(p_1, p_2))$.

Proposition 1. *When neither firm discloses its position, the equilibrium prices, denoted by* p_1^{nn} *and* p_2^{nn}*, are given by* $p_1^{nn} = p_2^{nn} = c + t$*, and the associated profits are* $\pi_1^{nn} = \pi_2^{nn} = t/2$.

Under Assumption 1, all consumers buy a product either from firm 1 or firm 2 at the equilibrium price. In fact, because the firms are treated as identical, it is easy to see that the indifferent consumer is located at $x = 1/2$, and according to (1), her net utility is positive under Assumption 1.

Information disclosure via advertisement

One of (traditional) information disclosure means is advertising. We use superscript "a" to indicate the scenario in which a firm discloses its position via advertising, and for convenience, we refer to this means of information disclosure as option a. As such, superscript "aa" refers to the scenario in which both firms take option a. The total advertising cost $K(s|l)$ is convex in the advertising level and independent of the production quantity and sales volume; see, e.g., Kultti and Pekkarinen (2021). Moreover, we assume that a firm's advertising cost is related to its position. Specifically, it is less costly for the firm to achieve the same advertising level if it is in a better position. For simplicity of analysis, we assume a quadratic form of the cost function. We also consider other cost functions, such as cubic, exponential, and fractional functions, to test the robustness of the conclusions. The details of our robustness testing with respect to different cost functions are given in Appendix B.

Assumption 2: *The advertising cost for advertising level $s \in [0, 1/2]$, denoted by $K(s|l)$, takes the following form:*

$$K(s|l) = \frac{k}{2}\left(\frac{s}{l}\right)^2,$$

where $k > tl^2/9$ is the advertising cost rate.

As we will see shortly, we rely on Assumption 2 (i.e., the quadratic convex function with a sufficiently large k) to ensure that the profit function of the firm is concave in the advertising level. A similar assumption is made in Yu et al. (2021), Huang et al. (2020a), and Fang et al. (2024). This proposed advertising cost function results in closed-form equilibrium solutions, which allow for further analysis, such as comparing different information disclosure modes.

In addition, the proposed advertising cost function possesses two more characteristics. Recall that l is the firm's true position (product attribute) while s is the advertising level. The term, s/l, thus measures the relative advertising effort. Assumption 2 specifies that the advertising cost is convex in the relative advertising effort. Here comes the first characteristic of the advertising cost function: the return of relative effort exertion is diminishing. The second characteristic is that the advertising cost decreases with the firm's position/product attribute l, which has been acknowledged by Chenavaz and Jasimuddin (2017), Moorthy and Hawkins (2005), and Orzach et al. (2002). Moreover, one can check that this characteristic leads to an optimal advertising level increasing with l, which is consistent with the phenomenon that the products of better attribute are more heavily advertised (Ackerberg, 2003; Caves, 1986; Chenavaz and Jasimuddin, 2017; Nelson, 1975).

When both firms take option a, the events occurred in the following order. Firstly, the two firms choose their own advertising levels $s_1 \in [0, 1/2]$ and $s_2 \in [0, 1/2]$. Secondly, they engage in price competition.

In our model, firms can choose an advertising level s that differs from their true attribute l. This allows for two possibilities. We define **excessive advertising** as the case where a firm's advertised position is overstated, i.e., $s > l$. This strategy can be attractive as it moves the firm's perceived position closer to the ideal point of 1/2. Conversely, we define **deficient advertising** as the case where $s < l$, which may occur if a firm is unwilling to bear the high costs associated with promoting its product.

In practice, excessive advertising can have negative consequences for firms, such as diminished consumer willingness to buy in the future or penalties from market regulators. Suppose the negative utility of excessive advertising for the firm is $P((s-l)^+)$. However, it usually takes time for excessive advertising to be recognized by consumers and market regulators, and our focus is on the effect of excessive advertising on competition in the short term. For analytical tractability, we therefore assume that this negative utility is normalized to zero, which does not affect the robustness of our main conclusions.

Given the advertising levels (s_1, s_2), the net utility that a consumer at [0, 1] can get from firm 1 or firm 2, respectively, is

$$\begin{aligned} U_1^{aa}(p_1|s_1, s_2) &= R - p_1 - t|x - s_1|, \\ U_2^{aa}(p_2|s_1, s_2) &= R - p_2 - t|1 - s_2 - x|. \end{aligned}$$

Let $x^{aa}(p_1, p_2)$ solve $U_1^{aa}(p_1|s_1, s_2) = U_2^{aa}(p_2|s_1, s_2)$ with respect to x. Then, the demands for firms 1 and 2 are $x^{aa}(p_1, p_2|s_1, s_2)$ and $1 - x^{aa}(p_1, p_2|s_1, s_2)$, and the profit functions are given by $\pi_1^{aa}(p_1, p_2|s_1, s_2) = (p_1 - c)x^{aa}(p_1, p_2|s_1, s_2) - \frac{k}{2}\left(\frac{s_1}{l}\right)^2$ and $\pi_2^{aa}(p_1, p_2|s_1, s_2) = (p_2 - c)(1 - x^{aa}(p_1, p_2|s_1, s_2)) - \frac{k}{2}\left(\frac{s_2}{l}\right)^2$, respectively. We solve the game by backward induction.

According to the preceding analysis, given (s_1, s_2), the equilibrium prices $p_1^{aa}(s_1, s_2) = \frac{(3+s_1-s_2)t}{3} + c$ and $p_2^{aa}(s_1, s_2) = \frac{(3+s_2-s_1)t}{3} + c$. Then, the associated profits are $\pi_1^{aa}(s_1, s_2) = \frac{(3+s_1-s_2)^2 t}{18} - \frac{k}{2}\left(\frac{s_1}{l}\right)^2$ and $\pi_2^{aa}(s_1, s_2) = \frac{(3+s_2-s_1)^2 t}{18} - \frac{k}{2}\left(\frac{s_2}{l}\right)^2$.

Proposition 2. The equilibrium advertising levels are $s_1^{aa} = s_2^{aa} = \min\left\{\frac{tl^2}{3k}, 1/2\right\}$, and the equilibrium prices are $p_1^{aa} = p_2^{aa} = t + c$. Correspondingly, the profits are $\pi_1^{aa} = \pi_2^{aa} = \max\left\{\frac{t}{2} - \frac{(tl)^2}{18k}, \frac{t}{2} - \frac{k}{8l^2}\right\}$.

When both firms take option a, they are in a better position in the market. However, because their positions are symmetric, their relative competitiveness does not change, and so, the product price does not change. Furthermore, we observe that the equilibrium advertising level s_1^{aa} increases in the mismatch sensitivity t and the firm's true position l but decreases in the advertising cost rate k. It is particularly noteworthy that s_1^{aa} increases in l. This is because as l increases, the cost of achieving a certain advertising level decreases.

Propositions 1 and 2 reveal a counterintuitive conclusion that disclosing information through advertising actually reduces firms' profits. This finding is in line with Tan et al. (2024), who explain that in a duopoly market, the costs associated with disclosure lead to lower profits for firms. Despite this, in a competitive environment, firms still have the incentive to advertise and disclose information about their products. If a competitor chooses to disclose information through advertising, the firm that does not disclose information will end up with lower prices and demand in the market, ultimately resulting in lower profits. Therefore, although firms would be more profitable if neither of them disclosed information, the competitive pressures lead to both firms opting to disclose information, even though it decreases their profits.

Corollary 1. *Excessive advertising happens when $k < tl/3$, whereas deficient advertising happens when $k > tl/3$.*

As Corollary 1 shows, the firm advertises excessively when the cost rate of advertising is sufficiently low, consumers' mismatch sensitivity is sufficiently large, or the firm's actual position is sufficiently high. While the conclusions regarding k and l are from the cost perspective, that regarding t is from the demand perspective. As t increases, consumers suffer more from the difference between their ideal product position and a firm's position (in its advertisement), thereby inducing the firm to advertise for a better position. As k increases or l decreases, the advertising cost for a certain level increases, thereby discouraging the firm from advertising a better position. Deficient advertising can be explained similarly.

Information disclosure via blockchain

Another tool of information disclosure is blockchain. We use superscript "b" to indicate the scenario in which a firm discloses its position via blockchain, and for convenience, we refer to this means of information disclosure as option b. As such, superscript "bn" refers to the scenario in which firm 1 takes while firm 2 does not take option b. Under option b, a firm can reveal its true position to consumers. The cost of adopting blockchain consists of two main components: a fixed investment and a variable unit cost (Li et al., 2022). The fixed cost, which we denote by F, represents the significant initial investment required to build and deploy the blockchain platform. The unit cost, denoted by f, is related to the number and size of transactions and is thus proportional to the sales quantity, q. It typically includes expenses for information verification, data storage, and energy consumption. Therefore, we formalize the total cost of blockchain adoption as a function of sales quantity q:

$$C_b(q) = F + fq.$$

For analytical tractability and to focus on the strategic decision of incurring the fixed investment, we follow the literature (e.g., Cao et al., 2022; Liao et al., 2025) and normalize the unit cost to zero (i.e., $f = 0$) in our main analysis. This simplification allows us to incorporate the fixed cost F directly into the firm's profit function. We later demonstrate that our key results are robust to the inclusion of a positive unit cost ($f > 0$) in "Unit cost of blockchain". Assume that both firms take option b. The net utility that a consumer at [0,1] can get from firm 1 or firm 2, respectively, is

$$\begin{aligned} U_1^{bb}(p_1) = \quad & R - p_1 - t|x - x_1|, \\ U_2^{bb}(p_2) = \quad & R - p_2 - t|1 - x_2 - x|, \end{aligned} \tag{2}$$

where $x_1 = x_2 = l$.

Let $x^{bb}(p_1, p_2)$ solve $U_1^{bb}(p_1) = U_2^{bb}(p_2)$ with respect to x. Then, the demands for firms 1 and 2 are $x^{bb}(p_1, p_2)$ and $1 - x^{bb}(p_1, p_2)$, and the profit functions are given by $\pi_1^{bb}(p_1, p_2) = (p_1 - c)x^{bb}(p_1, p_2) - F$ and $\pi_2^{bb}(p_1, p_2) = (p_2 - c)(1 - x^{bb}(p_1, p_2)) - F$, respectively.

Proposition 3. *Suppose that the two firms take option b. The equilibrium prices, denoted by p_1^{bb} and p_2^{bb}, are given by $p_1^{bb} = t + c$ and $p_2^{bb} = t + c$, and the associated profits are $\pi_1^{bb} = \frac{t}{2} - F$ and $\pi_2^{bb} = \frac{t}{2} - F$.*

When both firms take option b, the indifferent consumer is located at $x = 1/2$. It is worth noting that all consumers would definitely buy from one of the two firms under Assumption 1 because $U_1^{bb}(p_1^{bb})|_{x=0} > 0$, $U_2^{bb}(p_2^{bb})|_{x=1} > 0$, and $U_1^{bb}(p_1^{bb})|_{x=1/2} = U_2^{bb}(p_2^{bb})|_{x=1/2} > 0$.

Note that when firm 1 (resp., firm 2) does not take option b, we can set $x_1 = 0$ (resp., $x_2 = 0$) in all functions and $F = 0$ in its own profit function to obtain the equilibrium result. Thus, the result below follows.

Corollary 2. (i) *Suppose that firm 1 takes option b while firm 2 does not. The equilibrium prices, denoted by p_1^{bn} and p_2^{bn}, are given by $p_1^{bn} = \frac{(3+l)t}{3} + c$ and $p_2^{bn} = \frac{(3-l)t}{3} + c$, and the associated profits are $\pi_1^{bn} = \frac{(3+l)^2 t}{18} - F$ and $\pi_2^{bn} = \frac{(3-l)^2 t}{18}$.*

(ii) *Suppose that firm 2 takes option b while firm 1 does not. The equilibrium prices, denoted by p_1^{nb} and p_2^{nb}, are given by $p_1^{nb} = \frac{(3-l)t}{3} + c$ and $p_2^{nb} = \frac{(3+l)t}{3} + c$, and the associated profits are $\pi_1^{nb} = \frac{(3-l)^2 t}{18}$ and $\pi_2^{nb} = \frac{(3+l)^2 t}{18} - F$.*

In the following, we characterize the equilibrium regarding whether to take option b. Based on the payoff bimatrix, the equilibrium conditions for each type can be derived. Table 2 We find that the equilibrium regarding whether to take option b always exists, but it is not necessarily unique.

Proposition 4. *Both firms take option b if $F \le \frac{l(6-l)t}{18}$, either of the two firms takes option b while the other does not take option b if $\frac{l(6-l)t}{18} < F \le \frac{l(6+l)t}{18}$, and no firm takes option b if $F > \frac{l(6+l)t}{18}$.*

As Proposition 4 shows, there are multiple equilibria when the cost of disclosing information through blockchain is moderate, i.e., $\frac{l(6-l)t}{18} < F \le \frac{l(6+l)t}{18}$. Under this circumstances, either firm 1 takes while firm 2 does not take option b or firm 2 takes while firm 1 does not take option b. Moreover, when F is sufficiently large (resp., small), both firms do not take (resp., take) option b, which is consistent with the practice and the result of Li et al. (2022).

Table 2 The payoff bimatrix when adopting or not adopting blockchain.

A \ B	option b	option n
option b	(π_1^{bb}, π_2^{bb})	(π_1^{bn}, π_2^{bn})
option n	(π_1^{nb}, π_2^{nb})	(π_1^{nn}, π_2^{nn})

The impact of blockchain on advertising. In this part, we study the firms' choice of information disclosure tools. Note that if a firm chooses zero advertising level, information disclosure via advertising reduces to the case without information disclosure. Therefore, our analysis also accounts for the scenario where no information is disclosed. Suppose that a firm, say firm 1, takes option a, whereas the other, i.e., firm 2, takes option b. In this scenario, the events occurred in the following order. Firstly, firm 1 chooses its advertising level. Secondly, the two firms engage in price competition.

The net utility that a consumer at [0,1] can get from firm 1 or firm 2, respectively, is

$$\begin{aligned} U_1^{ab}(p_1|s_1) = \quad & R - p_1 - t|x - s_1|, \\ U_2^{ab}(p_2) = \quad & R - p_2 - t|1 - l - x|. \end{aligned}$$

Let $x^{ab}(p_1,\ p_2)$ solve $U_1^{ab}(p_1|s_1) = U_2^{ab}(p_2)$ with respect to x. Then, the demands for firms 1 and 2 are $x^{ab}(p_1,\ p_2|s_1)$ and $1 - x^{ab}(p_1,\ p_2|s_1)$, and the profit functions are given by $\pi_1^{ab}(p_1, p_2|s_1) = (p_1 - c)x^{ab}(p_1, p_2) - \frac{k}{2}\left(\frac{s_1}{l}\right)^2$ and $\pi_2^{ab}(p_1, p_2|s_1) = (p_2 - c)(1 - x^{aa}(p_1, p_2)) - F$, respectively.

According to the preceding analysis, given s_1, the equilibrium prices $p_1^{ab}(s_1) = \frac{(3+s_1-l)t}{3} + c$ and $p_2^{ab}(s_1) = \frac{(3+l-s_1)t}{3} + c$. Then, the associated profits are $\pi_1^{ab}(s_1) = \frac{(3+s_1-l)^2 t}{18} - \frac{k}{2}\left(\frac{s_1}{l}\right)^2$ and $\pi_2^{ab}(s_1) = \frac{(3+l-s_1)^2 t}{18} - F$.

Proposition 5. *When firm 1 takes option a and firm 2 takes option b, the equilibrium outcomes are as follows.*

(i) *If $k \le \frac{tl^2}{9}(7 - 2l)$, the equilibrium advertising level is $s_1^{ab} = 1/2$, and the equilibrium prices are $p_1^{ab} = \frac{(7-2l)t}{6} + c$ and $p_2^{ab} = \frac{(5+2l)t}{6} + c$. The resulting profits are $\pi_1^{ab} = \frac{(\frac{7}{2}-l)^2 t}{18} - \frac{k}{2}\left(\frac{1}{2l}\right)^2$ and $\pi_2^{ab} = \frac{(\frac{5}{2}+l)^2 t}{18} - F$.*

(ii) *If $k > \frac{tl^2}{9}(7 - 2l)$, the equilibrium advertising level is $s_1^{ab} = \frac{(3-l)tl^2}{9k - tl^2}$, and the equilibrium prices are $p_1^{ab} = \frac{3(3-l)tk}{9k - tl^2} + c$ and $p_2^{ab} = 2t - \frac{3(3-l)tk}{9k - tl^2} + c$. The resulting profits are $\pi_1^{ab} = \frac{(3-l^2)tk}{2(9k - tl^2)}$ and $\pi_2^{ab} = \frac{\left(6 - \frac{9k(3-l)}{9k - tl^2}\right)^2 t}{18} - F$.*

Proposition 5 shows the equilibrium outcomes when the firms use different tools for information disclosure. For the firm using blockchain, its attribute position is fixed at l. For the other firm using advertisement, its advertising level is fixed at the upper bound of 1/2 when the advertising cost rate k is sufficiently low; otherwise, the advertising level is below 1/2. Furthermore, we can show that the advertising level decreases with the advertising cost rate k but increases with the true attribute position l.

Table 3 The payoff bimatrix with advertisement or blockchain.

A \ B	option a	option b
option a	(π_1^{aa}, π_2^{aa})	(π_1^{ab}, π_2^{ab})
option b	(π_1^{ba}, π_2^{ba})	(π_1^{bb}, π_2^{bb})

Proposition 6. *The advertising level is higher (resp., lower) when firm 1 takes option a and firm 2 takes option b than when both firms take option a, i.e.,* $s_1^{ab} \geq s_1^{aa}$ *(resp.,* $s_1^{ab} < s_1^{aa}$*), if* $k \leq tl/3$ *(resp.,* $k > tl/3$*).*

Proposition 6 shows how the advertising level of a firm is affected when its rival adopts blockchain for information disclosure. The firm's blockchain adoption increases its rival's advertising level when the cost rate of advertising is low enough, i.e., $k < tl/3$. Recall from Corollary 1 that it is economical for both firms to advertise their position excessively if $k < tl/3$. Now, from option a to option b, the firm that chooses option b is known to have a worse position, i.e., from a position better than l to the position of l. As such, the benefit of increasing the advertising level increases so that $s_1^{ab} > s_1^{aa}$. As acknowledged by Sun and Li (2023) and Park et al. (2023), the food industry is prone to excessive advertising in the benefits of food. In these situations, blockchain adoption exaggerates excessive advertising. By contrast, if $k > tl/3$, the advertising level is lower than firm's actual position in the absence of blockchain. A firm gains a better competitive position when switching to the blockchain, which curtails the benefits of increased levels of advertising by its rival. As a consequence, $s_1^{ab} < s_1^{aa}$.

Note that when option a is available, option n is dominated. This is because firms that choose option a can mimic their action in option n by setting the advertising level to 0. Subsequently, Table 3 we deduce the equilibrium regarding the choice between option a and option b according to the following payoff bimatrix.

Proposition 7. *There exist* F_1 *and* F_2 *such that both firms take option a if* $F > F_1$*, both firms take option b if* $F < F_2$*, and either of the two firms takes option a while the other takes option b if* $F_2 \leq F \leq F_1$*, where*

$$(F_1, F_2) = \begin{cases} \left(\frac{\left(\frac{5}{2}+l\right)^2 t}{18} - \frac{t}{2} + \frac{k}{8l^2}, \frac{t}{2} - \frac{\left(\frac{7}{2}-l\right)^2 t}{18} + \frac{k}{8l^2}\right), & 0 < k \leq \frac{2tl^2}{3} \\ \left(\frac{\left(\frac{5}{2}+l\right)^2 t}{18} - \frac{t}{2} + \frac{(tl)^2}{18k}, \frac{t}{2} - \frac{\left(\frac{7}{2}-l\right)^2 t}{18} + \frac{k}{8l^2}\right), & \frac{2tl^2}{3} < k \leq \frac{tl^2}{9}(7-2l) \\ \left(\frac{\left(6-\frac{9k(3-l)}{9k-tl^2}\right)^2 t}{18} - \frac{t}{2} + \frac{(tl)^2}{18k}, \frac{t}{2} - \frac{(3-l)^2 tk}{2(9k-tl^2)}\right), & k > \frac{tl^2}{9}(7-2l) \end{cases}.$$

Furthermore, F_2 increases in k, while F_1 decreases in k if $\frac{2tl^2}{3} < k \leq \frac{tl^2}{9}(7-2l)$ and increases in k if $k \leq \frac{2tl^2}{3}$ or $k > \frac{tl^2}{9}(7-2l)$; $F_1 < F_2$ only if (i) $\underline{l} < l \leq \bar{l}$ and $k < tl/3$, or (ii) $l > \bar{l}$ and $k \in (\frac{tl^2}{9}((2l-1)^2 + \sqrt{(2l-1)^4 + 6^2}), tl/3)$, where $\underline{l} = \frac{15-\sqrt{217}}{8}$ and $\bar{l} = 2\sqrt{7}\cos\left(-\cos^{-1}(31\sqrt{7}/196)/3 + 300\right) - 1/2$.

Figure 2 plots F_1 and F_2 in different scenarios. Figure 2a shows that when $l < \underline{l}$, F_1 and F_2 have no intersection points in the dimension of k and there are multiple equilibria (one firm chooses blockchain while the other does not) when $F \in (F_2, F_1)$. This equilibrium structure is similar to that when advertisement is unavailable; see Proposition 4 for illustration. Figure 2b demonstrates the scenario with $\underline{l} < l \leq \bar{l}$, in which there is an

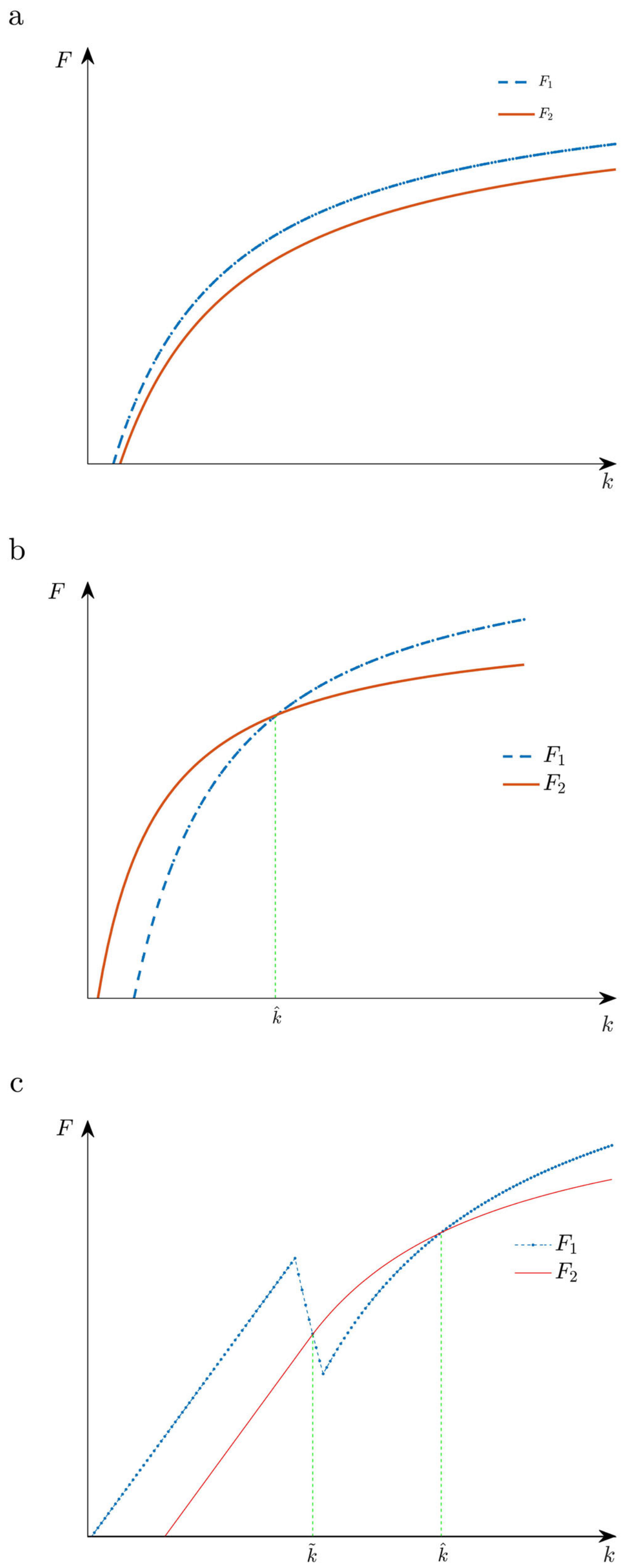

Fig. 2 Illustration of F_1 and F_2. The blue line represents F_1, and the red line represents F_2. **a** shows that when $l<\underline{l}$, F_1 and F_2 intersection points in the dimension of k and there are multiple equilibria (one firm chooses blockchain while the other does not) when $F \in (F_2, F_1)$. **b** shows that when $\underline{l}<l \leq \bar{l}$, there is an intersection between F_1 and F_2 in the dimension of k. **c** shows that when $l>\bar{l}$, there are two intersections between F_1 and F_2 in the dimension of k.

intersection between F_1 and F_2 in the dimension of k. When the advertising cost rate k exceeds the intersection point, the equilibrium structure is the same as that with $l < \underline{l}$ as shown in Fig. 2b. However, when k is smaller than the intersection point, multiple equilibria do not exist if $F \in (F_1, F_2)$: both firms use either blockchain or advertisement; for other values of F, the equilibrium is unique, in which both firms use either blockchain (if $F \le F_1$) or advertisement (if $F \ge F_2$). Note that the optimal advertising level increases in l and decreases in k. With a moderate l and a small k, the optimal advertising level is close to l, thereby resulting in similar profitability of blockchain adoption and advertisement. Thus, the equilibrium in which the firms use different information disclosure tools does not exist when F is moderate. Figure 2c illustrates the scenario with $l > \bar{l}$, in which F_1 and F_2 intersect twice in the dimension of k. In this scenario, the equilibrium structure when k exceeds the first intersection point is the same as that in Fig. 2b. When k is sufficiently small, the equilibrium structure is the same as that in Fig. 2a. With a small k and a large l, excessive advertisement occurs. However, because l is large, the return of advertising is large. As a result, the competition is rather intensive if the firms choose the same information disclosure tool. In other words, when F is moderate, one firm chooses blockchain while the other chooses advertisement.

According to Proposition 7 and Fig. 2, blockchain adoption occurs, i.e., at least one firm chooses blockchain, in the market when $F \le \max\{F_1, F_2\}$. Conventional wisdom suggests that as the advertising cost k increases, blockchain adoption is more likely to occur; that is, $\max\{F_1, F_2\}$ increases in k. However, our result indicates that this is not true when l is sufficiently large and k is moderate, as shown in Fig. 2c. The following is the explanation for this counterintuitive result. Note that the result is implied by the decreasing monotonicity of F_1 with respect to k in Fig. 2c. In this region, k is smaller than the first intersection point, and excessive advertisement occurs once a firm chooses advertisement. Consider $F = F_1$, by which both firms choose advertisement. As k increases, the degree of excessive advertisement is reduced, thereby resulting in less intensive competition between the firms. Suppose that one firm switches to blockchain; its position becomes inferior, thus encouraging further excessive advertisement by its rival. As a result, competition becomes more intensive. Hence, this strategy is not rational. To conclude, as k increases, it is more likely that both firms choose advertisement; that is, F_1 decreases in k.

The impact of blockchain on stakeholders

In this part, we explore the impact of blockchain adoption on the industry, consumers, and the whole system. Recall that multiple equilibrium in which one firm takes option a while the other takes option b is possible. For these scenarios, we assume that firm 1 takes option a and firm 2 takes option b. This assumption is without loss of generality because the performance indicators we consider are aggregated indicators of the two firms. In this part, we provide several numerical examples to more intuitively demonstrate the effect of advertising cost rate k on the blockchain cost threshold.

Industry profit. Denote π_I as the total profit of the industry. When both firms take option a, we have

$$\pi_I^{aa} = \pi_1^{aa} + \pi_2^{aa} = \begin{cases} t - \frac{k}{4l^2}, & k \le \frac{2tl^2}{3} \\ t - \frac{(tl)^2}{9k}, & k > \frac{2tl^2}{3} \end{cases}.$$

When both firms take option b, $\pi_I^{bb} = t - 2F$. When one firm takes option a while the other takes option b, we have

$$\pi_I^{ab} = \begin{cases} t + \frac{t}{9}\left(l - \frac{1}{2}\right)^2 - \frac{k}{8l^2} - F, & k \le \frac{tl^2}{9}(7-2l) \\ \frac{(3-l)^2 tk}{2(9k - tl^2)} + \frac{\left(6 - \frac{9k(3-l)}{9k - tl^2}\right)^2 t}{18} - F, & k > \frac{tl^2}{9}(7-2l) \end{cases}.$$

Lemma 1. (i) $\pi_I^{bb} > \pi_I^{aa}$ if $F < F_I^{bb}$, where

$$F_I^{bb} = \begin{cases} \frac{k}{8l^2}, & k \le \frac{2tl^2}{3} \\ \frac{(tl)^2}{18k}, & k > \frac{2tl^2}{3} \end{cases}.$$

(ii) $\pi_I^{ab} > \pi_I^{aa}$ if $F < F_I^{ab}$, where

$$F_I^{ab} = \begin{cases} \frac{t}{9}\left(l - \frac{1}{2}\right)^2 + \frac{k}{8l^2}, & 0 < k \le \frac{2tl^2}{3} \\ \frac{t}{9}\left(l - \frac{1}{2}\right)^2 - \frac{k}{8l^2} + \frac{(tl)^2}{9k}, & \frac{2tl^2}{3} < k \le \frac{tl^2}{9}(7-2l) \\ \frac{(3-l)^2 tk}{2(9k - tl^2)} + \frac{\left(6 - \frac{9k(3-l)}{9k - tl^2}\right)^2 t}{18} + \frac{(tl)^2}{9k} - t, & k > \frac{tl^2}{9}(7-2l) \end{cases}.$$

Because the analysis of comparing F_1, F_2, F_I^{bb}, and F_I^{ab} is intractable, we resort to numerical study. We plot these thresholds as functions of the advertising cost rate in Fig. 3 below. Recall that blockchain is adopted if $F < F_1$ or $F < F_2$, i.e., $F < \min\{F_1, F_2\}$. As Fig. 3 shows, conditional on $F < \min\{F_1, F_2\}$, the industry profit may or may not increase. Particularly, when the advertising cost rate k is low enough($k < 1$), the industry profit increases in the presence of blockchain adoption. However, when $k > 1$, blockchain adoption decreases the industry profit if F is sufficiently large; see $(k, F) = (1.4, 0.5)$ for an example. We have run a large number of instances and obtained the same conclusion as summarized in the following observation.

Observation 1: *When a firm or both firms find it beneficial to adopt blockchain in equilibrium, blockchain adoption increases the industry profit unless the advertising cost rate and fixed costs of adopting blockchain are both large enough.*

It is interesting to note that the condition under which blockchain adoption increases the industry profit requires a sufficiently low k rather than a high one. This result is somewhat counterintuitive because it is natural to believe that when the advertising cost rate is high, blockchain adoption is beneficial to the industry because this avoids the high advertising cost. However, when the advertising cost rate is low, the requirement for blockchain adoption by a firm or firms is more stringent, i.e.,

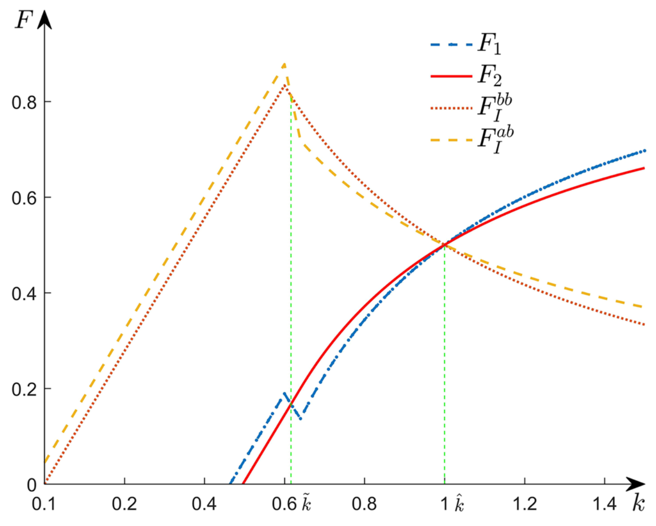

Fig. 3 The industry profit: $t = 10$, $l = 0.3$. It explores the changes in industry profits as advertising cost rates change in the presence of blockchain.

the upper bound of F is lower. With such a lower F, blockchain adoption benefits the industry.

Social welfare. Social welfare, denoted by SW, is the total net benefit of the whole system, which equals the difference between the total product value and the total cost. see, e.g., Wang and Buccella (2020). Particularly, the total cost includes the production cost and the cost of information disclosure and that associated with consumers' taste mismatch. Note that the firm's actual position should be used when we calculate the total taste mismatch. In the following, we calculate the equilibrium social welfare when both firms take option a. Recall that the indifferent consumer is at the midpoint of the line so that the total cost of taste mismatch equals $l^2 + (1/2{-}l)^2$. Together with Proposition 2, we have

$$SW^{aa} = \begin{cases} R - c - \left[l^2 + (1/2 - l)^2\right] - \frac{k}{4l^2}, & k \le \frac{2tl^2}{3} \\ R - c - \left[l^2 + (1/2 - l)^2\right] - \frac{(tl)^2}{9k}, & k > \frac{2tl^2}{3} \end{cases}.$$

Similarly, when both firms take option b, we have

$$SW^{bb} = R - c - [l^2 + (1/2 - l^2)] - 2F.$$

The calculation of social welfare when a firm takes option a while the other takes option b is complicated because the indifferent consumer is not necessarily located at the midpoint of the line. When a firm takes option a while the other takes option b, we have

$$SW^{ab} = \begin{cases} R - c - \left[l^2 + (x - l)^2/2 + (1 - l - x)^2/2\right] - \frac{k}{8l^2} - F, & k \le \frac{tl^2}{9}(7 - 2l) \\ R - c - \left[l^2 + (x - l)^2/2 + (1 - l - x)^2/2\right] - \frac{k}{2}\left(\frac{s_1^{ab}}{l}\right)^2 - F, & k > \frac{tl^2}{9}(7 - 2l) \end{cases}.$$

Lemma 2. $SW^{bb} > SW^{aa}$ if $F < F^{bb}_{SW}$, where

$$F^{bb}_{SW} = \begin{cases} \frac{k}{8l^2}, & k \le \frac{2tl^2}{3} \\ \frac{(tl)^2}{18k}, & k > \frac{2tl^2}{3} \end{cases},$$

$SW^{ab} > SW^{aa}$ if $F < F^{ab}_{SW}$, where

$$F^{ab}_{SW} = \begin{cases} \frac{k}{8l^2} - \left(\frac{1-2l}{12}\right)^2, & 0 < k \le \frac{2tl^2}{3} \\ \frac{(tl)^2}{9k} - \frac{k}{8l^2} - \left(\frac{1-2l}{12}\right)^2, & \frac{2tl^2}{3} < k \le \frac{tl^2}{9}(7 - 2l) \\ \frac{(tl)^2}{9k} - \frac{1}{36}\left(s_1^{ab} - l\right)^2 - \frac{k}{2}\left(\frac{s_1^{ab}}{l}\right)^2, & k > \frac{tl^2}{9}(7 - 2l) \end{cases}.$$

Due to the analytical intractability, we use numerical study to research the impact of using blockchain for information disclosure on social welfare. We present a representative example in Fig. 4. The numerical result for social welfare turns out to be similar to that for industry profit.

Observation 2: *When a firm or both firms find it beneficial to adopt blockchain in equilibrium, blockchain adoption increases the social welfare unless the advertising cost rate and fixed costs of adopting blockchain are both large enough.*

The effect of blockchain adoption on social welfare is driven by a trade-off between the efficiency gains from altered market competition and the total costs of information disclosure. The primary mechanism for the welfare increase is that when one or both firms adopt blockchain, they commit to a fixed, truthful position. This increased market differentiation softens price competition, allowing firms to secure higher profit margins. In most cases, this increase in producer surplus is the main driver for the overall growth in social welfare. However, when both the advertising cost rate (k) and the fixed cost of blockchain (F) are sufficiently high, the costs of information disclosure themselves become a significant drain on the system's total value. The efficiency gains from softened competition are no longer large enough to offset these substantial disclosure costs, leading to an overall decrease in social welfare.

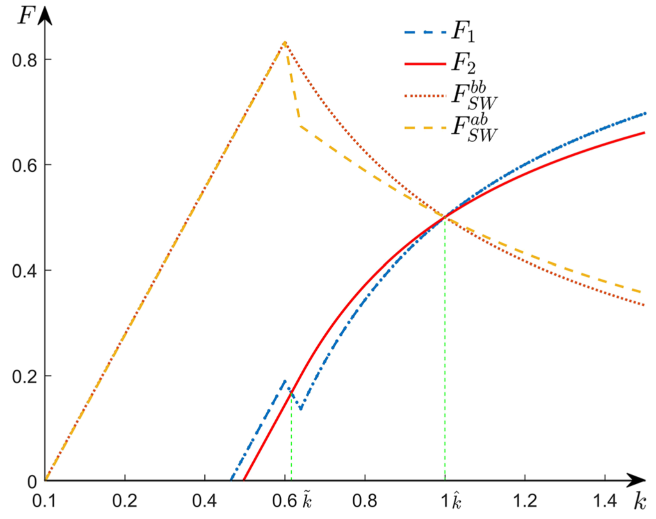

Fig. 4 Social welfare: $t = 10$, $l = 0.3$. It explores the changes social welfare as advertising cost rates change in the presence of blockchain.

Consumer surplus. In the end, we examine the impact of disclosing quality information via blockchain on consumer surplus. By definition, consumer surplus is equal to the difference between social welfare and industry profits; see, e.g., Wang and Buccella (2020). Recall that the indifferent consumer is at the midpoint of the line, so that the total cost of taste mismatch equals $l^2 + (1/2{-}l)^2$. Following this rule, consumer surplus can be calculated easily. In particular, when both firms take option a, consumer surplus is

$$CS^{aa} = R - (c + t) - \left[l^2 + \left(\frac{1}{2} - l\right)^2\right].$$

When both firms take option b, it is

$$CS^{bb} = R - (c + t) - \left[l^2 + \left(\frac{1}{2} - l\right)^2\right].$$

When a firm takes option a while the other takes option b, it is

$$CS^{ab} = \begin{cases} R - \left[c + t + \frac{t}{9}\left(l - \frac{1}{2}\right)^2\right] - \left[l^2 + (x - l)^2/2 + (1 - l - x)^2/2\right], & k \le \frac{tl^2}{9}(7 - 2l) \\ R - c - \left[l^2 + (x - l)^2/2 + (1 - l - x)^2/2\right] - \frac{k}{2}\left(\frac{s_1^{ab}}{l}\right)^2 - \frac{(3-l)^2 tk}{2(9k - tl^2)} - \frac{\left(6 - \frac{9k(3-l)}{9k - tl^2}\right)^2 t}{18}, & k > \frac{tl^2}{9}(7 - 2l) \end{cases}.$$

According to the expressions above, it is clear that consumer surplus does not change when both firms switch from advertisement to blockchain. This is because when the firms use the same tool, their competitiveness and the resulting market structure are the same. When the firms use different tools for information disclosure, the impact on consumer surplus is complex. We thus conduct numerical analysis to investigate it. As shown in Fig. 5, consumer surplus is reduced when only one firm finds it beneficial to adopt blockchain.

Observation 3: *Under the equilibrium conditions where blockchain adoption is profitable for one or both firms, we find that consumer surplus does not increase. Specifically, compared to the scenario where both firms use advertising, consumer surplus is often strictly lower when blockchain is introduced.*

Counterintuitively, the adoption of a transparency-enhancing technology such as blockchain could lead to a decrease in consumer surplus. The underlying mechanism, however, stems from the competitive interplay between the firms. When one firm commits to revealing its true attributes by adopting blockchain, it fundamentally alters the strategic incentives of its rival. Faced with a competitor whose information is now fixed and transparent, the advertising firm may find it optimal to engage in more *excessive* (or *deficient*) advertising. This is because a more extreme advertising position can serve as a powerful differentiation tactic, allowing the firm to carve out a distinct market niche and soften price competition.

This strategic response, however, imposes two distinct costs on consumers. First, the intensified product differentiation can lead to softer price competition, resulting in higher equilibrium prices overall. Second, the advertiser's more extreme positioning increases the total mismatch cost for the segment of consumers who purchase its product, as the perceived attributes deviate further from the true ones. Our analysis shows that, in equilibrium, these negative effects—higher prices and greater mismatch costs—often outweigh the benefits that some consumers gain from the newly available transparent information. This finding is consistent with recent literature, such as Liu et al. (2022), which also identifies scenarios where enhanced transparency can paradoxically harm consumers.

Model extension

In this section, we consider extensions regarding the advertising and blockchain cost functions to test the robustness of the main conclusions. Firstly, we consider alternative advertising cost functions in "Advertising cost". Then in "Unit cost of blockchain," we explore the impact of incorporating blockchain unit cost into the model. In this section, we evaluate the robustness of our conclusions in terms of equilibrium structure, industry profits, social welfare, and consumer surplus. A detailed analysis of the extensions is provided in Appendix B.

Advertising cost. We consider alternative advertising cost functions, including the cubic cost function $\frac{k}{3}(s/l)^3$, the exponential cost function $ke^{s/l-1}$, and the fractional cost function $ks/(l(1-s))$, respectively. All advertising cost functions are increasingly convex in the advertising level and decreasing in the firm's actual position. Holding all other conditions and assumptions unchanged, we conduct robustness checking for the main conclusions of our main model through a numerical experiment. By plotting the figures for the three cost functions, we find that regardless of the firm's advertising cost structure, the market may still exhibit no equilibrium, one equilibrium, or multiple equilibria when the firms can strategically choose one of the information disclosure measures. Moreover, when the value of l is large and the value of

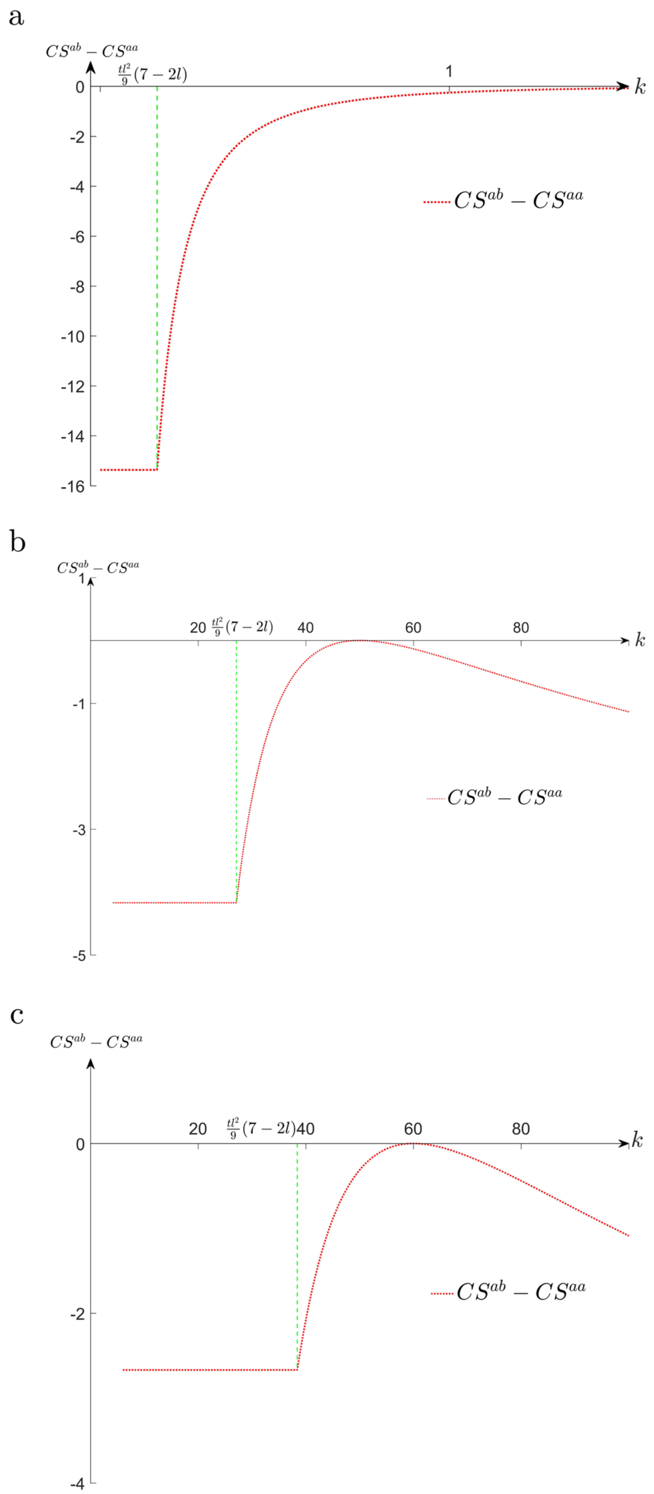

Fig. 5 Illustration of $CS^{ab} - CS^{aa}$. The red line is the difference between the consumer surplus when the two firms adopt advertising and blockchain separately and the consumer surplus when they both adopt advertising. **a** shows that when l ≤ \underline {l}(t = 600, l = 0.02) consumer surplus under the scenario where one firm adopts blockchain while the other adopts advertising is lower than that when both firms adopt advertising. **b** shows that when\underline {l} <l≤\ overline {l} (t = 600, l = 0.25), consumer surplus under the scenario where one firm adopts blockchain while the other adopts advertising is lower than that when both firms adopt advertising. **c** shows that when l>\ overline {l} (t = 600, l = 0.3), consumer surplus under the scenario where one firm adopts blockchain while the other adopts advertising is lower than that when both firms adopt advertising.

k is small, excessive advertising is more prevalent in the market. By comparison, we also find that excessive advertising is more prevalent in the market under the cubic advertising cost function. However, the fractional advertising cost function helps prevail the equilibrium of both firms choosing blockchain disclosures.

Unit cost of blockchain. In this section, we extend the main model by incorporating the unit (usage) cost of blockchain. The unit cost of blockchain is generated by the processing of data uploaded to the blockchain platform and is related to the number and size of transactions on the blockchain. The unit cost includes the cost of verifying information, storage cost, energy consumption, and network cost, which also indicates the uniqueness of blockchain, unlike advertising. When the two firms adopt different disclosure strategies, blockchain unit cost has different impacts on the profits of the two firms. Specifically, blockchain unit cost positively affects the profit of firm using advertising disclosure and negatively affects the profit of firm using blockchain disclosure. We also numerically find that the blockchain unit cost enhances firms' incentives to excessive advertising while weakening the willingness of firms to adopt blockchain.

Conclusion

Main findings. In recent years, blockchain technology has been used for information disclosure in the supply chain. Moreover, advertising is also a common approach to information disclosure. Consumers can obtain information about product attribute from a firm's advertising. However, firms may overpromote the attributes of their products, which is known as excessive advertising. In this paper, we examine a scenario where a firm can choose between advertising and blockchain as a disclosure tool in the framework of the Hotelling model.

Our analysis shows that when only advertisement is available, the equilibrium is unique, and excessive advertising occurs when the advertising cost rate is low enough or the firm's actual attribute is sufficiently high. When blockchain is also available for information disclosure, there may be a unique equilibrium, no equilibrium, or multiple equilibria in the game of choosing the information disclosure tool, with the equilibrium structure being driven by the firm's actual attribute, the advertising cost, and the cost of blockchain adoption. Surprisingly, we find that blockchain adoption by one firm may induce its rival to further overpromote its attribute. That is, although blockchain adoption can provide true information for the user, it does not necessarily help create a completely credible environment for the industry unless all parties there adopt blockchain. One of the interesting findings is that firms may switch from using blockchain to advertising as the advertising cost rate increases. Particularly, this counterintuitive result occurs when the advertising cost rate is moderate, in which case excessive advertising occurs. If a firm adopts blockchain, it will encourage its rival to conduct excessive advertising to a greater extent, thus intensifying competition. In other words, advertising helps reduce the competitive intensity. Finally, we conduct robustness checking of our findings by considering other cost functions of advertising and blockchain unit cost, and show that the main findings qualitatively hold in these settings.

Management significance. Our findings provide practical guidance for firms on blockchain adoption and information disclosure in a competitive environment. This paper examines two information disclosure tools (blockchain and advertising) separately and their interplay. It is believed that blockchain, as a decentralized technology, can help firms gain information and competitive advantages. However, our research conclusions suggest that market competition weakens blockchain's information advantage. For example, under some conditions, it is optimal for the firms to choose advertising rather than blockchain as the information disclosure tool. Furthermore, blockchain adoption by one firm may aggravate excessive advertising by its competitor, thus resulting in a more significant information disadvantage for the firm. Therefore, in a competitive environment, firms must trade off important factors such as disclosure costs, product attributes, market competition, and the disclosure strategy of opponents for their blockchain adoption decision. This reactive dynamic, where one firm's strategic shift toward transparency triggers an aggressive advertising response from its competitor, finds parallels in the classic competitive dynamics of the "Cola Wars." In those cases, a strategic move by one party based on a product "truth" (e.g., taste tests) was often met with an intensified and escalating counter-campaign from the rival.

In addition, our research provides guidance for government regulation of blockchain development. Many governments strongly endorse the development and application of blockchain. Our work shows that blockchain adoption by one or both firms may increase industry profits and social welfare. In this case, governments should encourage firms to adopt blockchain. However, governors should be aware that blockchain adoption in a competitive environment decreases consumer surplus, which may prevent the development and application of blockchain. To address this situation, governments should provide guidance or monetary incentives to firms to offer value-added services based on blockchain to consumers. This counterintuitive outcome, where a well-intentioned transparency initiative can inadvertently harm consumers, is consistent with real-world observations in other domains. For instance, the mandatory disclosure of calorie counts on restaurant menus has been shown to trigger strategic responses from firms. Some firms use marketing cues to distract from calorie information, which can undermine the intended benefits for consumers and illustrates the complex interplay between information disclosure and market competition.

Limitations and future studies. As the first attempt to compare blockchain to advertising, this paper has some limitations. Research on information disclosure and blockchain adoption can be further explored. Firstly, in practice, a firm can choose more than one disclosure tool for information disclosure simultaneously. Future research can consider the substitutability and complementarity between the multiple disclosure tools used by a firm. Secondly, different regions have different viewpoints on the application of blockchain technology. If policymakers intervene in the innovation and application of blockchain technology, future research can investigate the impact of different policies on the adoption equilibrium of disclosure tools. Thirdly, this study assumes that consumers trust the attribute of information disclosed by firms. However, consumers may be skeptical about the authenticity of attribute information disclosed through advertising. Moreover, although blockchain can ensure the authenticity of the data after upload, it does not guarantee the authenticity of the original data. Future research may incorporate the issue of reliability of advertising and blockchain in disclosing information. Additionally, it is a valuable research direction to consider the negative utility to firms of consumers being aware of excessive advertising in a multi-period model. Finally, our study only measures the interactions between the adoption of disclosure tools by competing firms in a duopoly. Future research can expand our model to include the case of multiple competing firms.

Data availability

No datasets were generated or analysed during the current study.

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Notes

1 https://mobile-cuisine.com/marketing/unethical-and-false-marketing/
2 https://www.altoros.com/blog/blockchain-at-walmart-tracking-food-from-farm-to-fork/

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Weixiang Huang: Conceptualization, Methodology, Supervision, Validation, Writing—Original Draft, Writing—Review and Editing. Xinlu Cao: Methodology, Investigation, Validation, Writing—Review and Editing. Wenhui Zhou: Conceptualization, Writing—Original Draft, Writing—Review and Editing. Xinying Fan: Methodology, Investigation, Validation, Writing—Review and Editing.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

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Additional information

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