POMS PRODUCTION AND OPERATIONS MANAGEMENT

PRODUCTION AND OPERATIONS MANAGEMENT

Vol. 31, No. 1, January 2022, pp. 138–154
ISSN 1059-1478 | EISSN 1937-5956 | 22 | 3101 | 0138
DOI 10.1111/poms.13456

Combating Copycats in the Supply Chain with Permissioned Blockchain Technology

Bin Shen
Glorious Sun School of Business and Management, Donghua University, Shanghai 200051, China, binshen@dhu.edu.cn

Ciwei Dong*
School of Business Administration, Zhongnan University of Economics and Law, Wuhan 430073, China, dongciwei@zuel.edu.cn

Stefan Minner
TUM School of Management, Technical University of Munich, Munich 80333, Germany, stefan.minner@tum.de

The phenomenon of copycats is common in a wide range of industries. Recently, to indicate product authenticity and combat copycats, many brand name companies (BNCs) have started selling products through retailers. These BNCs deploy a scalable protocol that is integrated into a permissioned blockchain technology (PBT) platform. We examine how PBT combats copycats in the supply chain and how it benefits BNCs. Although PBT implementation helps novice customers identify product authenticity and the real quality of products, that is, to take advantage of a *quality disclosure effect*, we show that, if and only if the number of novice customers is large enough, then selling through a PBT retailer can effectively combat copycats. Thus, PBT increases the profit of the BNC, consumer surplus, social welfare, and reduces the profit of a copycat. Moreover, conventional wisdom tells us that PBT ensures supply chain transparency and motivates a firm to improve its product quality. However, the BNC reduces the quality of its products when using PBT, because an improvement in product quality is not profitable if consumers can distinguish between genuine and imitation products. Furthermore, we extend the model by considering the case where the BNC itself implements PBT. Without the *double marginalization effect*, even if the number of novice customers is small, blockchain technology may exist in the market (the BNC self-implements). In addition, if the unit production cost of a genuine product is large enough, social welfare increases when production cost increases.

Key words: permissioned blockchain technology; copycat; supply chain; product quality
History: Received: May 2020; Accepted: April 2021 by Subodha Kumar, after 2 revisions.
*Corresponding author.

1. Introduction

1.1. Background and Motivation

Copycats are a common phenomenon in a wide range of industries (e.g., fashion, electronic items, and vehicles). Copycats mimic the incumbent's design and quickly produce similar products. For example, many fast fashion brands mimic the product designs of designer brands by applying the quick response approach (Eytan 2017). In the electronics industry, the e-cigarette brand Juul is confronted with many copycats in the market (Becker 2019). In the food industry, coffee traders copy the packaging design of Blue Mountain coffee to deceive consumers (Taylor 2020). In general, imitation products have the following main characteristics:

- *Imitation products have a high degree of similarity*. Copycats mimic a brand name company's (BNC) product and pretend that their product is the genuine article. Product quality cannot be judged at the time of purchase. However, novice consumers who have limited product knowledge will be deceived by copycats. A copycat steals the brand value of a genuine product from a BNC (Gao et al. 2017b).
- *A copycat is a follower in the market*. A BNC, as the incumbent, sells a new product first. A copycat then follows to develop and sell a similar product (Qian 2014). The copycat will intentionally offer a lower price than the BNC to gain the market share of novice consumers who cannot use the price signal to judge the quality of the product.
- *The quality of an imitation product is lower than that of a genuine product*. Copycats cannot reach the quality standard of a genuine product in a short time (Cho et al. 2015). Consumers know that a genuine product has better quality than the imitation. If consumers do not know the

true quality of a product, then they will have a common prior belief about the likelihood that a product is genuine or an imitation (Feng and Xie 2012).

- *Not all consumers can identify imitation products*. Novice and expert consumers coexist in the market. Despite a difference in quality, an imitation product can only be identified by expert consumers, but not by novice consumers, because identification requires "knowledge" (Qian 2014). The number of experts and novices depends on how familiar a customer is with a product. When a newly designed product is launched, the number of novice consumers will be large. For example, Juul launched its new e-cigarette in 2016 and had to "fight" many copycats that sold imitation products to numerous novice consumers (Becker 2019). If a product is widely accepted by consumers, then the market will be composed of a large number of expert consumers. For example, the BYD version of the Toyota Corolla can be recognized by most Chinese consumers who are expert consumers, because they have seen the real Corolla for years.

Brand name companies want to combat the entry of copycats, because it threatens a loss of market share (Li and Kumar 2018, Luo et al. 2011). However, so far, efforts to combat copycats have not been effective. Traditional technologies, such as barcodes and RFID tags, can be duplicated and printed on imitation products. As a result, consumers may not fully trust quality information processed by traditional technologies. Copycats are increasingly rampant due to sophisticated imitations that consumers cannot recognize (Pun and DeYong 2017). On the one hand, expert consumers can distinguish between genuine and imitation products. They intentionally buy imitation products because they cannot afford or are not willing to pay the price of genuine products. On the other hand, novice consumers have limited product knowledge. They may buy imitation products unintentionally because they cannot distinguish between imitation and genuine products by the difference of prices. According to a survey conducted by the global market research firm MarkMonitor, 31% of novice consumers unintentionally purchase imitation products, mainly in the clothing and electrical goods sectors (MarkMonitor 2017).

New technologies, such as blockchain technology, are key drivers that change the business environment (Babich and Hilary 2020, Choi 2019, Guha and Kumar 2018, Hastig and Sodhi 2020, Niu et al. 2019, Whitaker and Kräussl 2020). Gartner estimates that BNCs' products with a value of US$5 billion will contain blockchain technology by 2023, and this number will continue to increase over the next decade (Dimitrov 2019). Many BNCs have started selling products through retailers like Amazon, Walmart, and Alibaba, which deploy a scalable protocol integrated into a permissioned blockchain technology (PBT) platform accessible only to those with authorization (Chen 2019, Masters 2019). A PBT has properties of both public and private blockchain. Public blockchain provides an access to people who are willing to join and participate in the activities of the blockchain network (e.g., public services), whereas private blockchain allows only selected entry of verified participants who can override, edit, or delete the necessary entries on the blockchain (e.g., bank). The PBT provides participants specific functions such as read, access, and write information on the blockchain. For example, firms producing a product may use PBT that also takes care of supply chain activities such as manufacturing, logistics, and retailing. The process information in terms of manufacturing, logistics, and retailing can be edited by supply chain members in the PBT. Consumers can learn supply chain information through PBT. Therefore, PBT is specifically designed for companies that want to provide visible supply chain information to consumers, suppliers, vendors, and distributors in the supply chain (Chang et al. 2018) and to combat copycats (Pun et al. 2021).

Recently, PBT has been implemented in many industries, such as the fashion and food industries. Using PBT to combat copycats is becoming increasingly common. For example, Walmart collaborated with IBM to develop PBT for many food suppliers (e.g., Nestlé, Dole Food, and Driscoll's). Such PBT creates a transparent supply chain and identifies product quality (Jagati 2019). Consumers can scan the QR code on the packaging. PBT is a good solution for a traceability system in the food sector because of its focus on trust, immutability, and transparency. Alibaba now asks fashion brands to upload their designs and content to the PBT system as proof of originality, and the system will automatically detect similar products to determine if they are copycats (Chen 2019). Identified copycats are removed from the platform. Humble Marketplace sells luxury fashion products incorporated with blockchain technology. Customers could verify the authenticity of products through scanning a digital signature QR code from the blockchain technology system (DeAcetis 2021). Amazon is currently helping Nestlé's new coffee brand "Chain of Origin" to develop blockchain technology that shows information about in which small farm the beans were planted, where they were roasted, and when and how beans were made (Castillo and Schifrin 2020). Hence, with PBT, consumers can know information such as who the designer of a product is, which factory

produces the product, when the product is produced, where the product is sold, and what materials were used in the product. Technologies that collect and share information (e.g., RFID) currently exist. The main differences between blockchain and such existing technologies are data encryption and record validation. Consumers trust PBT because the quality data are unique and cannot be modified or altered by an individual (Babich and Hilary 2020). PBT provides a unique "certificate" to consumers who then know that a product is authentic. Nobody can duplicate information in the PBT system. Thus, PBT can realize the *quality disclosure effect*.

1.2. Core Research Questions and Contributions

We examine how the use of a PBT retailer helps a BNC combat a copycat and how it affects the BNC (i.e., incumbent) in the supply chain. We consider two distribution strategies: (i) without the PBT retailer, the BNC and the copycat sell their products directly to consumers (direct selling); and (ii) with PBT, the BNC sells through the PBT retailer, whereas the copycat sells directly to consumers (mixed selling).

We answer the following research questions (RQs):

RQ 1: Under what conditions can selling through a PBT retailer be an effective anti-copycat solution (i.e., increase the profit of BNCs, reduce the profit of copycats, and improve consumer surplus and social welfare)?
RQ 2: How does PBT affect the choice of distribution strategies for a BNC?
RQ 3: What are the optimal pricing and quality strategies for a BNC with PBT?

We provide new perspectives on the effectiveness of combating copycats under the use of PBT. If and only if the number of novice consumers is large enough, then selling through a PBT retailer can be an effective anti-copycat solution (i.e., it increases the profit of the BNC, reduces the profit of the copycat, and improves consumer surplus and social welfare). This result first implies that selling through a PBT retailer is recommended for newly developed products (of which a large group of consumers have no product quality knowledge) but not for mature products (with a large group of "knowledgeable" consumers). Second, if the number of novice consumers is large enough, then consumer surplus can increase, as some of consumers who were deceived by the copycat will know the quality of a product from the PBT and thus gain more surpluses. This result differs from that of the economics literature, where direct selling eliminates double marginalization and better satisfies consumers (Chipty 2001). In our paper, if the number of novice consumers is large enough, then consumer surplus under direct selling is worse because the surplus improvement by using PBT exceeds the loss caused by double marginalization. In addition, by extending the model to consider PBT self-implementation, without the *double marginalization effect*, due to the *quality disclosure effect* of PBT, even if the number of novice consumers is small, PBT can still exist in the market. However, the BNC itself should implement it and sell its genuine product directly to consumers.

Our paper contributes to the literature on pricing strategies in terms of various channel choices when using PBT. Compared with the distribution strategy of selling a product directly to consumers without PBT, if the number of novice consumers is large (small) enough, then using a PBT retailer to sell a genuine product only encourages the BNC to lower (increase) its price. When the number of novice consumers is large enough, a low price will be offered to attract novice consumers and motivate them to buy the genuine product from the PBT retailer. However, when the number of novice consumers is small enough, the BNC will not sell through the PBT retailer because it wants to avoid the *double marginalization effect* in the supply chain.

Furthermore, our paper highlights the effects of genuine product quality choice in the presence of a copycat. Surprisingly, the implementation of PBT decreases the quality of the genuine product in the presence of a copycat. This result is not consistent with conventional wisdom, which suggests that PBT ensures supply chain transparency and encourages firms to improve product quality. Previous research (e.g., Gao et al. 2017b) also finds that a BNC should improve its product quality to combat copycats. Without PBT, this strategy can be a good advice because the leading quality strategy encourages consumers to buy genuine products. However, an improvement in product quality is costly. With PBT, improving product quality may not be a wise decision, because PBT has been effective in helping consumers identify product quality.

1.3. Paper Organization

The rest of this study is organized as follows. In section 2, we review the relevant literature. In sections 3 and 4, we present the basic model and identify the value of selling through a PBT retailer. In section 5, we look at the endogenous quality. In section 6, we extend the model by considering the self-implementation, social status, privacy concern of blockchain technology, unit production cost of the genuine product, and marginal cost of implementing blockchain technology. In section 7, we conclude the paper and discuss important implications. All proofs can be found in the Online Supplementary Appendix.

2. Literature Review

2.1. Effects of the Entry of a Copycat

The concept of "copycat" is a widespread phenomenon in many industries and widely discussed in the literature on operations management. A copycat product is similar to counterfeits in terms of product imitation (Gao et al. 2017a). Grossman and Shapiro's (1988a, 1988b) studies are among the early works that developed equilibrium models for BNCs and low-quality counterfeit products with the risk of confiscation. Qian et al. (2015) consider a scenario where a deceptive counterfeiter sells products to consumers who cannot tell the difference between counterfeits and authentic products when their prices and perceived quality are the same.

Customers consider that product quality includes observable quality (e.g., brand name and appearance) and experiential quality (functionality). The former refers to dimensions that are observable to expert consumers at the time of purchase, whereas the latter refers to dimensions that are based on experience, which are unknown for expert consumers before the time of purchase. Consequently, they obtain different scenarios of the decision when an authentic firm should improve observable or experiential quality. Our paper focuses on examining observable qualities, which are observed by experts but unknown to novices at the time of purchase.

Gao et al. (2017a) investigate the effects of the entry of a copycat on the incumbent's decision and identify the optimal time for a copycat's entry. Gao et al. (2017b) evaluate the effect of copycats in luxury retail in terms of status effect. They find that a high level of product quality can discourage a copycat from entering the market, and that the entry of a copycat does not always improve consumer surplus and social welfare. Pun and DeYong (2017) investigate the effect of a copycat's entry. They assume that the quality of a copycat and that of authentic products is known to consumers. They find that a BNC will lower its product quality in the presence of a copycat. Our paper is similar to that of Gao et al. (2017a, 2017b) and Pun and DeYong (2017) in that we examine the effects of the entry of a copycat. However, we investigate how the use of PBT as anti-copycat technology combats copycats.

2.2. Current Strategies of Combating Copycats

Anti-copycat (anti-counterfeiting) solutions are important tools to prevent copycats (counterfeiters). To combat the entry of counterfeits, traditional anti-counterfeiting solutions include pricing signals and quality improvement. Qian (2014) evaluates a pricing signaling strategy to deter counterfeits. The author finds that, if the quality of a counterfeit is below a certain threshold, then the BNC can increase its price to increase its own profit and reduce that of the counterfeiter. Cho et al. (2015) investigate the effects of counterfeits on the supply chain performance. They use quality improvement and pricing strategies to combat counterfeits. We also examine ways to combat copycats. We propose the use of PBT, the disruptive new technology, to combat copycats. Qian (2014) and Cho et al. (2015) find that an improvement in product quality can combat counterfeits, but our results are different because blockchain is completely reliable for consumers who wish to identify copycats.

Gao (2018) examines how overt anti-counterfeiting technologies (OACTs) combat the entry of counterfeiters and illegitimate producers into the pharmaceutical industry. The results show that the implementation of OACTs can increase the sales of counterfeit products. Yao and Zhu (2019) evaluate how anti-counterfeiting technologies, such as certificates of authenticity and packaging, combat the entry of counterfeit products. They consider that anti-counterfeiting technologies are not perfect, which means that consumers will still be deceived by fake products even if anti-counterfeiting technologies are used. They examine the effect of deceptive counterfeiters and propose that if counterfeit products are detected by authorities, then the firm should pay a penalty.

Unlike Yao and Zhu (2019), we consider that a firm that produces genuine products uses PBT to prevent and combat the entry of a copycat. PBT helps consumers distinguish between imitation and genuine products. Sun et al. (2020) examine how an online platform invests in measures that reduce counterfeits. They find that a platform should make the maximum effort to combat the counterfeiter when the unit cost of the genuine product is sufficiently low, because with an increase in cost, the authentic firm will be less willing to invest in the selling effort. Consequently, the platform will be less willing to invest in the fight against the counterfeiter. In our paper, we examine the effects of distribution strategies on the fight against copycats. We consider two distribution strategies: mixed selling and direct selling.

2.3. The Use of Blockchain Technology

Using PBT improves supply chain transparency in terms of originality, materials, and production (Wang et al. 2021, Whitaker and Kräussl 2020). Babich and Hilary (2020) define the value of blockchain technology adoption in operations management. They argue that blockchain technology can provide visibility and information validation in supply chains and create a highly secure and transparent business environment. In this study, we apply the advantages of blockchain technology to combat copycats. This solution of combating copycats is unique and cannot be fully replaced by conventional technology, because

consumers fully trust the information of blockchain but do not fully trust conventional technologies.

Chod et al. (2020) evaluate the impacts of supply chain transparency through blockchain adoption. They find that blockchain technology can provide a favorable financing solution at low signaling costs. Cui et al. (2019) explore how transparency affects supply chain performance in parallel and serial supply chains. They find that, regardless of the supply chain structure, supply chain transparency can improve quality. The transparency in the parallel and serial supply chain can improve a buyer's cash flow and reduce the impacts of moral hazard. Therefore, transparency is an important argument in favor of using blockchain, because the profits of a supplier and a buyer can be improved in supply chains. Cai et al. (2020) examine how the use of blockchain technology eliminates moral hazard risk in supply chains.

In this study, we focus on examining the impact of PBT on combating copycats in various distribution strategies (i.e., direct selling and mixed selling). Pun et al. (2021) study how deceptive counterfeits can be eliminated by using blockchain technology. They find that the application of blockchain technology is effective in reducing post-purchase regrets and improving social welfare. Our paper is different from Pun et al. (2021) from three perspectives. First, they examine a market made up of one blockchain-based manufacturer and one copycat, but we study the effects of having a copycat in a supply chain consisting of one manufacturer, one copycat, and one PBT retailer. Our analyses outline the value of blockchain technology on different supply chain structures and identify under which supply chain structure, blockchain technology is preferable to adopt to combat copycats. Moreover, Pun et al. (2021) consider one type of customer, that is, novices. We follow Qian (2014) and consider that consumers can be subdivided into novices and experts. Experts can determine product quality, but novices cannot. The portion of consumer type will significantly influence the effectiveness of blockchain. In addition, in Pun et al. (2021), the major trade-off is between privacy concerns and the quality disclosure effect. Given that we consider the problem in a supply chain context, our major trade-off is between double marginalization and quality disclosure. In the extended model, we also examine the impacts of privacy concerns. A BNC should implement PBT when the quality disclosure effect dominates the double marginalization and privacy concern effects.

Table 1 summarizes the positioning of this study in the literature.

3. The Model

We consider an incumbent BNC that sells its genuine product to consumers and a copycat that follows the BNC by selling its imitation product on the same market. The copycat copies the genuine product and pretends that it is the genuine article. Product quality cannot be judged at the time of purchase. However, consumers know that the genuine product has better quality than the imitation one. If consumers do not know the true quality of the product, then they will have a common prior belief about the likelihood that a product is genuine or an imitation (Feng and Xie 2012). Similar to the BNC, the copycat may have a brand, which may or may not be similar to the genuine product. Copycats have four features. First, imitation products have a high degree of similarity. Second, a copycat is a follower in the market. Third, the quality of an imitation product is lower than that of a genuine product. Fourth, not all consumers can identify imitation products. We classify consumers into two groups. One group is composed of experts who can classify which product is genuine and which one is not. The other group is composed of novices who cannot classify products. Despite a difference in quality, an imitation product can only be identified by expert consumers, but not by novice consumers, because identification requires "knowledge" (Qian 2014).

The selling price of product i is p_i, with $i \in \{b, c\}$. Here, $i = b$ and $i = c$ denote the genuine product of

Table 1 Positioning of this Study in the Literature

Paper	Impacts of copycat/ counterfeit	Supply chain	Use of blockchain	Welfare analysis
Grossman and Shapiro (1988a, 1988b), Qian et al. (2015), Gao et al. (2017a, 2017b), Qian (2014) and Gao (2018)	✓			✓
Pun and DeYong (2017) and Sun et al. (2020)	✓			
Cho et al. (2015)	✓	✓		✓
Yao and Zhu (2019)	✓			
Babich and Hilary (2020), Cui et al. (2019), Cai et al. (2020) and Wang et al. (2021)		✓	✓	
Chod et al. (2020)			✓	
Pun et al. (2021)	✓		✓	✓
Our paper	✓	✓	✓	✓

the BNC and the imitation product of the copycat, respectively. We assume that the unit cost of production is zero (we consider the case where the production cost is not zero in section 6, and the main results where the production cost is zero remain valid when the production cost is non-zero). The quality of product i is q_i.

We assume that the quality level of the genuine product is higher than that of the imitation product, that is, $q_b > q_c$, because copycats imitate genuine products, but cannot spontaneously reach their exact quality standard. Let $q_c = \alpha q_b$, with $\alpha \in (0,\ 1)$, where α captures a fraction of the brand value in the quality of the genuine product (Cho et al. 2015). In the basic model, we assume that the product quality of the genuine product is exogenous, because for some products, product quality cannot be easily changed in a short time. We extend the model to examine endogenous quality in section 5.

When consumers decide to purchase the product, the perceived quality toward the product will be formed in terms of consumer types. Without PBT, consumers may not know the true quality of the product. Thus, customers' perception of the quality of product i, ϕ_i, may differ from its real quality q_i. Following Qian et al. (2015), we consider two types of consumers in the market. The first type of consumers is novices who cannot distinguish between genuine and imitation products due to their limited product knowledge. These consumers have a common prior belief about the likelihood that a product is genuine or an imitation. Following Hertzendorf (1993) and Feng and Xie (2012), we assume that the prior belief of novice consumers on the probability that the product is genuine is γ, with $\gamma \in (0,\ 1)$. Without PBT, the level of quality perceived by novice consumers (a fraction λ of the total number of consumers) is $\phi_i = \gamma q_b + (1-\gamma) q_c$. The second type of consumers is experts (a fraction $1-\lambda$ of the total number of consumers) who know the exact product quality at the time of purchase. The level of quality perceived by expert consumers is $\phi_i = q_i$.

To combat the copycat, the BNC can sell its product through a PBT retailer. PBT is a unique technology that reliably discloses quality. *By using PBT, consumers will trust that the product quality is reliably disclosed, because the quality data stored by the BNC are unique and cannot be modified or altered by an individual (*Babich and Hilary 2020*). By contrast, consumers may not fully trust quality information processed by traditional technologies, such as barcodes and RFID tags, because they can be duplicated and printed on imitation products*. As all consumers in the market can know the true quality of the two products by using PBT, the level of quality perceived by all consumers is $\phi_i = q_i$. The implementation cost of PBT is F. The perceived quality of novice and expert consumers with and without PBT is shown in Table 2.

Consumers are heterogeneous in their willingness to pay for quality. Without loss of generality, we assume that the market size is normalized to one. Each consumer purchases at most one unit of the product, either from the BNC or the copycat. Given the selling price, the utility received by a consumer from purchasing product i is $U_i = v\phi_i - p_i$, where v is the consumer's preference for quality, which is assumed to be uniformly distributed over $[0,\ 1]$, and ϕ_i is the aforementioned quality of the product perceived by the consumer when purchasing the product. Consumers can still purchase the imitation product if their utility to buy this imitation product is positive and greater than that of buying the genuine product.

The wholesale price and market demand of product i are w_i and D_i, respectively. The profits of the BNC and the copycat are π_b and π_c, respectively, and the profit of the PBT retailer is Π. Consumer surplus is CS and social welfare is SW. In addition, we add superscript j to the notation to represent the equilibrium outcomes, where j ($j \in \{N,\ B\}$) is used for indicating the case without PBT (N) and the case with PBT (B). Table 3 summarizes the major notation used in this paper.

The sequence of events is as follows. The BNC decides whether or not to sell through the PBT retailer. If the BNC does not sell through the PBT retailer (i.e., direct selling with no blockchain technology),

1. the BNC first determines the selling price of the genuine product;
2. the copycat determines the selling price of the imitation product on the basis of the BNC's decision.

If the BNC sells through the PBT retailer (i.e., mixed selling),

1. the BNC first determines the wholesale price of the genuine product;
2. the PBT retailer determines the selling price of the genuine product;
3. the copycat determines the selling price of the imitation product on the basis of the BNC's decision.

Figure 1 shows the two distribution strategies.

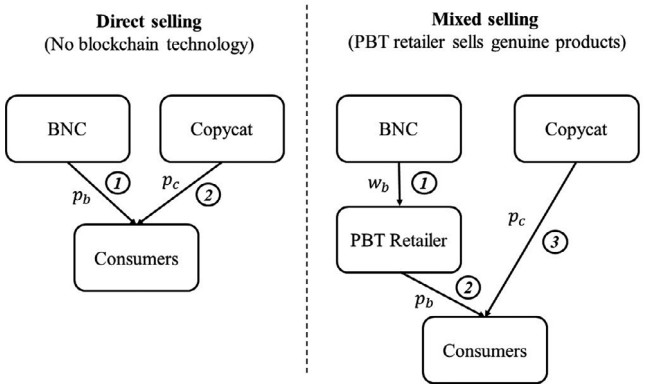
Table 2 Consumers' Perceived Quality with and without PBT

Consumer types	Without PBT	With PBT
Novice consumers	$\phi_i = \gamma q_b + (1-\gamma) q_c$	$\phi_i = q_i$
Expert consumers	$\phi_i = q_i$	

Table 3 Major Notation Used in this Study

Notation	Definition
q_i	The quality of product i, where $i = b$ and $i = c$ denote the genuine product of the BNC and imitation product of the copycat, respectively, and $q_b > q_c$
α	A fraction of the brand value in the quality of the genuine product, where $q_c = \alpha q_b$ and $\alpha \in (0, 1)$
ϕ_i	Customers' perception of the quality of product i
γ	The prior belief of novice consumers on the probability that the product is genuine, and $\gamma \in (0, 1)$
λ	The fraction of novice consumers
U_i	The utility received by a consumer from purchasing product i
v	The consumer's preference for quality, which is uniformly distributed over [0, 1]
w_i	The wholesale price of product i
p_i	The retail price of product i
D_i	The market demand for product i
F	The implementation cost of PBT
π_b	The profit of the BNC
π_c	The profit of the copycat
Π	The profit of the PBT retailer
CS	Consumer surplus
SW	Social welfare

Figure 1 Two Distribution Strategies (the numbers in the circle indicate the sequence of the game in the corresponding distribution strategy)



4. Combating the Copycat Using PBT

In this section, we perform an equilibrium analysis (a) disregarding PBT and (b) under the use of PBT. On the basis of the results, we evaluate the effects of using PBT to combat the copycat and the benefits for the BNC.

4.1. Selling the Genuine Product Directly to Consumers

We consider that novice consumers cannot distinguish between imitations and genuine products, and they form a common prior belief about the likelihood that a product is genuine or an imitation. Then, the selling prices essentially determine novice consumers' decisions about buying imitations or genuine products. Consequently, the copycat as a follower will offer a price that is lower than that of the genuine product to extract a fraction of consumers from the market. Then, a fraction λ of consumers will buy the imitation product instead of the genuine product if $U_c = v(\gamma q_b + (1-\gamma)q_c) - p_c$ is positive. Thus, the demand for the imitation product by novice consumers is $\lambda\left(1 - \frac{p_c}{q_b(\alpha+\gamma-\alpha\gamma)}\right)$. Note that novice consumers do not know whether the purchased product is an imitation or a genuine one. Thus, the price is an encouragement for novice consumers to make the purchase decision, rather than a signal that infers product authenticity.

We consider that expert consumers will buy the imitation product if and only if their utility when buying the imitation product is positive and greater than that when buying the genuine product. We have $U_c = vq_c - p_c$ and $U_b = vq_b - p_b$. Expert consumers who are indifferent about purchasing the genuine or the imitation product have a valuation $v = \frac{p_b - p_c}{q_b(1-\alpha)}$. Similarly, expert consumers who are indifferent about purchasing the imitation product or nothing have a valuation $v = \frac{p_c}{q_b\alpha}$. Consequently, for this $1-\lambda$ fraction of consumers, $(1-\lambda)\left(\frac{p_b-p_c}{q_b(1-\alpha)} - \frac{p_c}{q_b\alpha}\right)$ and $(1-\lambda)\left(1 - \frac{p_b-p_c}{q_b(1-\alpha)}\right)$ consumers choose the imitation product and the genuine product, respectively. The total demand for the imitation product and the genuine product is $D_c = \lambda\left(1 - \frac{p_c}{q_b(\alpha+\gamma-\alpha\gamma)}\right) + (1-\lambda)\left(\frac{p_b-p_c}{q_b(1-\alpha)} - \frac{p_c}{q_b\alpha}\right)$ and $D_b = (1-\lambda)\left(1 - \frac{p_b-p_c}{q_b(1-\alpha)}\right)$, respectively.

The copycat and the BNC maximize their individual profit by offering optimal prices. The optimization problems are as follows:

We use backward induction to obtain the equilibrium results in Appendix A.

$$\max_{p_c} \pi_c = p_c D_c = \underbrace{\lambda\left(1 - \frac{p_c}{q_b(\alpha+\gamma-\alpha\gamma)}\right)p_c}_{\text{Profit from novices}} + \underbrace{(1-\lambda)\left(\frac{p_b-p_c}{q_b(1-\alpha)} - \frac{p_c}{q_b\alpha}\right)p_c}_{\text{Profit from experts}} \text{ and}$$

$$\max_{p_b} \pi_b = p_b D_b = (1-\lambda)\left(1 - \frac{p_b-p_c}{q_b(1-\alpha)}\right)p_b$$

4.2. Selling the Genuine Product through a PBT Retailer

By selling the genuine product through a PBT retailer, the BNC can reveal its true quality to consumers. All consumers can distinguish between imitations and genuine products. In this case, the market demand for the imitation product and the genuine product is $D_c = \frac{p_b - p_c}{q_b - q_b\alpha} - \frac{p_c}{q_b\alpha}$ and $D_b = 1 - \frac{p_b - p_c}{q_b - q_b\alpha}$, respectively. The BNC, the copycat, and the PBT retailer aim to maximize their individual profit by offering optimal prices. The optimization problems are as follows:

$$\max_{w_b} \pi_b = w_b D_b = \left(1 - \frac{p_b - p_c}{q_b - q_b\alpha}\right) w_b,$$

$$\max_{p_c} \pi_c = p_c D_c = \left(\frac{p_b - p_c}{q_b - q_b\alpha} - \frac{p_c}{q_b\alpha}\right) p_c \text{ and}$$

$$\max_{p_b} \Pi = (p_b - w_b) D_b - F = (p_b - w_b)\left(1 - \frac{p_b - p_c}{q_b - q_b\alpha}\right) - F.$$

In the retailer's profit function, F is the PBT implementation cost. We model this cost as a lump sum payment to the retailer. Alternatively, the cost of using PBT can be modeled as a unit cost. Although the unit cost of using PBT is covered by the retailer, the effects of this cost are similar to those when the production cost is not zero, because due to the *double marginalization effect*, the retailer will transfer the cost to the BNC (we show the case that the production cost is non-zero and the case that the unit cost of using PBT is non-zero in section 6). Using backward induction, we show the equilibrium results in Appendix A.

On the basis of the equilibrium results, we compare the performance in terms of price, demand, profit, consumer surplus, and social welfare for direct selling without PBT and mixed selling with PBT in the following subsection.

4.3. Value of Using PBT to Combat the Copycat

By comparing the equilibrium outcomes of sections 4.1 and 4.2, we obtain the following results.

PROPOSITION 1 [Effects of PBT implementation on prices and demand]. *If and only if the number of novice consumers is large enough, then selling the genuine product through a PBT retailer in the supply chain*

(i) *lowers the prices of genuine and imitation products;*
(ii) *increases the demand for the genuine product but decreases the demand for the imitation product.*

Without PBT, novice consumers will unintentionally buy the imitation product. The sale of the genuine product through the PBT retailer allows novice consumers to distinguish between imitation and genuine products, that is, implementing PBT leads to a *quality disclosure effect*. As a leader, the BNC first determines the price of the genuine product. If the number of novice consumers is large enough, then the BNC will offer a low price to motivate them toward buying the genuine product with PBT. Then the copycat will follow and offer a lower price. If the number of novice consumers is small, then the BNC will not sell through the PBT retailer because of the *double marginalization effect*. The BNC will offer a high price to maximize its profit, and the copycat will follow accordingly. The results of Proposition 1(ii) are intuitive because if PBT is used, then some novice consumers will buy the genuine product rather than the imitation product. Naturally, PBT implementation will increase the demand for the genuine product but decrease the demand for the imitation product. Therefore, the number of novice consumers is an extremely important factor to know the value of implementing PBT when combating the copycat.

PROPOSITION 2 [Effects of PBT implementation on supply chain performance and welfare].

(i) *If and only if the number of novice consumers is large enough, then PBT implementation*
   (a) *increases the profit of the BNC but decreases the profit of the copycat;*
   (b) *increases consumer surplus.*
(ii) *If and only if the cost of implementing PBT is high enough, that is,* $F > \frac{q(28-\alpha-11\alpha^2)}{32(2-\alpha)^2} - SW^N$, *then PBT implementation decreases social welfare.*

Proposition 2(i)a indicates that the BNC benefits from the implementation of PBT if the number of novice consumers is large enough. The BNC uses PBT to achieve a *quality disclosure effect* and motivates novice consumers toward buying the genuine product. However, if the number of novice consumers is small, then selling through the PBT retailer is not profitable for the BNC, because the loss due to the *double marginalization effect* in the supply chain cannot be compensated by the benefits of the *quality disclosure effect* rendered by the use of PBT. The profit of the copycat will decrease if novice consumers purchase the genuine product with PBT.

Consumer surplus is influenced by the prices of and demands for genuine and imitation products. If the number of novice consumers is large enough, then consumer surplus can be improved mainly because some of the novice consumers deceived by the copycat will know the quality of the product from PBT and will therefore gain a high surplus. The economics literature shows that direct selling eliminates double marginalization and satisfies consumers (Chipty

2001). Our results differ from those in the economics literature, because we find that the reduction of profit due to the *double marginalization effect* and consumer surplus can be compensated by the *quality disclosure effect* of using PBT for a large number of novice consumers. However, if the number of novice consumers is large enough, then direct selling is less effective because the benefits obtained from using PBT exceeds the loss caused by double marginalization in a decentralized supply chain.

Social welfare is defined as the sum of the profits of the copycat and the BNC and consumer surplus. Proposition 2(ii) indicates that, if PBT implementation is too costly, then it will reduce social welfare. This argument is intuitive. However, conditions must be met to improve social welfare by implementing PBT even if its implementation cost is negligible.

PROPOSITION 3 *If the cost of implementing PBT is negligible, that is, $F = 0$, PBT implementation in the supply chain improves social welfare if the number of novice consumers is large enough and if the prior belief of novice consumers on the probability that the product is genuine is low enough.*

Proposition 3 provides two conditions under which PBT implementation in the supply chain improves social welfare if the implementation cost is negligible. The first condition is fundamental for the effectiveness of PBT. The second condition, regarding *the prior belief of novice consumers on the probability that the product is genuine*, indicates the utility of consuming the genuine product for novice consumers. A low level of prior belief reduces novice consumers' willingness to buy the imitation product. This reduction leads to a reduction of profit, which will be covered by the increase in profit with PBT for the BNC.

Consumers' knowledge of product quality is higher if the duration of sales in the market is long. As a result, during the entire product selling period, the number of novice consumers is usually large in the beginning and the number of expert consumers is usually large when the product is well known in the market, because consumer learning plays an important role in product quality knowledge (Villas-Boas 2004). On the basis of the above result, we obtain the following corollary.

COROLLARY 1 *Selling through a PBT retailer is ideal for the BNC when new products are launched, but not when products have been on the market for a long time.*

The BNC benefits from selling through a PBT retailer when its product is new in the market, that is, the number of novice consumers is large. By contrast, the value of using PBT is reduced when the number of novice consumers is small. When consumers are familiar with the product, that is, the number of expert consumers is large, the BNC should sell its product directly to consumers. In the technology adoption literature, the technology adoption curve is S-shaped, that is, rapid adoption occurs after a long slow initial period (Bessen 2002). This effect is mainly due to the trade-off between adoption costs, consumer acceptance, and productivity growth. Our results are different from those of the technology adoption literature. The BNC can benefit from PBT when the product has only been released, but this adoption should be avoided when the product is well known in the market. With the increased familiarity of consumers with the product, the *quality disclosure effect* of using PBT is reduced. However, the loss of double marginalization in the supply chain still occurs because sales are made through the PBT retailer.

5. Endogenous Quality Decision

In the basic model, we assume that the quality level of the genuine product is exogenous. For example, Apple cannot simply change the quality of its iPhone X in a short time. However, this assumption may not be true for products in the food sector. A food supplier can improve or reduce its product quality by changing its sources of supply and packaging.

In this section, we consider the case where the quality of the genuine product can be improved or reduced strategically. The quality of the genuine product q_b is determined by the BNC. Similar to Cho et al. (2015), we set the unit cost of quality improvement to $\frac{1}{2}kq_b^2$, with $k > 0$. The profits of the BNC without and with PBT are $\pi_b(p_b,\ q_b) = (p_b - \frac{1}{2}kq_b^2)D_b$ and $\pi_b(w_b,\ q_b) = (w_b - \frac{1}{2}kq_b^2)D_b$, respectively.

The BNC first maximizes its profit by determining the level of quality. Then, depending on the corresponding distribution strategy, other decisions will follow accordingly. Using backward induction, we obtain the equilibrium results presented in Appendix A.

With endogenous quality, the results of the effectiveness of combating copycats are similar to those of Propositions 1 and 2 (details are provided in the Online Supplementary Appendix). In this section, we focus on the effects of PBT implementation on product quality.

PROPOSITION 4 [Effects of PBT implementation on product quality]. *The implementation of PBT decreases the quality of the genuine product in the supply chain.*

Conventional wisdom tells us that PBT ensures supply chain transparency and that its implementation encourages a firm to improve product quality.

Previous research (e.g., Cho et al. 2015, Gao et al. 2017b, Qian 2014) also shows that a BNC should improve the quality of its products if it wants to combat a copycat or counterfeiter, so that the profit of the BNC will increase, whereas that of the copycat/counterfeiter will decrease. Surprisingly, PBT implementation decreases the quality of the genuine product in the presence of a copycat. Without PBT, quality improvement may be the right choice because a quality-leading strategy encourages consumers to buy the genuine product. However, with PBT, novice consumers can identify product authenticity and know that the quality of the genuine product is superior to that of the imitation; hence, quality improvement may not be economical. Our analytical results indicate that if a large number of consumers are novices, then the BNC should sell its products at a lower price and a lower quality through the PBT retailer. If a large number of consumers are experts, then the BNC should use the low-price and high-quality strategy under direct selling.

6. Extensions

6.1. Extension 1: Blockchain Self-implementation

In the main model, we examine whether the BNC should sell through a PBT retailer. In this extension, we consider the scenario in which the BNC implements PBT itself and sells directly to consumers. In practice, giant luxury fashion companies like Louis Vuitton implement PBT to combat copycats (Newbold 2019). Similarly, the diamond brand De Beers incorporates PBT into its high-value diamonds to trace provenance and authenticity (Castillo and Schifrin 2020).

In this case, the BNC first maximizes its profit $\pi_b(p_b) = p_b D_b - F = \left(1 - \frac{p_b - p_c}{q_b - q_b\alpha}\right)p_b - F$ by optimally setting its selling price p_b. Here, the BNC takes PBT implementation cost F. The copycat acts as a follower and maximizes its profit $\pi_c(p_c) = p_c D_c = \left(\frac{p_b - p_c}{q_b - q_b\alpha} - \frac{p_c}{q\alpha}\right)p_c$ by optimally setting its selling price p_c. Using backward induction, we derive the corresponding equilibrium outcomes. Compared with the case without PBT, we obtain the following results.

PROPOSITION 5 [Effects of blockchain self-implementation]. *The implementation of PBT by the BNC itself*

(i) *lowers the prices of genuine and imitation products;*
(ii) *increases the demand for the genuine product but decreases the demand for the imitation product;*
(iii) *decreases the profit of the BNC if and only if the cost of implementing PBT is high enough, that is,* $F > \frac{q_b(1-\alpha)}{2(2-\alpha)} - \pi_b^N$, *and decreases the profit of the copycat;*
(iv) *increases consumer surplus if the number of novice consumers is large enough or if the prior belief of novice consumers on the probability that the product is genuine is low enough;*
(v) *decreases social welfare if and only if the cost of implementing PBT is high enough, that is,* $F > \frac{q_b\left(12 - 9\alpha + \alpha^2\right)}{8(2-\alpha)^2} - SW^N$.

Propositions 5(i) and (ii) indicate that implementing PBT can reduce the prices of both products and can increase the market demand of the BNC and decrease that of the copycat. By using PBT, the BNC will offer a lower price to attract novice consumers and motivate them to buy the genuine product. The copycat will follow the pricing strategy of the BNC. Unlike Proposition 1, selling through the PBT retailer has the same effect in terms of price and market demand for the BNC and the copycat if the number of novice consumers is large enough. When the number of novice consumers is small, then selling through the PBT retailer is not profitable for the BNC.

As the BNC implements PBT itself, the implementation cost is essential to affect the profit of the BNC and social welfare. Intuitively, if the cost is high enough, then implementing PBT is not profitable for the BNC as it will reduce social welfare.

PROPOSITION 6 *If the PBT implementation cost is negligible, that is,* $F = 0$, *then the implementation of PBT by the BNC itself*

(i) *increases the profit of the BNC if and only if the number of novice consumers is small enough;*
(ii) *increases social welfare if the number of novice consumers is large enough or the prior belief of novice consumers on the probability that the product is genuine is low enough.*

Surprisingly, if the PBT implementation cost is negligible, the results of PBT self-implemented by the BNC are different from those of the main model. This result is mainly due to the *double marginalization effect* on the selling price when sales are made through the PBT retailer. Nonetheless, this effect disappears when PBT is implemented by the BNC itself. Specifically, in the main model, we show that when PBT is implemented by the retailer, it increases the profit of the BNC if and only if the number of novice consumers is large enough. In the main model, if the number of novice consumers is large, then the selling price of the

genuine product will be lower to encourage more consumers to buy it, even if there is a greater effect on the price due to double marginalization. The benefits of increased market demand can offset the loss caused by double marginalization. If the number of novice consumers is small, then the *double marginalization effect* of selling through the PBT retailer will drive up the price, and the benefits of PBT will disappear. Therefore, not using PBT when selling the genuine product is more profitable.

Interestingly, in this extension, the implementation of PBT by the BNC itself can increase the profit of the BNC if and only if the number of novice consumers is small enough, provided that the implementation cost is negligible. The reasons are as follows: without the loss of double marginalization, the BNC will always reduce its selling price to attract consumers when implementing PBT. If the number of novice consumers is small, then the BNC will not use a very low price to attract consumers. Thus, the implementation of PBT is beneficial for the BNC. If the number of novice consumers is large, then the BNC will use a lower price to attract consumers. However, the loss of profit cannot be offset by the advantage of increased market demand.

The above result provides interesting and important information on PBT implementation for the direct selling distribution strategy. That is, if the cost of implementing PBT is negligible and the number of novice consumers is small, then the BNC should sell its genuine product directly to consumers using PBT. Conversely, if the number of novice consumers is large enough, then the BNC should sell through a PBT retailer.

Similar to Proposition 3, Proposition 6(ii) implies that the implementation of PBT can increase social welfare if the implementation cost is negligible. We derive the following condition: a large number of novice consumers imply that more consumers benefit from PBT; and a low probability that the product is initially considered genuine by novice consumers implies that the profit obtained from these consumers after the implementation of PBT is high.

6.2. Extension 2: Social Status of Having the Genuine Product

Copycats are active in copying luxury goods (Gao et al. 2017b). The use of luxury goods can increase the social status of consumers (Chiu et al. 2018). Consumers can benefit from an additional social effect when they are known to have the genuine product (i.e., positive social status of having the genuine product). Social status is a major driver of the demand for copycat luxury goods (Wilcox et al. 2009). In this subsection, we examine whether PBT can effectively combat the copycat through social status and how this social status affects supply chain performance.

We denote s as the additional status utility of having the genuine product, with $s > 0$. When ss is large, the social status of consumers is high. We consider that without PBT, the utility of expert consumers includes social status when the genuine product is purchased, but does not include it when the imitation product is purchased, that is, $U_b = vq_b - p_b + s$ and $U_c = vq_c - p_c$, respectively. Novice consumers have a prior belief that the product is genuine, that is, γ, and the expected additional status utility when purchasing the genuine product for novice consumers is γs. Thus, the utilities of novice consumers when buying the genuine product and the imitation product are $U_b = v(\gamma q_b + (1-\gamma)q_c) - p_b + \gamma s$ and $U_c = v(\gamma q_b + (1-\gamma)q_c) - p_c + \gamma s$, respectively. With PBT, consumer utilities when buying from the BNC and the copycat are $U_b = vq_b - p_b + s$ and $U_c = vq_c - p_c$, respectively. We use an approach similar to that of our basic model to derive the equilibrium results. To ensure that the demand for the copycat is nonnegative, we assume that $s \le \frac{2q_b(1-\alpha)}{2-\alpha}$. To provide accurate results, we use the same approach as in the main model to examine exogenous quality.

In this subsection, we focus on the effects of social status on the BNC with the possibility of using PBT. The corresponding results in the main model hold when considering social status. For more details, we refer the reader to the Online Supplementary Appendix. In addition, we examine the negative social effect of having the imitation product with PBT in the Online Supplementary Appendix. The corresponding results in the main model hold.

Proposition 7 [Social effect of having the genuine product with PBT] *Whether or not PBT is used, the price and demand for the genuine product as well as the profit of the BNC increase with s.*

Proposition 7 is intuitive because consumers are willing to pay more for high-status products, and the demand for the genuine product increases with social status. Consistent with Gao et al. (2017b), we call this effect (the increase in price and demand for the genuine product with higher social status) the status effect. In the luxury industry, the status effect increases consumers' willingness to buy luxury products (Han et al. 2010). Moreover, the profit of the BNC increases with social status because the price and demand increase with social status.

Figure 2 shows that social status can increase the effects of PBT on the profit of the BNC. The difference in profit for the BNC when using and not using PBT increases with social status. We offer a new perspective on the status effect in the luxury industry on the basis of PBT. When selling products with which

consumers are familiar (i.e., the number of novice consumers is small enough), the BNC should sell high social impact products directly to consumers. Conversely, when selling new products (i.e., the number of novice consumers is large enough), the BNC should sell high social impact products to consumers through the PBT retailer.

6.3. Extension 3: Privacy Concern regarding Blockchain Technology

Consumers may have privacy concerns about blockchain technology (Pun et al. 2021). Consumers may worry that their private information may be accessed by firms adopting blockchain technology when they purchase products from these firms. The information may be leaked or abused by firms. The privacy concern about blockchain technology can be considered the cost of using blockchain for consumers. In this subsection, we examine the effect of the privacy concern on the implementation of blockchain technology.

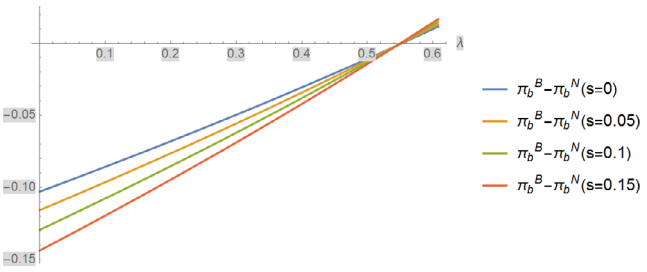
We consider that the privacy concern about blockchain technology is negative for consumers. We denote $t>0$ as the additional negative effect of the privacy concern on consumers when purchasing the genuine product from the retailer with PBT. When t is large, the privacy concern of consumers is high. With PBT, consumer utilities when buying from the BNC are $U_b = vq_b - p_b - t$. Other utilities are the same as those in the main model. To ensure that the demand for the genuine product with PBT is positive, we assume that $t < \frac{2q_b(1-\alpha)}{2-\alpha}$. In this subsection, we focus on the effects of the privacy concern on the BNC with the possibility of using PBT. The corresponding results in the main model hold when considering the privacy concern. For more details, we refer the reader to the Online Supplementary Appendix.

PROPOSITION 8. ***[Privacy concern regarding blockchain technology]*** *(i) With PBT, the price of and demand for the genuine product as well as the profit of the BNC decrease with t; the price of and demand for the imitation product as well as the profit of the copycat increase with t; consumer surplus decreases with t, and social welfare increases with t if and only if t is large enough. (ii) Even with privacy concern, PBT implementation increases the profit of the BNC, if and only if the number of novice consumers is large enough.*

Proposition 8(i) shows that if the privacy concern is significant (i.e., the cost of using blockchain for consumers is large), the price of and demand for the genuine product will be low, and the BNC will earn less. Moreover, the copycat will offer a higher price, and the demand for imitation products will also be increased due to the increased price of the genuine product. Thus, the copycat will earn more. These results are intuitive, because the privacy concern will lead to the disutility of buying the genuine product from the firm with PBT. We call this effect the privacy concern effect. Under the privacy concern effect, consumer surplus will decrease because the prices of both products have increased. Interestingly, social welfare will increase in the privacy concern if the privacy concern is significant. In this situation, the increased profit of the copycat dominates the decrease in other terms in social welfare. Proposition 8(ii) shows that our results regarding the effects of the PBT implementation on the BNC in the main model are robust with the consideration of the privacy concern.

As indicated in Proposition 8, Figure 3 shows that the privacy concern will decrease the effects of PBT on the profit of the BNC. The implementation of PBT is likely to be ineffective when the privacy concern is significant. The difference in profit for the BNC when using and not using PBT decreases with the privacy concern. Whether the PBT should be implemented is now interactively determined by the quality disclosure effect, double marginalization effect, and the privacy concern effect. The BNC should implement the PBT when the quality disclosure effect dominates the double marginalization and the privacy concern effects.

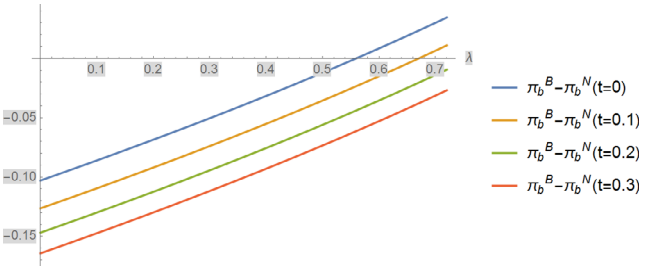
Figure 2 **Effect of s on the Profit of the BNC ($\alpha = 0.3$, $\gamma = 0.03$, $q_b = 1$, $F = 0$) [Color figure can be viewed at wileyonlinelibrary.com]**



6.4. Extension 4: Unit Production Cost of the Genuine Product

In this extension, we consider the unit production cost c ($c>0$) of the genuine product, whereas the unit production cost of the imitation product is normalized to zero. Thus, we can assume that c is the cost difference between the genuine product and the imitation product. The profit functions of the BNC without and with PBT become $\pi_b(p_b) = (p_b - c)D_b$ and $\pi_b(w_b) = (w_b - c)D_b$, respectively. To ensure that both the demands for the genuine product without and with PBT are positive, we assume that $c < \min\left\{\frac{q_b(\alpha^2+2\gamma-3\alpha\gamma+\alpha^2\gamma)}{2\alpha}, \frac{2q_b(1-\alpha)}{2-\alpha}\right\}$.

Figure 3 Effect of t on the Profit of the BNC ($\alpha = 0.3$, $\gamma = 0.05$, $q_b = 1$, $F = 0$) [Color figure can be viewed at wileyonlinelibrary.com]



PROPOSITION 9 [Unit production cost of the genuine product]. *Whether or not PBT is used, the price of the genuine product increases with c, and the demand for the genuine product and the profit of the BNC decrease with c; the price of and demand for the imitation product as well as the profit of the copycat increase with c; consumer surplus decreases with c, and social welfare increases with c if and only if c is large enough.*

Proposition 9 shows the effects of the unit production cost of the genuine product, which are similar to the privacy concern effect. If the unit production cost of the genuine product is large, then the price of the genuine product will be increased; and then the demand for the genuine product and the profit of the BNC will decrease. As the follower, the copycat will follow the pricing strategy of the genuine product to increase the price of the imitation product. Despite the increasing effect of the price of the imitation product, the demand for the imitation product will be also increased due to the increase in the price of the genuine product. Obviously, the profit of the copycat will be increased. In addition, consumer surplus will naturally decrease because the prices of both products have increased. Moreover, social welfare may be increased in the unit production cost of the genuine product. If the unit production cost of the genuine product is large enough, then social welfare will be increased when the unit production cost increases. This result is because when the unit production cost of the genuine product is large enough, the increasing effect of the profit of the copycat dominates the decreasing effects of consumer surplus and the profit of the BNC (and the decreasing effect of the profit of the retailer with PBT).

To further present the results with a positive unit production cost of the genuine product, we conduct extensive numerical tests and find that our basic model is robust. The major insights for a positive production cost of the genuine product are the same as those of the basic model. We present the following figures to evaluate the effects of the unit production cost when the BNC uses PBT to combat the copycat.

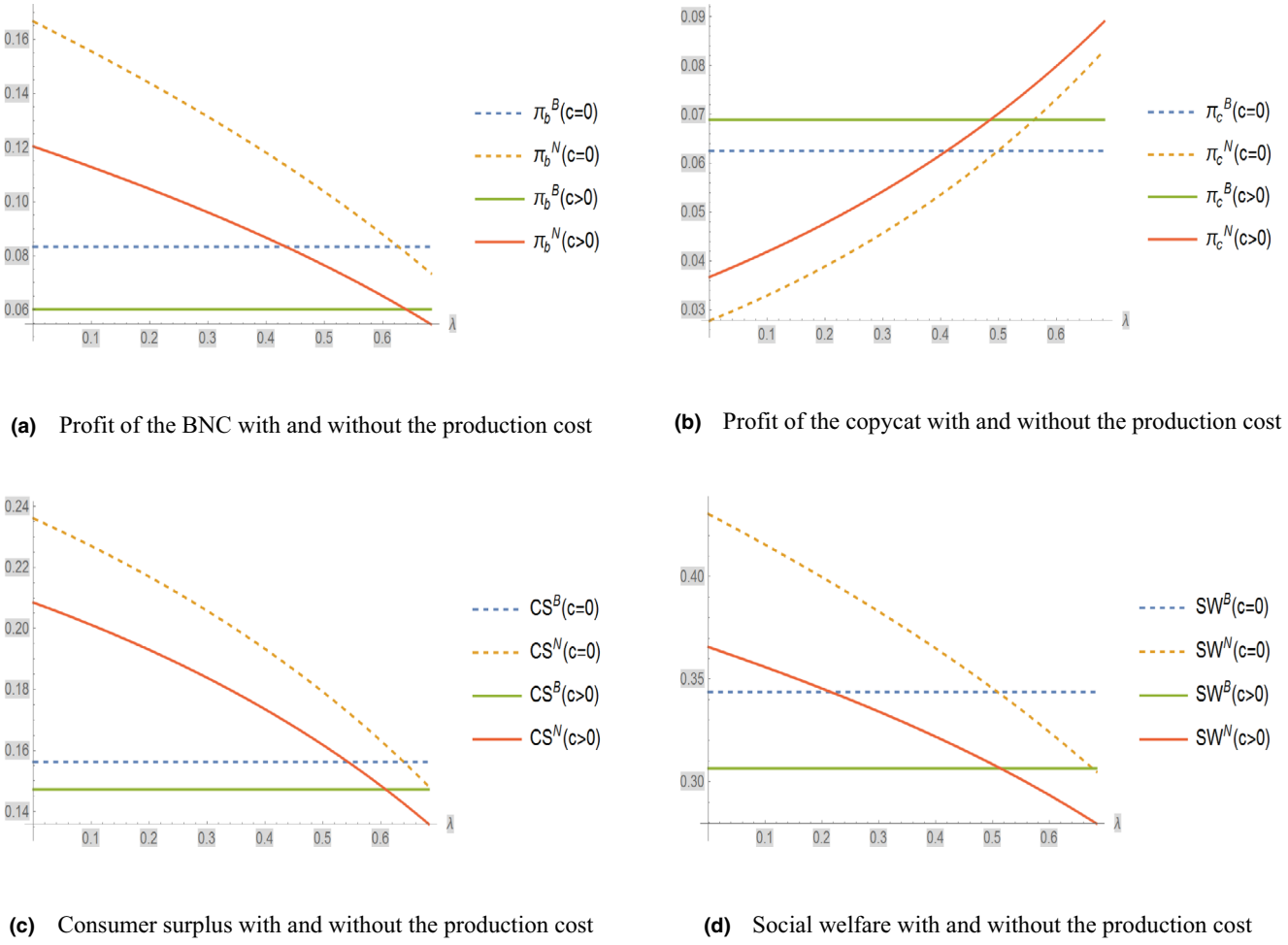
Figure 4 confirms the results of our basic model. If the number of novice consumers is large enough, then PBT implementation increases the profit of the BNC, consumer surplus, and social welfare, and decreases the profit of the copycat. This finding indicates that the results of our basic model are robust. In addition, compared with the zero production cost, the profit of the BNC, consumer surplus, and social welfare decreases with a positive production cost, whereas the profit of the copycat increases. These results are intuitive because a higher production cost for the genuine product will make the product more expensive and will reduce its market demand. Thus, consumers and society are not inclined to buy expensive products.

6.5. Extension 5: Marginal Cost of Implementing Blockchain Technology

In the main model, we consider a lump sum payment for implementing blockchain technology to the retailer, and assume that the unit cost of using PBT is negligible. In this extension, we consider a positive marginal cost of using PBT to the retailer. Alternatively, we can model the marginal cost as the unit cost of using PBT to the BNC. In this case, the modeling of the marginal cost of using PBT is the same as the unit production cost of the genuine product with PBT in section 6.4. To avoid redundancy, we only consider the marginal cost to the retailer. Let c_b denote the marginal cost of using PBT to the retailer. Then, the profit function of the retailer with PBT becomes $\Pi(p_b) = (p_b - w_b - c_b)D_b$. To ensure that the demand for the genuine product with PBT is positive, we assume that $c_b < \frac{2q_b(1-\alpha)}{2-\alpha}$.

Taking the same approach in the main model, we can derive the equilibrium outcomes with a positive marginal cost. The expressions of the most outcomes (e.g., wholesale price, demands, profits, consumer surplus, and social welfare) with positive marginal cost of using PBT are the same as those with privacy concern regarding blockchain technology in section 6.3, if we use the same notation for these two extensions, that is, $t = c_b$. This is because the retailer will transfer the marginal cost to the retail price, which will affect the demands of both products. This effect is similar to the privacy concern regarding blockchain technology. As we have shown the effects of the privacy concern on implementing PBT in section 6.3, here, the corresponding results in the main model hold when considering the positive marginal cost. For more details, we refer readers to the Online Supplementary Appendix.

Figure 4 Profits of the BNC and the Copycat, Consumer surplus, and Social Welfare with and without the Unit Production Cost ($\alpha = 0.5$, $\gamma = 0.1$, $q_b = 1$, $c = 0.1$, $F = 0$) [Color figure can be viewed at wileyonlinelibrary.com]



(a) Profit of the BNC with and without the production cost

(b) Profit of the copycat with and without the production cost

(c) Consumer surplus with and without the production cost

(d) Social welfare with and without the production cost

Notes. (a) Profit of the BNC with and without the production cost. (b) Profit of the copycat with and without the production cost. (c) Consumer surplus with and without the production cost. (d) Social welfare with and without the production cost.

7. Conclusions

We examine how the PBT retailer helps the BNC combat copycats. The BNC is the leader and the copycat is the follower. The BNC can sell its product directly to consumers or through a PBT retailer. The PBT retailer can also sell the imitation product on the market. Selling through the PBT retailer leads to a *double marginalization effect*. We divide consumers into expert and novice consumers in the market. Without PBT, expert consumers know the true quality of the product, but novice consumers do not. However, when using PBT, all consumers in the market know the true quality of the product. This difference means that using PBT has a *quality disclosure effect*. We focus on the effects of selling through the PBT retailer to fight against the imitation product by considering the trade-off between *double marginalization* and the *quality disclosure effect*. Moreover, we extend the model by considering consumer learning, self-implementation, social status, privacy concern, production cost, and marginal implementation cost.

We could answer three research questions as follows. First, whether or not selling through a PBT retailer can be an effective anti-copycat solution (i.e., it increases the profit of the BNC and reduces the profit of the copycat, and improves consumer surplus and social welfare) depends on the number of novice consumers. If the number of novice consumers is large enough, then selling through a PBT retailer is an effective anti-copycat solution. This result provides insights into supply chain management and identifies when direct selling or mixed selling is effective to combat copycats using blockchain. Second, adopting PBT is ideal when launching new products, because consumers are not familiar with products and the number of novice consumers may be large. By contrast, it is not ideal when products have been on the

market for a long time, because consumers may be familiar with the products and the number of expert consumers may be large. However, PBT may exist in the market even if the number of novice consumers is small. With a small number of novice consumers, self-implementation of PBT is preferable for BNCs. Third, PBT induces a low (high) price of a genuine product when the number of novice consumers is large (small) enough. Surprisingly, implementing PBT decreases the quality of a genuine product in the presence of a copycat. This finding implies that improving product quality may not be wise, because PBT is effective in helping consumers identify product quality.

On the basis of our analytical results, we offer several important recommendations for BNCs, including how to sell through a PBT retailer, when to implement PBT, and what to sell using PBT (see Table 4).

This study provides several directions, which can be applicability areas, for future research. First, we assume that novice consumers buy a product according to their utility in terms of product quality and price. Without PBT, product quality is identical to genuine and imitation products according to the perception of novice consumers. As a result, novice consumers will always buy the cheaper product, that is, the imitation product. In future research, it will be interesting to assume that some novice consumers know that an expensive product has a high probability of being genuine. Thus, a fraction of novice consumers will buy the genuine product even if its price is high. Second, in our paper, we assume that using PBT can help consumers determine the quality of a product. PBT can be an effective marketing tool to increase consumers' willingness to buy a product. Future research should explore the externalities of blockchain use for consumers. Consumers may have various preferences: some may like blockchain and have an additional utility or willingness to pay when purchasing a product with PBT (Gupta and Çakanyıldırım 2016), but some may not like it. Third, we assume that the market is made up of one BNC and one copycat. Future research can examine the competition effect when various substitutable imitation products compete in the market (Gupta et al. 2020), for example, a market made up of multiple copycats that follow one BNC. Finally, exploring the impacts of multiple copycats on the optimal demand and how a BNC sells through the PBT retailer to combat multiple copycats will be interesting (Perera et al. 2020).

Table 4 Managerial Implications of Using PBT for BNCs

Actions of the BNC	Details
How to sell through a PBT retailer	• Selling through the PBT retailer leads the BNC to increase its prices • Selling a genuine product directly to consumers with self-implemented PBT leads the BNC to reduce its prices • Implementing PBT leads the BNC to reduce the quality of its products for quality competition
When to implement PBT	• Selling through the PBT retailer (blockchain self-implementation) is profitable (not profitable) when launching new products • Blockchain self-implementation (selling through the PBT retailer) is profitable (not profitable) when products are mature on the market • Implementing PBT is effective in reducing social welfare only when the implementation cost is low enough
What to sell using PBT	• If consumers are familiar with its products, then the BNC should sell high social impact products directly to consumers • If the products are newly developed and consumers are not familiar with them, then the BNC should sell high social impact products to consumers through the PBT retailer in the supply chain

Acknowledgment

Ciwei Dong is the corresponding author. The authors sincerely thank Kalyan Singhal, Subodha Kumar, the senior editor, and three anonymous reviewers for their constructive comments on this study. The paper is partially supported by the National Natural Science Foundation of China (grant numbers 71871051, 71971215, 71832001, 71601187). Bin Shen thanks TUM School of Management for hosting him as Humboldt Fellow.

References

Babich, V., G. Hilary. 2020. Distributed ledgers and operations: What operations management researchers should know about blockchain technology. *Manuf. Serv. Oper. Manag.* **22**(2): 223–240.

Becker, R. 2019. Juul's imitators are copying the popular vape's high nicotine levels. *The Verge*, February 8. Available at: https://www.theverge.com/2019/2/8/18217738/juul-vape-nicotine-salts-electronic-cigarette-competitors (accessed date May 1, 2020).

Bessen, J. 2002. Technology adoption costs and productivity growth: The transition to information technology. *Rev. Econ. Dyn.* **5**(2): 443–469.

Cai, Y., T. M. Choi, J. Zhang. 2020. Platform supported supply chain operations in the blockchain era: Supply contracting and moral hazards. *Decis. Sci.* (in press). https://doi.org/10.1111/deci.12475.

Castillo, M., M. Schifrin. 2020. Forbes Blockchain 50. *Forbes*, February 19. Available at: https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/#4292e9427553 (accessed date May 1, 2020).

Chang, J., M. N. Katehakis, B. Melamed, J. Shi. 2018. Blockchain design for supply chain management. Working paper, Rutgers Business School – Newark and New Brunswick.

Chen, Z. 2019. 4 intellectual property guidelines that are crucial for luxury brands. *Jing Daily*, November 26. Available at: https://jingdaily.com/luxury-brands-china-intellectual-property/ (accessed date May 1, 2020).

Chipty, T. 2001. Vertical integration, market foreclosure, and consumer welfare in the cable television industry. *Am. Econ. Rev.* **91**(3): 428–453.

Chiu, C. H., T. M. Choi, X. Dai, B. Shen, J. Zheng. 2018. Optimal advertising budget allocation in luxury fashion markets with social influences. *Prod. Oper. Manag.* **27**(8): 1611–1629.

Cho, S. H., X. Fang, S. Tayur. 2015. Combating strategic counterfeiters in licit and illicit supply chains. *Manuf. Serv. Oper. Manag.* **17**(3): 273–289.

Chod, J., N. Trichakis, G. Tsoukalas, H. Aspegren, M. Weber. 2020. On the financing benefits of supply chain transparency and blockchain adoption. *Management Sci.* **66**(10): 4378–4396.

Choi, T. M. 2019. Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains. *Transp. Res. Part E Log. Transp. Rev.* **128**: 17–29.

Cui, Y., M. Hu, J. Liu. 2019. Values of traceability in supply chains. Working paper, Cornell University, Ithaca, NY.

DeAcetis, J. 2021. Innovative blockchain technology creates new opportunities for the high-end fashion industry. *Forbes*, March 27. Available at: https://www.forbes.com/sites/josephdeacetis/2021/03/27/innovative-blockchain-technology-creates-new-opportunities-for-the-high-end-fashion-industry/?sh=602cfdd6c68e (accessed date May 1, 2020).

Dimitrov, B. 2019. How Walmart and others are riding a blockchain wave to supply chain Paradise. *Forbes*, December 5. Available at: https://www.forbes.com/sites/biserdimitrov/2019/12/05/how-walmart-and-others-are-riding-a-blockchain-wave-to-supply-chain-paradise/ (accessed date May 1, 2020)

Eytan, D. 2017. In Madrid, the worlds of fast-fashion and high fashion battle things out on the same runway. *Forbes*, January 31. Available at: https://www.forbes.com/sites/declaneytan/2017/01/31/in-madrid-the-worlds-of-fast-fashion-and-high-fashion-battle-things-out-on-the-same-runway/ (accessed date May 1, 2020)

Feng, J., J. Xie. 2012. Research note – Performance-based advertising: Advertising as signals of product quality. *Inf. Syst. Res.* **23**(3): 1030–1041.

Gao, Y. 2018. On the use of overt anti-counterfeiting technologies. *Market. Sci.* **37**(3): 403–424.

Gao, Y., W. S. Lim, C. S. Tang. 2017a. The impact of the potential entry of copycats: Entry conditions, consumer welfare, and social welfare. *Decis. Sci.* **48**(4): 594–624.

Gao, Y., W. S. Lim, C. S. Tang. 2017b. Entry of copycats of luxury brands. *Market. Sci.* **36**(2): 272–289.

Grossman, G. M., C. Shapiro. 1988a. Counterfeit-product trade. *Am. Econ. Rev.* **78**(1): 59–75.

Grossman, G. M., C. Shapiro. 1988b. Foreign counterfeiting of status goods. *Q. J. Econ.* **103**(1): 79–100.

Guha, S., S. Kumar. 2018. Emergence of big data research in operations management, information systems, and healthcare: Past contributions and future roadmap. *Prod. Oper. Manag.* **27**(9): 1724–1735.

Gupta, V., M. Çakanyıldırım. 2016. A WTP-choice model: Empirical validation, competitive and centralized pricing. *Prod. Oper. Manag.* **25**(11): 1866–1884.

Gupta, V., D. Ivanov, T. M. Choi. 2020. Competitive pricing of substitute products under supply disruption. *Omega* **101**: 102279.

Han, Y., J. C. Nunes, X. Dreze. 2010. Signaling status with luxury goods: The role of brand prominence. *J. Market.* **74**(4): 15–30.

Hastig, G. M., M. S. Sodhi. 2020. Blockchain for supply chain traceability: Business requirements and critical success factors. *Prod. Oper. Manag.* **29**(4): 935–954.

Hertzendorf, M. N. 1993. I'm not a high-quality firm–but I play one on TV. *RAND J. Econ.* **24**(2): 236–247.

Jagati, S. 2019. Walmart's foray into blockchain, how is the technology used? Available at: https://cointelegraph.com/news/walmarts-foray-into-blockchain-how-is-the-technology-used (accessed date May 1, 2020).

Li, B., S. Kumar. 2018. Should you kill or embrace your competitor: Cloud service and competition strategy. *Prod. Oper. Manag.* **27**(5): 822–838.

Luo, Y., J. Sun, S. L. Wang. 2011. Emerging economy copycats: Capability, environment, and strategy. *Acad. Manage. Perspect.* **25**(2): 37–56.

MarkMonitor. 2017. Nearly half of consumers fear buying counterfeit holiday gifts. Available at: https://markmonitor.com/brand-protection-domain-management-resources/press-releases/release/nearly-half-of-consumers-fear-buying-counterfeit-holiday-gifts/ (accessed date May 1, 2020).

Masters, K. 2019. The one change that would drastically reduce counterfeiting on Amazon's U.S. marketplace. *Forbes*. November 13. Available at: https://www.forbes.com/sites/kirimasters/2019/11/13/the-one-change-that-would-drastically-reduce-counterfeiting-on-amazons-us-marketplace/ (accessed date May 1, 2020).

Newbold, A. 2019. Louis Vuitton to launch first blockchain to help authenticate luxury goods. *Vogue*, May 17. Available at: https://www.vogue.co.uk/article/lvmh-blockchain (accessed date May 1, 2020).

Niu, B., K. Chen, X. Fang, X. Yue, X. Wang. 2019. Technology specifications and production timing in a co-opetitive supply chain. *Prod. Oper. Manag.* **28**(8): 1900–2007.

Perera, S., V. Gupta, W. Buckley. 2020. Management of online server congestion using optimal demand throttling. *Eur. J. Oper. Res.* **285**(1): 324–342.

Pun, H., G. D. DeYong. 2017. Competing with copycats when customers are strategic. *Manuf. Serv. Oper. Manag.* **19**(3): 403–418.

Pun, H., J. M. Swaminathan, P. Hou. 2021. Blockchain adoption for combating deceptive counterfeits. *Prod. Oper. Manag.* **30**(4): 864–882. https://doi.org/10.1111/poms.13348

Qian, Y. 2014. Brand management and strategies against counterfeits. *J. Econ. Manage. Strat.* **23**(2): 317–343.

Qian, Y., Q. Gong, Y. Chen. 2015. Untangling searchable and experiential quality responses to counterfeits. *Market. Sci.* **34**(4): 522–538.

Sun, J., X. Zhang, Q. Zhu. 2020. Counterfeiters in online marketplaces: Stealing your sales or sharing your costs. *J. Retail.* **96**(2): 189–202.

Taylor, P. 2020. Jamaica launches crackdown on counterfeit coffee. *Securing Industry*, February 18. Available at: https://www.securingindustry.com/food-and-beverage/jamaica-launches-crackdown-on-counterfeit-coffee/s104/a11345 (accessed date May 1, 2020).

Villas-Boas, J. M. 2004. Consumer learning, brand loyalty, and competition. *Market. Sci.* **23**(1): 134–145.

Wang, Z., Z. Zheng, W. Jiang, S. Tang. 2021. Blockchain-enabled data sharing in supply chains: Model, operationalization, and tutorial. *Prod. Oper. Manag.* **30**(7): 1965–1985.

Whitaker, A., R. Kräussl. 2020. Fractional equity, blockchain, and the future of creative work. *Management Sci.* **66**(10): 4594–4611.

Wilcox, K., H. M. Kim, S. Sen. 2009. Why do consumers buy copycat luxury brands? *J. Mark. Res.* **46**(2): 247–259.

Yao, S., K. Zhu. 2019. The role of anticounterfeit technology in combating counterfeit products. Working paper, Monash University, Melbourne, Australia.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix A: Main Equilibrium Results.
Appendix B: Proofs.
Appendix C: Additional Results.