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Information disclosure structure in supply chains with rental service platforms in the blockchain technology era

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ABSTRACT

In platform operations for rental services, product information disclosure (supported by the blockchain technology) is critical to attract customers. We build a stylized duopoly model to analyze the product-information-disclosure Nash game between two rental service platforms whose products-to-rent are substitutable. We derive the equilibrium level of product information disclosure and identify conditions under which the platforms choose to disclose or not to disclose information, which correspond to different types of supply chains. For the basic model, we find that there exists a critical threshold on the information-sensitive consumers which helps each platform decide whether or not to disclose product information. If the information auditing cost is sufficiently small, both platforms should disclose the product information as much as possible. For products with higher profit margin, both platforms are more likely to disclose information. We also explore the impacts of product information disclosure on the consumer surplus and seller benefits, and discuss the roles played by the blockchain technology. To check robustness of the results as well as to examine different supply chain configurations, we extend the analysis to the cases including (i) the platforms are risk averse in decision making, (ii) rather than selling the product, the seller (owner of the product) consigns the product to the platform and shares a revenue, and (iii) rather than two competing platforms, there is a common rental service platform providing service for two substitutable products. We find that the core insights remain valid in all the extended models. Managerial implications are discussed.

1. Introduction

1.1. Background and motivation

Service supply chains, including those related to platform services, face challenges such as demand uncertainty (Dolgui et al., 2018) and risk (Asian and Nie, 2014; Ivanov 2018; Ivanov and Dolgui, 2018; Ivanov et al., 2018; Choi et al., 2019). In the blockchain technology era, how a change of the service supply chain's information structure affects operations efficiency is an important topic. This is especially critical when the supply chain may face disruptions and other probable risks. This paper would like to address this issue by exploring the information disclosure game in platform rental operations.

Platform operations are very important in information systems (Tiwana et al., 2010; Tiwana, 2015; Im et al., 2016; Hong and Pavlou, 2017). In the sharing economy (Eckhardt, 2015; Wang et al., 2019), supported by the blockchain technology (Iansiti and Lakhani, 2017), platform operations play an even more critical role for different kinds of services (Constantinides et al., 2018). In terms of business volume, PriceWaterhouseCoopers[1] reported that the service platform operations (across different sectors) will reach a global business revenue of $335 billion by 2025. In a more humble scale, for a Chinese luxury handbag rental service platform "Dou Bao Bao"[2] (which recently merged and formed a company called "Real" (in Chinese)), Asian Times estimated its corporate value to be a few hundred million US dollars. There is no doubt that the service platform operations are very critical and influential, and they are crucial in the sharing economy.

Consider a commonly seen sellers and users platform such as the one

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[1] https://www.pwc.com/us/en/industry/entertainment-media/publications/consumer-intelligence-series/assets/pwc-cis-sharing-economy.pdf (accessed: 15 May 2019).

[2] http://www.atimes.com/article/luxury-handbags-join-chinas-super-hot-sharing-economy/(accessed: 15 May 2019).

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offering rental services for luxury handbags (e.g., bagborroworsteal.com in the US; “Dou Bao (Real) [3]” in China). Sellers are the people who own the products and they want to trade them via platforms. Users are consumers who want to enjoy and use the products via the support of the platform. As an example, if we look at the platforms for rental services of luxury handbags, sellers can send their luxury handbags to the platforms (either by “buyout” or consignment) and platforms post product information online for users to choose. Users who want to enjoy the rental service have to pay a fee, which can be charged daily or monthly.[4] One interesting issue behind the scene is: How many details should the platform disclose regarding the products? Usually, the platform will show a picture of the product and the rental fee (these are basic and “necessary” details that will be shown for every product). But how about whether the product has some unique features, e.g., in a particularly good shape? Purchased from the flagship stores? With the signature of the designer? If there are multiple generations of the same product style, which generation and year does the product carry? Has the product been used by some celebrities[5]? For some products, there are different versions with subtle differences, should such related “favorable” information be posted, too? For the platforms, if more information is posted, potentially, users in the market who treasure more information will be enticed to enjoy the rental services more (i.e. demand is expectedly higher). However, disclosing more product details and information requires more information checking, auditing and updating every time the product returns from renting (i.e. after every rental transaction) to ensure accuracy. A tradeoff hence exists between the potential benefit of disclosing more information in improving demand and the cost associated with it. As a remark, nowadays, information disclosure can be implemented by the blockchain technology. This means all the previous information disclosed will be permanently present and users now and in the future can view the history of all disclosed information. This is also an important factor which attracts some users to try the services as everything is more transparent and the product's authenticity can be traced. As a remark, if information disclosure is supported by the blockchain technology, platforms have to take it especially seriously and avoid mistakes because the information is there forever. Table 1 shows the features of the blockchain technology which are relevant to product information disclosure and use of data for operations.

Regarding rental service platform operations, in addition to the importance of product information disclosure, we observe that the industry is highly competitive and there is high market uncertainty in the market. These points are best illustrated in the rental services for luxury handbags and even cars in which multiple platforms are present and demand is totally uncontrollable. Table 2 illustrates some important features of platform operations that we observe in practice and want to capture in this paper. As a remark, for “consignment or buyout”, this refers to the choice offered by some platforms (such as bagborroworsteal.com) to the sellers in providing the product.

1.2. Research questions and major findings

Motivated by the observed real world industrial practice on platform operations for rental services and the importance of product information disclosure in the blockchain era, we analytically build a game-theoretic duopoly economic model to explore the product information disclosure game between two competing platforms offering rental services. We also extend the models and analyses in a number of directions and generate additional insights.

To be specific, we aim to address the following research questions.

1. In the basic model with two competing platforms: What are the features of the optimal[6] levels of product information disclosure in the rental service platform operations under competition? When will it be optimal to disclose or not to disclose product information? When will it be optimal to disclose full information?
2. If the platforms possess risk averse attitudes towards profit risk, how would the degrees of risk aversion and demand volatilities affect the optimal product information disclosure levels and consumer surplus?
3. Comparing between the buyout or consignment arrangement for the product sellers, does it make a difference in the optimal product information disclosure levels, consumer surplus and seller benefits? If the game is changed to the single platform operations, will it affect the main managerial insights?
4. How would the product information disclosure affect seller benefits? What are the roles played by the blockchain technology in the product information disclosure game?

To address the above research questions, as we will show in the subsequent sections, we build the analytical model and derive the optimal level of product information disclosure. We analytically identify the conditions in which it is optimal to disclose or not to disclose information. To check robustness of the results, we extend the analysis to the cases when (i) the platform operations managers are risk averse (and hence profit risk is incorporated into the decision making process), (ii) rather than selling the product at a fixed price, the seller consigns the product to the platform and shares a revenue, (iii) there is a common rental service platform which receives and provides rental services for two substitutable products.

We have the following major findings: Under the basic model with the two competing platforms scenario, the two-platform (TPF) scenario, we uncover that from each platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which the platform can decide whether it is optimal to disclose product information or not. If the information auditing cost is sufficiently small, it is optimal for the platform to disclose the full product and achieve the maximum consumer surplus. It is interesting to note that when the rental service profit margin of the product (either the platform itself or its competitor's) increases, the likelihood that both platforms will disclose information for their products is higher and it is more likely for both platforms to disclose the full product information for their respective products. Under the case when the two competing platforms are risk averse, they will set a higher product information disclosure level and achieve a higher consumer surplus compared to the case when they are risk neutral. If the degree of risk aversion of either platform increases or the demand volatility of either platform increases, we uncover that (i) the likelihood that both platforms will disclose product information of their products will be higher, and (ii) it will be more likely for both platforms to disclose the full product information for their respective products. If the platforms change their way of acquiring products of sellers from “buyout” to consignment, we reveal that the optimal product information disclosure level and consumer surplus under consignment are lower than the corresponding ones under buyout. Finally, in an extended model when we consider the presence of a common platform selling two substitutable (or competing) products, we have the same conclusion that from the platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which it can decide whether it is optimal to disclose product information or not. We conclude that the qualitative managerial insights from the basic model

[3] http://www.zhen-de.com/#home-about-us (accessed: 15 May 2019).

[4] The platform “Real” changes per day, and the platform bagborroworsteal.com offers rental services charged per month.

[5] Companies can intentionally invite some celebrities to use the rental service to enhance the product's value if the respective information will be disclosed.

[6] In this paper, we use the term “optimal” decision and “equilibrium” decision interchangeably.

Table 1
Features of the blockchain technology for product information disclosure of rental services.

Features	Details
Permanent record	The information cannot be erased and can always be checked and verified.
Trustworthy data	The blockchain based systems store data in a secure way and data are trustworthy.
Distributed "ledgers"	Data can be added by the related parties.
Smart matching	With the large amount of data, the blockchain technology can better match requirements between supply and demand.
Low information sharing/disclosure cost	Information sharing/disclosure is facilitated with a low cost.

Table 2
Some features of rental service platform operations.

Features	Rental Service Platform Operations
Information disclosure	Product information disclosure is critical because users need information to judge if they want the rental services or not. Supported by the blockchain technology, if the platform can provide more trustworthy and favorable product information, the corresponding rental service demand should increase.
Competitive environment	Platforms are usually competing with one another, and the level of competition is non-trivial.
Profit risk	The rental service demand faced by each platform is highly volatile which implies a high level of profit risk.
Product acquisition	Rental service platforms (e.g., those for luxury handbag rental services) acquire products from sellers usually by "consignment" and "buyout".

remain valid in the extended models with the consideration of risk averse attitudes of platforms, the change of product acquisition policy from buyout to consignment, and also the common platform scenario.

1.3. Contribution statements and organization

To the best of our knowledge, this paper is the first paper in the literature which analytically explores the product information disclosure game between two competing platforms for rental services in the blockchain technology era. Impacts brought by risk averse attitudes of the platforms, the choice of consignment versus buyout, the presence of a common platform, and the roles of blockchain technology are uncovered. The findings are novel and some important insights are revealed. This paper lays the foundation for future studies in information disclosure games for platforms operations with the use of blockchain technology and also generates valuable managerial insights for platform operations in practice.

The rest of this paper is organized as follows. We review the related literature of platform operations and product information disclosure in Section 2. We construct the basic model for the two competing platforms scenarios in Section 3. We derive the optimal product information disclosure levels and determine the critical thresholds to find the cases in which it is optimal to disclose or not to disclose any additional favorable product information, and generate the respective insights in Section 4. To check robustness of the major insights generated from the basic model, we conduct further analysis on various extended models in Section 5. We discuss the roles of blockchain technology and seller benefits in Section 6. We conclude this paper with a discussion of managerial implications and future research in Section 7. To enhance exposition, we present all proofs in Appendix (A3), summarize technical insights in propositions and report the managerial insights in theorems. Moreover, a notation table is included in Appendix (A1).

2. Related literature

2.1. Platform operations

Platform operations emerge in the sharing economy with collaborative commerce. In operations management, prior studies have examined platform operations. For instance, Smedlund (2012) link the platform service operations models with service theories. The author explores value co-creation by platforms and illustrates the arguments by using an example from the video game industrial sector. He argues that capability-based model can be used for value co-creation effectively. Gaivoronski et al. (2013) conduct an analysis on the platform for cloud brokering platforms. The authors study the problem under a stochastic setting and consider both profit and risk with the financial portfolio management concept. Chang et al. (2017) study the car-sharing service platform in the sharing economy. The authors investigate the optimal location design as well as the car-sharing fleet arrangement with the consideration of carbon emission. They employ the minimum-cost flow optimization model and implement the FCFS (first-come, first-serve) rule in their analysis. Most recently, Bai et al. (2018) explore the on-demand service platform operations in the presence of impatient customers. The authors interestingly find that the optimal charged price is not necessarily monotonic in the platform's capacity. Other related studies include Kung and Zhong (2017) and Du et al. (2019).

Focusing on peer-to-peer operations, Chen et al. (2015b) propose how peer-to-peer platform based information and knowledge sharing can benefit farmers in the developing countries. Jiang et al. (2017) study the platform based peer-to-peer marketplace operations with valuation uncertainty from consumers. Ghasemkhani et al. (2018) study the contracting mechanism for peer-to-peer content sharing networks. Benjaafar et al. (2018) study the platform operations for peer-to-peer (P2P) product-share. The authors explore the situation when the platform operates with different objectives, namely for profit or social welfare. They prove that consumers can always benefit from this kind of P2P product-share platform operations. Similar to the above studies, we also explore the platform operations. However, to the best of our knowledge, our focal point is on the product information disclosure game which has never been examined in the prior literature.

2.2. Information disclosure

Information disclosure is a popular issue that has been examined in the literature. This topic is especially timely owing to the emergence of the blockchain technology (Babich and Hilary, 2018). For instance, Umehara and Ohta (2009) employ game theory to study risk related information disclosure by the government. The authors argue that information disclosure is critical to the public. They propose the use of a guardian agent to help reduce the information gap on risk. Rayo and Segal (2010) study information disclosure in a sender-receiver game. The authors prove that partial information disclosure can lead to maximization of the sender's profit. Zimmer et al. (2010) study information disclosure in the online channel. The authors highlight people's intention to disclose information online with factors such as risk and trust. Drobetz et al. (2014) study the disclosure of CSR (corporate social responsibility) information in transportation. The authors employ the Monte Carlo techniques for analysis and prove that the firm's business performance is positively correlated with information disclosure. Gao et al. (2014) explore voluntary information disclosure in the export-processing trade by using the Bayesian gaming model. The authors establish the optimal information disclosure policy that relates to two-yield-rate-based thresholds. Chen et al. (2015a) empirically investigate the information privacy challenge related to information disclosure by peers on social media. The authors mention that the image discrepancy is a critical factor to determine whether decisional control should be imposed or not. Huang and Yang (2016) study acquisition of information in supply chains and highlight the importance of supply chain transparency. The authors explore a single-retailer single-supplier supply chain and examine the information disclosure action of the supplier. They reveal the role played by the forecasting cost is crucial. Simhon et al. (2016) and Kim and Kim (2017) both explore queueing models and derive the optimal policies for information disclosure. They highlight the structure of the optimal policies as well as the significance of information. Li and Shu (2017) conduct an economic study on information disclosure. The authors establish a gaming model with incomplete information and demonstrate how a way of releasing tailored amount of information to different types of buyers is in fact better than disclosing and sharing all information. Guan and Chen (2017) study the interaction of information acquisition and disclosure of quality information for a manufacturer. The authors show that information acquisition can do more harm than good to the manufacturer if information disclosure is too costly. Markopoulos and Hosanagar (2018) build a game-theoretic model and explore the investment decisions on information disclosure. They prove that enhanced information availability via information disclosure may counterintuitively lead to quality reduction in some cases. Most recently, Yang and Dong (2018) explore the rebate policy with a goal to entice reviews from online customers. They find that the customer review effort determines the retailer's marketing decisions such as rebates and pricing decisions. Similar to the above reviewed literature, this paper also focuses on information disclosure. However, different from all of them, this paper focuses on the rental service platform operations in the sharing economy and also examines how the level of information disclosure should be set in a competitive environment when demand for rental services depends on the level of information disclosure.

2.3. Blockchain technology

The blockchain technology (Choi, 2019) has emerged since the time when bitcoin was born. Iansiti and Lakhani (2017) reveal many facts behind the blockchain technology. They also discuss many features of it. In a recent paper, Babich and Hilary (2018) discuss and review how the blockchain technology may enhance operations management. The authors highlight areas such as smart contracts and information visibility that can be achieved by the blockchain technology. They also propose different research agendas such as supply chain risk management which can be supported by the blockchain technology. Observe that the blockchain technology is also related to big data analytics (Choi et al., 2018; Fisher and Raman, 2018; Guha and Kumar 2018). In fact, Cai et al. (2018) establish that the blockchain technology based information sharing scheme can make use of big data to achieve perfect coordination of the newsvendor supply chain. Shi and Choi (2018) analytically explore how the blockchain technology can enhance food supply chain management by providing higher food sourcing information visibility and traceability. They prove that the blockchain technology can enhance consumer surplus. Similar to the above reviewed studies, this paper also studies the use of blockchain technologies. However, in terms of models and scope (product information disclosure game), this paper is totally different from the others. In particular, this paper aims to conduct an economics analysis (Cao et al., 2018) for the information disclosure games of rental service platforms in the blockchain technology era.

3. Basic model: two-platform (TPF) scenario

Consider the case that in the market, two groups of sellers, called Seller Group 1 and Seller Group 2, offer the same type of product (e.g., an LV luxury handbag) to the market (e.g., for rental service) by directly selling the product to the platforms (i.e. under the buyout scheme). The product for rent on Platform i is referred to as Product i, $i = 1, 2$, respectively. The platform i can decide the amount of product information[7] α_i to disclose via the blockchain technology, where $i = 1,\ \ 2$. Note that the product information disclosure α_i refers to those "additional" "favorable" product information[8] which is treasured, but not necessarily required, by the users (i.e. consumers) in the market for the rental services. For example, for luxury bag rental services, it is a norm and in fact necessary for the platforms to show the picture and the rental fee for each product. These details have to be shown and are not considered as a part of α_i. However,[9] which special version the product belongs to, any special nice features which are unique of the specific product, whether any famous people have used it before, etc are not necessary but they may positively improve demand as some users may be interested to know and will be attracted. These positive product details are collectively known as the product information that can be disclosed (i.e. α_i). Note that for blockchain technologies, we have public and private versions. Some blockchain technology supported systems do not allow the disclosure of selective information but some allow. Observe that since the information mentioned above is not blockchain user specific, any type of blockchain (public, private or closed) should support the disclosure. This also applies to the more blockchain-specific track-and-trace type of information.

In the market, a proportion of consumers $(0 \le \lambda \le 1)$ is not information-sensitive (called "information-insensitive") and the rest $1 - \lambda$ is information-sensitive. For the platform i, disclosing product information incurs a unit cost $\hat{I}_i = k\alpha_i$, where $k\alpha_i$ (P.S.: $k > 0$, and $0 \le \alpha_i \le 1$) refers to the checking, auditing and updating cost to ensure the posted product information is correct (and hence it is increasing in α_i) before and after the rental service (especially to check for authenticity). Moreover, there is also a certain per unit cost incurred for each rental transaction (e.g. the unit product delivery cost, handling cost, etc) b_i [10]. Thus, we note that each unit of rental service transaction incurs a cost as follows:

We now construct the market demand functions. Let $D_i(\alpha_i)$ denote the market demand for Product i with product information disclosure level α_i, where $i = 1,\ \ 2$. We have[11]:

[7] Note that although the blockchain technology can make information disclosure easily, the platform need not share all information if it is not beneficial to do so. As a matter of fact, the platform can always choose the level of product information to disclose with respect to its own benefits.

[8] It is natural that only favorable product information will be disclosed as the purpose is to entice more demand for rental services. It does not make sense for the platforms to intentionally reveal unfavourable product information.

[9] NFC chips along with Blockchain can provide credible track and trace information (due to the immutability of blockchain). So, in addition to the info mentioned here, it can provide more such as where the product is manufactured (in France or elsewhere), number of rental times, and city of previous renters (this is provided by the GPS information collected when the renters scan the NFC chips attached to the product to verify the product info provided online or/and the product authenticity).

[10] Note that for platforms like bagborroworsteal.com and Real for rental services of luxury fashion bags, they offer free product delivery and returns services.

[11] Please see Appendix (A4) for the details of the meaning behind these demand functions, which are consistent with the consumer utility based on demand functions. However, in this paper, we do NOT consider the problem from

$$\tilde{D}_1(\alpha_1) = \lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2) + \tilde{\delta}_1, \quad (3.1)$$

$$\tilde{D}_2(\alpha_2) = \lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1) + \tilde{\delta}_2, \quad (3.2)$$

where for $i = 1, \ 2$, $\tilde{\delta}_i$ is a random variable following a symmetric distribution with zero mean and a constant variance V_i; $0 \le a \le 1$ is the base market demand; c represents the level of product information disclosure competition between the two platforms, and $c < 1$ which means the marginal effect of increasing α_i to demand for Product i is more significant than increasing α_j, for any $i \neq j$. As a remark, in this paper, we focus on information disclosure and we do not consider pricing. Thus, we assume that the same rental price is offered by the platform.

Note that in the basic model, for analytical tractability and to focus on the exploration of the effect brought by λ and α_i, we consider the case in which the base demand for $\tilde{D}_1(\alpha_1)$ and $\tilde{D}_2(\alpha_2)$ are the same. We will relax these in the heterogeneous demand model (see Appendix (A2)) and find that the major results remain the same. We also consider the situation when the realized demand for rental services will all be fulfilled finally.

In the platform operations, for $i = 1, \ 2$: Seller i charges the platform a certain buyout price m_i for each Product i; the platform charges the consumers (i.e. the users of rental services) a unit rental fee p_i. Thus, $p_i - I_i$ represents the platform's profit margin each time the rental service is offered with respect to Product i. Platform i's expected profit is given as follows:

$$\Pi_{TPF,1}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)) - m_1, \quad (3.3)$$

$$\Pi_{TPF,2}(\alpha_1, \alpha_2) = (p_2 - I_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)) - m_2. \quad (3.4)$$

For $i = 1, \ 2$, checking the structural properties of $\Pi_{TPF,i}(\alpha_1, \alpha_2)$ reveals that $\Pi_{TPF,i}(\alpha_1, \alpha_2)$ is a concave function of α_i. This feature ensures that we can conduct closed form analytical analysis in the basic model.

Furthermore, we also want to explore how the product information disclosure game affects the consumer surplus. We denote the consumer surplus from product information disclosure for those consumers (i.e. users) of Platform i by CS_i. We denote the consumer surplus at the equilibrium by CS_{i*}. As more product information should be beneficial to the consumers (when the other parameters should be rental service charge remain unchanged), we model the information-sensitive consumer's utility gain with the product information disclosure level α_i as: $u_i = \psi\alpha_i$, where $\psi > 0$. Assuming that for the information-sensitive consumer who likes to try the service at Platform i, her valuation towards the rental service is a random variable v_i which follows a probability distribution function $f_i(\cdot)$.

Without product information disclosure, the consumer surplus is:

$$CS_{i,\overline{PID}} = \int_{p_i}^{\infty} (v_i - p_i) f_i(v_i) dv_i \quad (3.4a)$$

With product information disclosure, the consumer surplus is:

$$\begin{aligned} CS_{i,PID} &= \int_{p_i - \psi\alpha_i}^{\infty} (v_i - (p_i - \psi\alpha_i)) f_i(v_i) dv_i \\ &= CS_{i,\overline{PID}} + \int_{p_i - \psi\alpha_i}^{p_i} (v_i - p_i) f_i(v_i) dv_i + \psi\alpha_i(1 - F_i(p_i - \psi\alpha_i)) \end{aligned} \quad (3.4b)$$

By definition, the consumer surplus from product information disclosure for those consumers of Platform i is given by:

$$CS_i = CS_{i,PID} - CS_{i,\overline{PID}}, \quad (3.5)$$

which yields Lemma 3.1.

Lemma 3.1. *For the TPF scenario, the consumer surplus from product information disclosure for those consumers of Platform i is given by:*

$$CS_i = \Omega(\alpha_i), \quad (3.6)$$

where $\Omega(\alpha_i) = \int_{p_i - \psi\alpha_i}^{p_i} (v_i - p_i) f_i(v_i) dv_i + \psi\alpha_i(1 - F_i(p_i - \psi\alpha_i))$, which is positive and increasing in α_i.

Lemma 3.1. shows that the consumer surplus earned from product information disclosure is increasing in the optimal product information disclosure level. This result will be employed in the subsequent parts of analysis.

4. Analysis

Define the ratio of λ (proportion of information-insensitive consumers in the market) to $1 - \lambda$ (proportion of information-sensitive consumers in the market) by R.

$$R = \frac{\lambda}{(1-\lambda)}. \quad (4.1)$$

Note that from (4.1), we can see that a smaller R means the proportion of information-sensitive consumers in the market is larger. When R is equal to 1, the market has 50% information sensitive and 50% information-insensitive consumers. An R less than (more than) 1 means the market has more (less) information-sensitive consumers than information-insensitive consumers. We represent the consumer surplus under the TPF scenario by $CS_{i,TPF} = \Omega(\alpha_{i,TPF})$. We have Proposition 4.1.

Proposition 4.1. *(a) For the TPF scenario, the game is supermodular and a unique Nash equilibrium exists. The equilibrium product information disclosure levels for Products 1 and 2 are given as follows:*

$$\alpha_{1,TPF*} = Z_1 - \frac{R}{(2-c)}, \text{ where } Z_1 = \frac{2(p_1 - b_1) + c(p_2 - b_2)}{k(2-c)(2+c)},$$

$$\text{and } \alpha_{2,TPF*} = Z_2 - \frac{R}{(2-c)}, \text{ where } Z_2 = \frac{2(p_2 - b_2) + c(p_1 - b_1)}{k(2-c)(2+c)}$$

(b) For $i = 1, \ 2$, (i) $\alpha_{i,TPF*}$ and $CS_{i,TPF*}$ are decreasing functions of R and k, and increasing functions of the level of competition c, where $CS_{i,TPF*} = \Omega(\alpha_{i,TPF*})$; (ii) $\alpha_{i,TPF*}$ is increasing in Product i's rental service profit margin as well as Product j's rental service profit margin.

Proposition 4.1(a) gives the closed form expressions for the optimal[12] product information disclosure levels for Products 1 and 2 at the equilibrium. From Proposition 4.1(b) (i), it is intuitive to note that when k is larger, the optimal product information disclosure level drops because the marginal cost of product information disclosure is higher when k is larger. It is also interesting to observe that $\alpha_{i,TPF*}$ is a decreasing function of R. According to the definition ($R = \lambda/(1-\lambda)$), a larger R implies that in the market, the proportion of information-insensitive consumers is relatively higher compared to the proportion of information-sensitive consumers. This directly implies that the significance of product information disclosure is lower. Thus, a smaller $\alpha_{i,TPF*}$ results. From Proposition 4.1(b) (ii), we can also see how the rental service profit margins of the two products affect the optimal product information disclosure level. To be specific, if the rental service profit margin for Product i is higher, it is optimal to increase the product information disclosure level to attract more demand for it. It is interesting to note that if the competing platform (Platform j)'s rental service profit margin is higher, it is beneficial for the platform (Platform i) itself to increase the product information disclosure. Since the equilibrium consumer surplus $CS_{i,TPF*}$ is increasing in the equilibrium product information disclosure level, all the increasing or decreasing properties (except the ones associated with profit margins) which hold for the equilibrium product information disclosure level would apply

(*footnote continued*)
the consumer utility perspective. We adopt the more classical approach in operations research in which the demand function is simply given as a linear function of the decision under considerations).

[12] In this paper, we use the term "optimal decision" and "equilibrium decision" interchangeably.

for the consumer surplus at equilibrium. All these results are logical and neat.

Now, even though disclosing information may increase demand for the rental service, under competition, the situation is more complicated. Will it be optimal in some cases that the platform should not disclose any product information? Will it be optimal to disclose full information? We first define the following and then present Proposition 4.2, which provides the answers to these questions.

$\hat{\lambda}_{1,TPF} = \frac{Z_1(2-c)}{1+Z_1(2-c)}$, $\hat{\lambda}_{2,TPF} = \frac{Z_2(2-c)}{1+Z_2(2-c)}$, $\hat{k}_{1,TPF} = \frac{2(p_1-b_1)+c(p_2-b_2)}{(R+2-c)(2+c)}$, $\hat{k}_{2,TPF} = \frac{2(p_2-b_2)+c(p_1-b_1)}{(R+2-c)(2+c)}$

Proposition 4.2. *For $i = 1, \ 2$: (a) If $\lambda \geq \hat{\lambda}_{i,TPF}$, then $\alpha_{i,TPF*} = 0$; if $\lambda < \hat{\lambda}_{i,TPF}$, then $\alpha_{i,TPF*} > 0$ and $CS_{i,TPF*} > 0$. (b) If $k \leq \hat{k}_{i,TPF}$, then $\alpha_{i,TPF*} = 1$.*

Note that in Proposition 4.2(a), $\lambda \geq \hat{\lambda}_{i,TPF}$ means that the proportion of information-insensitive consumers in the market is sufficiently large. In this case, the effect of product information disclosure is small and hence it is optimal for Platform i to set $\alpha_{i,TPF*} = 0$. On the contrary, if $\lambda < \hat{\lambda}_{i,TPF}$ which means the proportion of information-insensitive consumers in the market is sufficiently small, and hence the proportion of information sensitive consumers in the market is sufficiently large, then it is optimal for Platform i to set a positive level of product information disclosure, which also leads to a positive consumer surplus at the equilibrium. In Proposition 4.2(b), we see the impact brought by k, the coefficient of auditing cost to ensure the posted product information is accurate. If k is sufficiently small, then it is optimal for Platform i to disclose all the available information. This result is intuitive because when k is sufficiently small, a positive benefit will always be derived by disclosing more information.

To generate more insights, we conduct an analytical sensitivity analysis towards the critical thresholds. Table 3 summarizes the results.

Theorem 4.1. . *Under the TPF scenario (basic model): a) From each platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which it can decide whether it is optimal to disclose product information or not. (b) If the information auditing cost to ensure the posted product information being correct is sufficiently small, it is optimal for the platform to disclose as much information as possible for its product. (c) When the rental service profit margin of Product i or Product j increases, the likelihood that non-zero levels of product information disclosure for Product i and j will appear is higher and it is more likely for both platforms to disclose the full product information for their respective products. (d) When R increases, it is less likely for both platforms to disclose the full product information for their respective products.*

Theorem 4.1. has several implications. First, we know that if the information auditing cost to ensure the posted product information being correct for a specific platform is sufficiently small, it is optimal for the platform to disclose as much information as possible for its product. This would mean achieving the maximum consumer surplus for the consumers of the corresponding platform. When the rental service profit margin is higher, the likelihood that the competing platforms will disclose more product information increases. For Theorem 4.1(d), the result is very intuitive.

Table 3
Sensitivity analysis towards the critical thresholds $\hat{\lambda}_{i,TPF}$ and $\hat{k}_{i,TPF}$.

	$\hat{\lambda}_{1,TPF}$	$\hat{\lambda}_{2,TPF}$	$\hat{k}_{1,TPF}$	$\hat{k}_{2,TPF}$
$(p_1 - b_1)\uparrow$	↑	↑	↑	↑
$(p_2 - b_2)\uparrow$	↑	↑	↑	↑
$R\uparrow$	–	–	↓	↓

Note that if $\hat{\lambda}_{i,TPF}$ is larger, then $\lambda < \hat{\lambda}_{i,TPF}$ is more likely to occur. This means that at the equilibrium, the likelihood that "a non-zero level of product information disclosure for Product i by Platform i will appear" is higher (See Proposition 4.2(a)). Similarly, a larger $\hat{k}_{i,TPF}$ also means that it is more likely for Platform i to disclose the full product information for Product i. By checking the impacts brought by an increase of the rental service's profit margin and R, as well as some prior analytical findings, we have Theorem 4.1.

5. Extended models

5.1. Risk averse attitude

In service supply chains, risk is a critical issue. Risk can come from, e.g., demand and supply disruptions and uncertainties. There is no doubt that platform operations are highly risky and hence taking a risk averse attitude is logical and natural for many platform operations. In this part, we consider the situation when the platform's optimal product information disclosure decision is made with a risk averse attitude. To be specific, we propose an alternative optimization objective for the platform:

$$U_{TPF,i,RA}(\alpha_1, \alpha_2) = \Pi_{TPF,i}(\alpha_1, \alpha_2) - \hat{\xi}_i SP_{TPF,i}(\alpha_1, \alpha_2), \ i = 1, \ 2, \tag{5.1}$$

where $SP_{TPF,i}(\alpha_1, \alpha_2)$ = standard deviation of the profit of Platform i;

$\hat{\xi}_i \geq 0$ is the risk averse threshold of Platform i (or more precisely, the risk averse threshold of Platform i's operations manager). $\hat{\xi}_i = 0$ means the platform is risk neutral; $\hat{\xi}_i > 0$ means the platform is strictly risk averse.

From the basic model, it is easy to find the profit function and then derive the standard deviation of profit to be the following: For $i = 1, \ 2, SP_{TPF,i}(\alpha_1, \alpha_2) = (p_i - b_i - k\alpha_i)\sqrt{V_i}$. Define:

$$\xi_{PFi} = \hat{\xi}_i \sqrt{V_i}, \ i = 1, \ 2 \tag{5.2}$$

Lemma 5.1. gives the analytical expression of $U_{TPF,i,RA}(\alpha_1, \alpha_2)$ and shows its key structural properties.

Lemma 5.1. *(a) $U_{TPF,1,RA}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)) - m_1 - \xi_{PF1}(p_1 - b_1 - k\alpha_1)$, and $U_{TPF,2,RA}(\alpha_1, \alpha_2) = (p_2 - I_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)) - m_2 - \xi_{PF2}(p_2 - b_2 - k\alpha_2)$. (b) For $i = 1, \ 2$, $U_{TPF,i,RA}(\alpha_1, \alpha_2)$ is a concave function.*

Note that Lemma 5.1 shows that $U_{TPF,i,RA}(\alpha_1, \alpha_2)$ is concave and this property is important for us to conduct analytical closed-form analyses. From Lemma 5.1, we can determine the optimal product information disclosure levels when the platforms possess risk averse attitudes. Define:

$$\Delta IDRA_1 = \frac{2\xi_{PF1} + c\xi_{PF2}}{a(1-\lambda)(2-c)(2+c)}, \tag{5.3}$$

$$\Delta IDRA_2 = \frac{2\xi_{PF2} + c\xi_{PF1}}{a(1-\lambda)(2-c)(2+c)} \tag{5.4}$$

We have Proposition 5.1 (P.S.: We use "RA" to denote the risk averse case). Define the consumer surplus:

$CS_{i,TPF,RA} = \Omega(\alpha_{i,TPF,RA})$

Proposition 5.1. *(a) For the TPF scenario with risk averse platforms, the game is supermodular and a unique Nash equilibrium exists. The equilibrium product information disclosure levels for Products 1 and 2 are given as follows:*

$$\alpha_{1,TPF,RA*} = \alpha_{1,TPF*} + \Delta IDRA_1, \tag{5.5}$$

$$\alpha_{2,TPF,RA*} = \alpha_{2,TPF*} + \Delta IDRA_2. \tag{5.6}$$

(b) A higher degree of risk aversion of Platform i will lead to a higher product information disclosure level and consumer surplus for Product i and Product j, where i ≠ j. (c) A higher degree of demand volatility faced by

Table 4
Sensitivity analysis towards $\Delta IDRA_i$, $\alpha_{i,TPF,RA*}$ and $CS_{i,TPF,RA*}$.

	$\hat{\lambda}_{1,TPF}$	$\hat{\lambda}_{2,TPF}$	$\hat{k}_{1,TPF}$	$\hat{k}_{2,TPF}$
$(p_1 - b_1)\uparrow$	↑	↑	↑	↑
$(p_2 - b_2)\uparrow$	↑	↑	↑	↑
$R\uparrow$	–	–	↓	↓

Platform i for Product i's rental service will lead to a higher product information disclosure and consumer surplus for Product i and Product j, where $i \neq j$. (d) For $i = 1,\ 2$, $\Delta IDRA_i$ is called the Platform i's product information disclosure surplus from risk aversion, and it is an increasing function of $\hat{\xi}_i$, $\hat{\xi}_j$, V_i, and V_j , where $i \neq j$ (see Table 4).

From Proposition 5.1(a), first of all, we observe that the optimal product information disclosure level under the risk averse case is higher than the risk neutral case because $\Delta IDRA_i$ is always positive. This is an interesting and neat result because if the platforms are averse to profit risk, our results prove that they will increase the level of product information disclosure. This point is also echoed by Proposition 5.1(b) as a higher degree of risk aversion of a platform will lead to higher product information disclosure levels of not just to its own product but also the competing platform's product. Similarly, Proposition 5.1(c) highlights the impacts brought by demand volatilities and the effect is similar to the degree of risk aversion. The reason is that both the demand volatility and degree of risk aversion related to profit risk. In the model, we actually put them together as a single term (P.S.: From (5.2), we have $\xi_{PFi}{=}\hat{\xi}_i\sqrt{V_i}$).

Note that for consumer surplus, since $CS_{i,TPF,RA} = \Omega(\alpha_{i,TPF,RA})$, we have $CS_{i,TPF,RA*} = \Omega(\alpha_{i,TPF,RA*})$ and hence all the analytical "increasing/decreasing" results for the optimal product information disclosure will apply for the consumer surplus. Finally, Proposition 5.1(d) shows the features of $\Delta IDRA_i$, the Platform i's product information disclosure surplus from risk aversion. We note that $\Delta IDRA_i$ is an increasing function of $\hat{\xi}_i$, $\hat{\xi}_j$, V_i, and V_j, where $i \neq j$, which means that this extra amount of product information disclosure is derived from the risk averse attitudes of the competing platforms and it is increasing in all profit risk related factors, including the degrees of risk aversion and demand volatilities faced by the platform itself and its competitor.

Similar to the basic model, we also want to check and see if there are conditions governing when (i) it is optimal to disclose information, (ii) it is optimal not to disclose information, and (iii) it is optimal to disclose full information. For these issues, we define the following notation and critical thresholds. Then, we present Proposition 5.2. To enhance presentation, for the definitions of Y_1, Y_2, X_1 , X_2, W_1 and W_2, please refer to Appendix (A1). For the critical thresholds, they are defined as follows: $\hat{\lambda}_{1,TPF,RA} = \frac{X_1}{X_1 + a(2+c)}$, $\hat{\lambda}_{2,TPF,RA} = \frac{X_2}{X_2 + a(2+c)}$, $\hat{k}_{1,TPF,RA} = \frac{2(p_1 - b_1) + c(p_2 - b_2)}{W_1(2-c)(2+c)}$, $\hat{k}_{2,TPF,RA} = \frac{2(p_2 - b_2) + c(p_1 - b_1)}{W_2(2-c)(2+c)}$.

Proposition 5.2. *For $i = 1,\ 2$: (a) If $\lambda \geq \hat{\lambda}_{i,TPF,RA}$, then we have $\alpha_{i,TPF*,RA} = 0$; if $\lambda < \hat{\lambda}_{i,TPF,RA}$, then $\alpha_{i,TPF,RA*} > 0$. (b) If $k \leq \hat{k}_{i,TPF,RA}$, then $\alpha_{i,TPF,RA*} = 1$.*

Note that Proposition 5.2 shows the analytical findings which help us derive further insights which are shown in Theorem 5.1. To generate more insights, we conduct an analytical sensitivity analysis towards the critical thresholds. Table 5 summarizes the results.

Table 5
Sensitivity analysis towards the critical threshold $\hat{\lambda}_{i,TPF,RA}$ and $\hat{k}_{i,TPF,RA}$.

	$\hat{\lambda}_{1,TPF,RA}$	$\hat{\lambda}_{2,TPF,RA}$	$\hat{k}_{1,TPF,RA}$	$\hat{k}_{2,TPF,RA}$
$\hat{\xi}_1\uparrow$	↑	↑	↑	↑
$\hat{\xi}_2\uparrow$	↑	↑	↑	↑
$V_1\uparrow$	↑	↑	↑	↑
$V_2\uparrow$	↑	↑	↑	↑
$(p_1 - b_1)\uparrow$	↑	↑	↑	↑
$(p_2 - b_2)\uparrow$	↑	↑	↑	↑

Observe that if $\hat{\lambda}_{i,TPF,RA}$ is larger, we know that $\lambda < \hat{\lambda}_{i,TPF}$ will be more likely to occur, which implies that a non-zero level of product information disclosure for Product i by Platform i will be more likely to appear. Similarly, a larger $\hat{k}_{i,TPF,RA}$ also indicates that it is more likely for Platform i to disclose the full product information for Product i. From Proposition 5.2 and observing the impacts brought by an increase of the rental service's profit margin, as well as profit risk related factors from Table 5.2, we have Theorem 5.1.

Theorem 5.1. *(a) For risk-averse platforms, they set a higher product information disclosure level compared to the risk neutral counterparts. (b) The presence of risk averse attitudes of the competing platforms does not change the qualitative managerial insights derived under the risk neutral scenario (i.e. basic model) on the existence of a critical threshold on the proportion of information sensitive consumers in the market. (c) For the unique insights from the "risk averse scenario": If the degree of risk aversion of either platform increases or the demand volatility of either platform increases, we have: (i) the likelihood that non-zero levels of product information disclosure for both products will appear is higher, and (ii) it will be more likely for both platforms to disclose the full product information for their respective products.*

Theorem 5.1. shows that the results under the basic model (with risk neutral platforms) continue to hold in the case when we consider risk averse platforms. However, risk averse attitudes of platforms also have some unique implications. For example, if the degree of risk aversion increases, the optimal product information disclosure level and consumer surplus are both larger and hence consumers should be benefited by the risk averse attitude taken by the platform.

5.2. Consignment versus buyout

In the basic model, we consider the case when the sellers simply sell the products to the respective platforms under the "buyout" model with a fixed price. However, in many cases, the platform allows the sellers to "consign" their products and share a revenue for each rental service. How will this consignment arrangement or model affect the optimal product information disclosure?

To address this issue, by making references to (3.3) and (3.4), we first build the expected profit function under the consignment case as shown below.

$$\Pi_{TPF,1}^{CON}(\alpha_1, \alpha_2) = (\eta_1 p_1 - I_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)),$$

$$\Pi_{TPF,2}^{CON}(\alpha_1, \alpha_2) = (\eta_2 p_2 - I_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)),$$

where $0 < \eta_1 < 1$ and $0 < \eta_2 < 1$ represent the remaining revenues that Platforms 1 and 2 keep after sharing the needed proportions ($0 < 1 - \eta_1 < 1$ and $0 < 1 - \eta_2 < 1$) to Sellers 1 and 2, respectively.

Denote the optimal product information disclosure levels under consignment for Product i as $\alpha_{i,TPF*}^{CON}$, $i = 1,\ 2$. We have Proposition 5.3 and Theorem 5.2.

Proposition 5.3. *For $i = 1,\ 2$: $\alpha_{i,TPF*}^{CON} < \alpha_{i,TPF*}$ and $CS_{i,TPF*}^{CON} < CS_{i,TPF*}$.*

Proposition 5.3. is a very strong result. It implies that under the consignment scenario, the level of product information disclosure at the equilibrium will be smaller than under the buyout scenario. This is rather intuitive because under buyout, the platform has a higher profit margin (without the need to share a proportion to the seller). As such, the platform has an incentive to attract more demand by disclosing more product information. As we can see from the Proof of Proposition 5.3, the consignment scenario and the buyout scenario are very similar. Consequently, the other managerial findings and insights developed under the buyout scenario in the basic model will continue to hold under the consignment scenario. It is interesting to note that for consumer surplus consignment is in fact an inferior operations model as $CS_{i,TPF*}^{CON} < CS_{i,TPF*}$. We summarize the major results in .Theorem 5.2

Theorem 5.2. *(a) The optimal product information disclosure levels and consumer surplus under consignment are lower than the corresponding ones under buyout. (b) All the other qualitative results and managerial insights remain the same under both buyout and consignment arrangements.*

One important implication of Theorem 5.2 is that, from the consumer surplus perspective, consumers should prefer to the buyout product acquisition model than the consignment. Other than that, the other major findings between the two product acquisition methods are similar.

5.3. Common-platform (CPF) scenario

In the basic model, we have two separate platforms for the two products' rental services. In many cases, the separate products' rental services may be supported by a single platform. For example, two sellers, called Seller 1 and Seller 2, offer the same type of product (e.g., luxury handbag) to the market (e.g., for rental service) via a common platform (e.g., Real (in China)). In this sub-section, we explore this case.[13] As a remark, the CPF scenario can also be viewed as the scenario when the two competing platforms form a strategic alliance or simply merged to establish a big platform. So, from this perspective, it is consistent with our TPF scenario and the CPF scenario is simply a centralized case.

In the platform operations, for $i = 1,\ 2$: Seller i charges the platform a certain buyout price m_i for Product i; the platform charges the consumers a unit rental fee p_i. Thus, $p_i - I_i$ represents the unit profit margin for Product i from the platform's perspective. The common platform (CPF) i's expected profit is given as follows:

$$\Pi_{CPF}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)) + (p_2 - I_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)) - m_1 - m_2.$$

Checking the structural properties of $\Pi_{CPF}(\alpha_1, \alpha_2)$, we know that without the need of imposing any additional conditions, $\Pi_{PF}(\alpha_1, \alpha_2)$ is a concave function in α_1 and α_2. This feature ensures that we can conduct closed form analytical analysis.

Define: $A_1 = \frac{a[(p_1 - b_1) - (p_2 - b_2)c]}{2k} - \frac{a\lambda}{1-\lambda}$, $A_2 = \frac{a[(p_2 - b_2) - (p_1 - b_1)c]}{2k} - \frac{a\lambda}{1-\lambda}$, $B = \frac{a(c+1)}{2}$. We have Proposition 5.4.

Proposition 5.4. *For the platform, the optimal product information disclosure level for Products 1 and 2 are given as follows:* $\alpha_{1,CPF*} = \frac{A_1 + A_2 B}{1 - B^2}$ and $\alpha_{2,CPF*} = \frac{A_2 + A_1 B}{1 - B^2}$.

Proposition 5.4. gives the closed form expressions for the optimal product information disclosure levels for the whole supply chain system. Define (P.S.: Please refer to Appendix (A1) for the definitions of J_1 and J_2):

$$\hat{\lambda}_{CPF,1} = \frac{2J_1}{2J_1 + 4ka(2 - a(c+1))},\quad \hat{\lambda}_{CPF,2} = \frac{2J_2}{2J_2 + 4ka(2 - a(c+1))}$$

$$\hat{k}_{1,CPF} = \frac{a(1-\lambda)\{[(p_1 - b_1) - (p_2 - b_2)c] + B[(p_2 - b_2) - (p_1 - b_1)c]\}}{2(1+B)(a\lambda + (1-\lambda)(1-B))},$$

$$\hat{k}_{2,CPF} = \frac{a(1-\lambda)\{[(p_2 - b_2) - (p_1 - b_1)c] + B[(p_1 - b_1) - (p_2 - b_2)c]\}}{2(1+B)(a\lambda + (1-\lambda)(1-B))}.$$

Define the consumer surplus $CS_{i,CPF*} = \Omega(\alpha_{i,CPF*})$. We have Proposition 5.5.

Proposition 5.5. *For $i = 1,\ 2$: (a) If $\lambda \geq \hat{\lambda}_{CPF,i}$, then $\alpha_{i,CPF*} = 0$; if $\lambda < \hat{\lambda}_{CPF,i}$, then $\alpha_{i,CPF*} > 0$ and $CS_{i,CPF*} > 0$. (b) If $k \leq \hat{k}_{i,CPF}$, then $\alpha_{i,CPF} = 1$.*

Note that Proposition 5.5 is similar to the findings in Section 4. With Propositions 5.4 and 5.5, we can derive and summarize the results in Theorem 5.3.

Theorem 5.3. *Comparing between the TPF and CPF scenarios, we have the same conclusion that from the platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which it can decide whether it is optimal to disclose product information or not.*

Theorem 5.3. indicates that the findings of our basic model are robust even if we change the platform operations from TPF to CPF. The results are still valid even if we consider a higher degree of heterogeneity than the model setting considered in this section (see Appendix A2.2).

6. Further analyses

With the above findings and model analyses, we drill deeper and uncover more analytical insights in this section.

6.1. Roles of blockchain technologies

6.1.1. Reducing k

With the blockchain technology, and supported by the well-established RFID system, platforms can keep track of the product details, and history of rental services in a more efficient and accurate manner. This will mean that in our model setting, the information auditing cost k will be reduced if the blockchain technology is well implemented and fully used. Then, what is the implication?

From all the above analyses, e.g., Propositions 4.2(b), 5.2(b), and 5.5. (b), it is obvious that if k is smaller, the situation that full product information disclosure is optimal will more likely to appear. Thus, the blockchain technology, which helps reduce k, enhances the likelihood of full product information disclosure (if all other parameters remain unchanged).

6.1.2. Reducing V_i and λ

Platform operations are risky as demand is uncertain. How does the blockchain technology relate to it? We observe that one common feature of the blockchain technology is to provide permanent information which can always be traced back by the users, sellers and platforms themselves. Thus, we argue that the deployment of blockchain technology will foster trust in the platform operations. When consumers trust the information disclosed by the platforms via the blockchain technology is accurate, they will more likely try the rental services. This trust should enhance two things: (i) Improving the proportion of consumers who are sensitive to information because the information is more trustworthy and useful. (ii) Reducing the demand volatility owing to a higher level of trust, variation drops.

For (i), if the proportion of information-sensitive consumers is higher, it means $(1-\lambda)$ is higher (or equivalently λ is lower) which implies R is lower. From Proposition 4.1, we can see that this will lead to a higher optimal product information disclosure level which also benefits consumers (see Table 6).

For (ii), if V_i is reduced, we have the impacts as shown in Table 6.1, which actually means that for the risk averse platforms, the optimal product information disclosure level ($\alpha_{i,TPF,RA*}$) will drop and the extra product information disclosure derived from risk aversion (i.e. $\Delta IDRA_i$) will also drop. Note that if the platforms are risk neutral, the change of V_i has no impact.

Thus, for the scenario when the competing platforms are risk neutral, the blockchain technology will definitely yield a higher optimal level of product information disclosure. For the scenario when the competing platforms are risk averse, there are two opposing effects (P.S.: The reduction of V_i leads to a decrease of the optimal product

[13] Note that in this extension, we follow the basic model in assuming the base demands of the two products are the same. See Appendix (A2) for the case when the base demands are different.

Table 6
Sensitivity analysis towards $\Delta IDRA_i$, $\alpha_{i,TPF,RA*}$ and $\alpha_{i,TPF*}$.

	$\Delta IDRA_1$	$\Delta IDRA_2$	$\alpha_{1,TPF,RA*}$	$\alpha_{2,TPF,RA*}$	$\alpha_{1,TPF*}$	$\alpha_{2,TPF*}$
$\lambda\downarrow$	↑	↑	↑	↑	↑	↑
$V_1\downarrow$	↓	↓	↓	↓	–	–
$V_2\downarrow$	↓	↓	↓	↓	–	–

information disclosure level whereas the reduction of λ yields an increase of the optimal product information disclosure level). The final impact depends on whether the reduction of V_i or the reduction of R is more significant.

Theorem 6.1. *If the blockchain technology can reduce the information auditing cost, increase the proportion of information-sensitive consumers and reduce demand volatility, then: (a) For the case when the competing platforms are all risk neutral, the blockchain technology will lead to an increase of the optimal product information disclosure level, an increase of consumer surplus, and the likelihood of having the full product information disclosure scenario is also higher. (b) For the case when the competing platforms are risk averse, the effect of blockchain technology is more tricky as it depends on the significance of several counter-forces. Thus, risk attitude is an important factor to accurately describe the impacts brought by the blockchain technology.*

Theorem 6.1. highlights the roles played by the blockchain technology under a few assumptions which we argue to be true if the blockchain technology is well implemented. We can see that the blockchain technology is in fact helpful as it can enhance consumer surplus and product information disclosure if the platform is risk neutral. However, if the platform is risk averse, then the situation is more complex as the exact impact depends on how much the blockchain technology reduces the demand volatility and increases the proportion of information-sensitive consumers (i.e. $(1-\lambda)$) in the market.

6.2. Seller benefits

In this sub-section, we explore how the product information disclosure game affects the seller benefit. Unless otherwise specified, we focus on the TPF scenario (i.e. the basic model). We denote the benefits for those sellers of Platform i by SB_i^l, where $l = (CON, BUY)$ and CON represents consignment, BUY represents buyout.

Under the buyout arrangement, the sellers receive m_i for each product sold to Platform i. We consider that the platform will estimate m_i by taking a look at the expected profit (without considering m_i). Thus, m_i is directly proportional to $\Pi_{TPF,i}(\alpha_1, \alpha_2) + m_i$ and hence:

$$SB_1^{BUY} = \Phi(p_1 - b_1 - k\alpha_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)),$$

$$SB_2^{BUY} = \Phi(p_2 - b_2 - k\alpha_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)),$$

where $\Phi > 0$.

If the consignment scheme is adopted, the sellers receive $0 < 1 - \eta_i < 1$ proportion of p_i for each product sold to Platform i. The total expected benefit is hence $(1-\eta_1)p_1(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2))$ and $(1-\eta_2)p_2(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1))$ for Platforms 1 and 2, respectively. The seller benefits are hence given as follows:

$$SB_1^{CON} = SB_1^{CON} = \Phi[(1-\eta_1)p_1(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2))],$$

$$SB_2^{CON} = \Phi[(1-\eta_2)p_2(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1))]$$

Define: $\hat{\alpha}_i = \left(\frac{(p_i - b_i)}{2k} - \frac{\lambda}{2(1-\lambda)} + \frac{c\alpha_j}{2}\right)$.

Proposition 6.1. *Under the basic model (TPF scenario), for $i = 1, 2$ and $i \neq j$: If α_i increases, then (i) SB_i^{CON} and SB_j^{CON} will all increase while SB_j^{BUY} will decrease; (ii) SB_i^{BUY} will strictly increase if $\alpha_i < \hat{\alpha}_i$ or strictly decrease if $\alpha_i > \hat{\alpha}_i$.*

We can see from Proposition 6.1 that with an increase of the product information disclosure in a particular platform, its corresponding sellers under consignment arrangement will be benefited. However, benefits of the competing platform's sellers under buyout arrangement will drop. At the equilibrium, with the optimal product information disclosure levels, we can further check to see if the change is beneficial to the sellers. Proposition 6.1 also characterizes the situations under the TPF scenario. If we check the extended models with risk averse platforms and the CPF scenario, we will find that similar results hold and we do not repeat the details here.

7. Conclusion

7.1. Concluding remarks and managerial implications

In the blockchain technology era (Dolgui et al., 2019), the service supply chain's information structure would significantly affect its operations efficiency. This is especially important in the market filled with uncertainties and disruptions. In rental service platform operations, users make their decisions on whether to rent the product based on the information provided by the platform. This is especially true in the blockchain technology era when information becomes especially critical and trustworthy. However, offering accurate product information also incurs an information auditing cost for the platform for every product after each rental service. Motivated by this industrial observation, we have constructed a stylized analytical model, and conduct a game-theoretic economic analysis to explore the product information disclosure game between two rental service platforms.

In the basic model with two competing platforms (i.e. a duopoly setting), we have derived the optimal level of product information disclosure. We analytically identified the conditions in which it is optimal to disclose product information or not to disclose product information at all. We have conducted sensitivity analyses to uncover how the major parameters affect the optimal product information disclosure decisions. To check robustness of the results, we have extended the analysis to the cases when (i) the platform operations managers are risk averse, (ii) rather than selling the product at a fixed price, the seller consigns the product to the platform and shares a revenue, (iii) there is a common rental service platform which receives and provides rental services for two substitutable products. We have proven that the major qualitative managerial insights derived from the basic model are still valid in all the extended models.

In the following, by addressing the research questions proposed in Section 1, we highlight some important findings, insights and managerial implications as follows.

Optimal product information disclosure policies: In the basic models as well as all extended models, we have proven that from each platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which the platform can decide whether it is optimal to disclose product information or not to disclose any information at all. If the information auditing cost (to ensure the posted product information is correct) is sufficiently small, it is optimal for the platform to disclose the full product information (i.e., as much "favorable information" as possible for its product). It is interesting to note that when the rental service profit margin of the product (either the platform itself or its competitor's) increases, the likelihood that both platforms will disclose information for their products is higher and it is more likely for both platforms to disclose the full product information for their respective products. From these findings, we note the conditions under which it is optimal for the platforms to disclose information, full information or not to disclose information at all, relate heavily to the market segment (i.e. the proportion of information-sensitive consumers). As the market is dynamic and always evolving, if the proportion of information-sensitive consumers increases, it will be more and more likely for the platforms to disclose more product information. This is a natural result while it does mean that operations managers cannot and should not ignore the importance of product information disclosure (even if right now, it is optimal to choose not to disclose information; it may no longer be true in the future).

Effects of risk averse attitudes: Under the case when the two competing platforms are risk averse, we have uncovered that they will set a higher product information disclosure level compared to the case when they are risk neutral. If the degree of risk aversion of either platform increases or the demand volatility of either platform increases, we have proved that the likelihood that both platforms will disclose product information (including full information) of their products will be higher. This finding implies that the risk averse attitudes of platforms are critical because they significantly affect the optimal product information disclosure levels. As a result, operations managers should carefully assess the risk preferences of both themselves and the competitor. Incorporating the risk averse preferences into the analysis will yield a more scientifically sound and accurate estimate of the optimal product information disclosure levels and policies.

Consignment versus buyout: If the platforms change their way of acquiring products of sellers from "buyout" to consignment, we reveal that the optimal product information disclosure levels and consumer surplus under consignment are lower than the corresponding ones under buyout. However, it doesn't mean the sellers will get worse off. As such, we see an inherent incentive difference between the sellers and the consumers (i.e. users of the rental services). If the choice on consignment and buyout is on the table, sellers may prefer consignment but it is known that this is an inferior choice to the consumers.

CPF versus TPF scenarios: We have found in an extended model that when there is only one common platform selling two substitutable (or competing) products, we have obtained the same qualitative conclusion as the one from the TPF scenario i.e. from the platform's perspective, there exists a critical threshold on the proportion of information sensitive consumers in the market with which it can decide whether it is optimal to disclose product information or not. This implies that in general, no matter we talk about a decentralized competitive environment between two platforms, or a centralized case with the presence of a single platform, our findings on the optimal product information disclosure policies are still valid. This gives reassurance to the operations managers of platforms that our managerial recommendations and guidance are robust. As a remark, the CPF scenario can also be viewed as the special scenario when the two competing platforms form an alliance to establish a single platform to serve the market.

Seller benefit and consumer surplus: We show that with an increase of the product information disclosure level in a particular platform, its corresponding sellers under consignment arrangement will be benefited, and the consumer surplus of consumers served by both platforms will increase. However, benefits of the competing platform's sellers will drop. It hence implies that under consignment, the increase of product information disclosure level of a specific platform will benefit all consumers (itself and the competitor's) but only benefit its own sellers but not the competitor's.

Roles of blockchain technology: If the blockchain technology can reduce the information auditing cost, increase the proportion of information-sensitive consumers and reduce demand volatility, then for the case when the competing platforms are all risk neutral, we have shown that the blockchain technology will lead to an increase of the optimal product information disclosure level, an increase of consumer surplus, and the likelihood of having the full product information disclosure scenario is also higher. For the case when the competing platforms are risk averse, we have uncovered that the effect of blockchain technology depends on the significance of several counter-forces. Thus, the findings imply that risk attitude is an important factor to accurately describe the impacts brought by the blockchain technology.

All-win information disclosure scenario: From our analysis, we have derived some situations in which the platform and its associated consumers and sellers will all be benefited by product information disclosure. For example, when the sellers adopt the consignment scheme to offer the products to the platform, then if a positive product information disclosure is optimal for the platform, then not only the platform itself will be benefited, but it will also enhance the welfare of its consumers and also benefit its sellers (i.e. achieving all-win). As a result, we can see that there are cases in which product information disclosure is an excellent all-win choice to the sellers, the consumers and the platform.

7.2. Future studies

In this paper, the focal point is on the commercial platform's operations and the respective product information disclosure game. However, there are platforms which focus on social welfare and aim to enhance sustainability. Future research can hence be extended to explore this meaningful aspect. Moreover, online social communities (Cao et al., 2018) may also disclose some relevant information regarding the rental service platform and its products. The impacts of them deserve further studies. In future work, we can develop a win-win coordination mechanism among luxury goods platforms, sellers (lenders) and buyers (borrowers). Another interesting extension would be to consider the intra-platform competition among multiple sellers who are willing to sell the same type product in a single platform, which can be investigated in addition to the competition between platforms (Asian et al., 2019). In addition, the location-based buyout and consignment service pricing can be an interesting future extension (Wei et al., 2018). Last but not least, information disclosure obviously relates to the use of big data (Choi et al., 2018; Fisher and Raman, 2018; Guha and Kumar 2018). Future research can examine their relationship together.

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Appendix (A1). Definitions of Some Notation

Table A1
Definitions of some notation.

Notation	Definition
$\hat{I}_i = k\alpha_i$	
$I_i = b_i + k\alpha_i$	
$\Omega(\alpha_i) = \int_{p_i-\psi\alpha_i}^{p_i} (v_i - p_i)f_i(v_i)dv_i + \psi\alpha_i(1 - F_i(p_i - \psi\alpha_i))$	
$R = \frac{\lambda}{(1-\lambda)}$	
$Z_1 = \frac{2(p_1-b_1)+c(p_2-b_2)}{k(2-c)(2+c)}$	
$Z_2 = \frac{2(p_2-b_2)+c(p_1-b_1)}{k(2-c)(2+c)}$	
$Y_1 = \frac{2(p_1-b_1)+c(p_2-b_2)}{k}$	
$Y_2 = \frac{2(p_2-b_2)+c(p_1-b_1)}{k}$	
$X_1 = aY_1 + 2\xi_{PF1} + c\xi_{PF2}$	
$X_2 = aY_2 + 2\xi_{PF2} + c\xi_{PF1}$	
$W_1 = 1 + \frac{R}{2-c} - \left(\frac{2\xi_{PF1}+c\xi_{PF2}}{a(1-\lambda)(2-c)(2+c)}\right)$	
$W_2 = 1 + \frac{R}{2-c} - \left(\frac{2\xi_{PF2}+c\xi_{PF1}}{a(1-\lambda)(2-c)(2+c)}\right)$	
$J_1 = (p_2 - b_2)a(a - (2 - a)c) + (p_1 - b_1)a(2 - ac(c + 1))$	
$J_2 = (p_1 - b_1)a(a - (2 - a)c) + (p_2 - b_2)a(2 - ac(c + 1))$	

Appendix (A2). Heterogeneous Demand Models

In Sections 3 and 5.2, we consider the case that the base demands in the market for Products 1 and 2 are the same. Now, we explore the case when this assumption is relaxed. To be specific, let $D_{i,HET}(\alpha_i)$ denote the market demand for Product i with product information disclosure level α_i, where $i = 1,\ 2$. We have:

$$\tilde{D}_{1,HET}(\alpha_1) = \lambda a_1 + (1-\lambda)a_1(\alpha_1 - c\alpha_2) + \tilde{\delta}_1, \tag{A1.1}$$

$$\tilde{D}_{2,HET}(\alpha_2) = \lambda a_2 + (1-\lambda)a_2(\alpha_2 - c\alpha_1) + \tilde{\delta}_2, \tag{A1.2}$$

where for $i = 1,\ 2, \tilde{\delta}_i$ is a random variable following a symmetric distribution with zero mean and a constant variance V_i, $0 \le a_i \le 1$ is the base demand for platform i, c represents the level of product information disclosure competition between the two products, and $c < 1$ which means the marginal effect of increasing α_i to demand for Product i is more significant than increasing α_j, for any $i \neq j$.

A2.1. The TPF Scenario

The expected profits of platforms are given as follows:

$$\Pi_{TPF,1,HET}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a_1 + (1-\lambda)a_1(\alpha_1 - c\alpha_2)) - m_1$$

$$\Pi_{TPF,2,HET}(\alpha_1, \alpha_2) = (p_2 - I_2)(\lambda a_2 + (1-\lambda)a_2(\alpha_2 - c\alpha_1)) - m_2$$

The game is supermodular because $\Pi_{TPF,1,HET}(\alpha_1, \alpha_2)$ and $\Pi_{TPF,2,HET}(\alpha_1, \alpha_2)$ are twice differentiable and $\partial^2\Pi_{TPF,1,HET}(\alpha_1, \alpha_2)/\partial\alpha_1\partial\alpha_2 \ge 0$ and $\partial^2\Pi_{TPF,2,HET}(\alpha_1, \alpha_2)/\partial\alpha_1\partial\alpha_2 \ge 0$, and a unique Nash equilibrium exists.

For $i = 1,\ 2$, checking the structural properties of $\Pi_{TPF,i,HET}(\alpha_1, \alpha_2)$ reveals that it is concave and we can easily find the optimal product information disclosure levels for Products 1 and 2 as follows:

$\alpha_{1,TPF,HET*} = Z_1 - \frac{R}{(2-c)}$, and $\alpha_{2,TPF,HET*} = Z_2 - \frac{R}{(2-c)}$, which are the same as the case when the base demands are the same in the basic model. Thus, for the TPF scenario, there is no difference in the results of the analysis.

A2.2. The CPF Scenario

The platform's expected profit is given as follows:

$$\Pi_{PF,HET}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a_1 + (1-\lambda)a_1(\alpha_1 - c\alpha_2)) + (p_2 - I_2)(\lambda a_2 + (1-\lambda)a_2(\alpha_2 - c\alpha_1)). =(p_1 - I_1)(\lambda a_1 + (1-\lambda)a_1(\alpha_1 - c\alpha_2)) + (p_2 - I_2)(\lambda a_2 + (1-\lambda)a_2(\alpha_2 - c\alpha_1))$$

Checking the structural properties of $\Pi_{PF,HET}(\alpha_1, \alpha_2)$ reveals that it is a concave function in α_1 and α_2 if a_1 is sufficiently close to a_2 or c is sufficiently small. For analytical tractability, we consider the case in which $\Pi_{SC}(\alpha_1, \alpha_2)$ is concave.

Define: $A_{1,HET} = \frac{(p_1-b_1)a_1-(p_2-b_2)a_2c}{2k} - \frac{a_1\lambda}{1-\lambda}$, $A_{2,HET} = \frac{(p_2-b_2)a_2-(p_1-b_1)a_1c}{2k} - \frac{a_2\lambda}{1-\lambda}$, $B_{1,HET} = \frac{a_1c+a_2}{2}$, $B_{2,HET} = \frac{a_2c+a_1}{2}$. We have Lemma A1.

Lemma A1. *For the platform, the optimal product information disclosure level for Products 1 and 2 are given as follows:*

$$\alpha_{1,HET*} = \frac{A_{1,HET} + A_{2,HET}B_{1,HET}}{1 - B_{1,HET}B_{2,HET}} \text{ and } \alpha_{2,HET*} = \frac{A_{2,HET} + A_{1,HET}B_{2,HET}}{1 - B_{1,HET}B_{2,HET}}.$$

Lemma A1 and Lemma 5.2 are very similar. Define:

$J_{1,HET} = (p_2 - b_2)a_2(a_2 - (2 - a_1)c) + (p_1 - b_1)a_1(2 - (a_1c + a_2)c),$

$J_{2,HET} = (p_1 - b_1)a_1(a_1 - (2 - a_2)c) + (p_2 - b_2)a_2(2 - (a_2c + a_1)c),$

$$\hat{\lambda}_{1,HET} = \frac{2J_{1,HET}}{2J_{1,HET} + 4ka_1(2 - a_1c - a_2)},$$

$$\hat{\lambda}_{2,HET} = \frac{2J_{2,HET}}{2J_{2,HET} + 4ka_2(2 - a_2c - a_1)}.$$

We have Proposition A1 which gives the same conclusion as that in the basic model's demand case.

Proposition A1. *For $i = 1,\ 2$: If $\lambda \ge \hat{\lambda}_{i,HET}$, then $\alpha_{i,HET*} = 0$; if $\lambda < \hat{\lambda}_{i,HET}$, then $\alpha_{i,HET*} > 0$.*

Appendix (A3). All Proofs

Proof of Lemma 3.1. : $\Omega(\alpha_i) = \int_{p_i-\psi\alpha_i}^{p_i} (v_i - p_i)f_i(v_i)dv_i + \psi\alpha_i(1 - F_i(p_i - \psi\alpha_i))$.

Since $\int_{p_i-\psi\alpha_i}^{p_i} (v_i - p_i)f_i(v_i)dv_i$ is positive and increasing in α_i, $\psi\alpha_i$ and $(1 - F_i(p_i - \psi\alpha_i))$ are both positive and increasing in α_i, it is obvious that $\Omega(\alpha_i)$ is an increasing function of α_i and it is also positive. (Q.E.D.)

Proof of Proposition 4.1. : From (3.3) and (3.4), we have the analytical expressions of $\Pi_{TPF,1}(\alpha_1, \alpha_2)$ and $\Pi_{TPF,2}(\alpha_1, \alpha_2)$. Checking the second order derivatives will show that: $\frac{\partial^2\Pi_{TPF,1}(\alpha_1,\alpha_2)}{\partial\alpha_1^2} = -2ka(1-\lambda) < 0$ and $\frac{\partial^2\Pi_{TPF,2}(\alpha_1,\alpha_2)}{\partial\alpha_2^2} = -2ka(1-\lambda) < 0$, which shows that for $i = 1,\ 2$, $\Pi_{TPF,i}(\alpha_1, \alpha_2)$ is a concave function of α_i.

(a) The game is super-modular because $\Pi_{TPF,1}(\alpha_1, \alpha_2)$ and $\Pi_{TPF,2}(\alpha_1, \alpha_2)$ are twice differentiable and $\partial^2\Pi_{TPF,1}(\alpha_1, \alpha_2)/\partial\alpha_1\partial\alpha_2 \ge 0$ and $\partial^2\Pi_{TPF,2}(\alpha_1, \alpha_2)/\partial\alpha_1\partial\alpha_2 \ge 0$. Thus, a unique Nash equilibrium exists. From Lemma 3.1, we know that for $i = 1,\ 2$, $\Pi_{TPF,i}(\alpha_1, \alpha_2)$ is a concave function of α_i. As a result, we can find the reactive equations by solving the respective first order conditions as follows:

$$\frac{\partial\Pi_{TPF,1}(\alpha_1, \alpha_2)}{\partial\alpha_1} = 0 \Rightarrow \alpha_1 = \left(\frac{1}{2ka(1-\lambda)}\right)((p_1 - b_1)(1-\lambda)a - ka\lambda + ka(1-\lambda)c\alpha_2)) = \left(\frac{(p_1 - b_1)}{2k} - \frac{\lambda}{2(1-\lambda)} + \frac{c\alpha_2}{2}\right). \tag{A2.1}$$

Similarly,

$$\frac{\partial\Pi_{TPF,2}(\alpha_1, \alpha_2)}{\partial\alpha_2} = 0 \Rightarrow \alpha_2 = \left(\frac{(p_2 - b_2)}{2k} - \frac{\lambda}{2(1-\lambda)} + \frac{c\alpha_1}{2}\right). \tag{A2.2}$$

Solving the reactive functions (A2.1) and (A2.2), we have the equilibrium product information disclosure levels:

$$\alpha_{1,TPF*} = \frac{2(p_1 - b_1) + c(p_2 - b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)},\ \alpha_{2,TPF*} = \frac{2(p_2 - b_2) + c(p_1 - b_1)}{k(2-c)(2+c)} - \frac{R}{(2-c)},\ \text{where } R = \frac{\lambda}{(1-\lambda)}.$$

(b) For $i = 1,\ 2$, when $\alpha_{1,TPF*}$ is positive, checking the first order derivative of $\alpha_{i,TPF*}$ with respect to each major parameter reveals that it is a decreasing function of R and k, an increasing function of c, and it is an increasing function of Product i's rental service profit margin and Product j's rental service profit margin. (Q.E.D.)

Proof of Proposition 4.2:

(a) Note that since $\alpha_1 \ge 0$, we have $\frac{2(p_1-b_1)+c(p_2-b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)} \le 0 \Rightarrow \alpha_{1,TPF*} = 0$. Since $R = \frac{\lambda}{(1-\lambda)}$, it is easy to see that $\frac{2(p_1-b_1)+c(p_2-b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)} \le 0 \Leftrightarrow \lambda \ge \frac{Z_1(2-c)}{1+Z_1(2-c)} \equiv \hat{\lambda}_{1,TPF}$. Moreover, $\frac{2(p_1-b_1)+c(p_2-b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)} > 0 \Rightarrow \alpha_{i,TPF*} > 0 \Leftrightarrow \lambda \ge \hat{\lambda}_{1,TPF}$. Similarly, we can prove the case for $\alpha_{2,TPF*} = 0$ and $\alpha_{2,TPF*} > 0$.

(b) Note that since $\alpha_1 \le 1$, we have: $\frac{2(p_1-b_1)+c(p_2-b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)} \ge 1 \Rightarrow \alpha_{1,TPF*} = 1$. It is easy to see that:

$$\frac{2(p_1 - b_1) + c(p_2 - b_2)}{k(2-c)(2+c)} - \frac{R}{(2-c)} \ge 1 \Leftrightarrow k \le \frac{2(p_1 - b_1) + c(p_2 - b_2)}{(R+2-c)(2+c)} \equiv \hat{k}_{1,TPF}.$$

Similarly, we can prove the case for $\hat{k}_{2,TPF}$. (Q.E.D.)

Derivation of Table 3: From the analytical expressions of the critical threshold $\hat{\lambda}_{i,TPF}$ and $\hat{k}_{i,TPF}$, we can derive Table A4.1.

Table A4.1
Sensitivity analysis towards Z_i.

	Z_1	Z_2
$(p_1 - b_1)\uparrow$	↑	↑
$(p_2 - b_2)\uparrow$	↑	↑
R ↑	–	–

Proof of Theorem 4.1. Directly from Proposition 4.1 and Table 3. (Q.E.D.)

Proof of Lemma 5.1:

(a) From (5.1), we have: $U_{TPF,i,RA}(\alpha_1, \alpha_2) = \Pi_{TPF,i}(\alpha_1, \alpha_2) - \hat{\xi}_i SP_{TPF,i}(\alpha_1, \alpha_2)$, $i = (1, 2)$. Thus, by definition, we have: $U_{TPF,1,RA}(\alpha_1, \alpha_2) = (p_1 - I_1)(\lambda a + (1-\lambda)a(\alpha_1 - c\alpha_2)) - m_1 - \xi_{PF1}(p_1 - b_1 - k\alpha_1)$, and $U_{TPF,2,RA}(\alpha_1, \alpha_2) = (p_2 - I_2)(\lambda a + (1-\lambda)a(\alpha_2 - c\alpha_1)) - m_2 - \xi_{PF2}(p_2 - b_2 - k\alpha_2)$.
(b) For $i = 1, 2$, checking the 2nd order derivative reveals that $U_{TPF,i,RA}(\alpha_1, \alpha_2)$ is a concave function.

Proof of Proposition 5.1:

(a) Similar to the Proof of Proposition 4.1, we can prove that the game is supermodular and a unique Nash equilibrium exists. Then, we can easily find that $\alpha_{1,TPF,RA*} = \alpha_{1,TPF*} + \Delta IDRA_1$ and $\alpha_{2,TPF,RA*} = \alpha_{2,TPF*} + \Delta IDRA_2$ by finding the reactive equations.
(b) and (c) Directly from the analytical closed-form expressions of the optimal product information disclosure levels, we can obtain the respective findings.
(d) Checking the first order derivative of $\Delta IDRA_i$ w.r.t. $\hat{\xi}_i$, $\hat{\xi}_j$, V_i, and V_j, where $i \neq j$, yields the result.

(Q.E.D.)
Derivation of Table 4: Directly obtained from the analytical expressions of $\Delta IDRA_i$ and $\alpha_{i,TPF,RA*}$. (Q.E.D.)

Proof of Proposition 5.2. : Similar to the proof of Proposition 4.2. (Q.E.D.)
Derivation of Table 5: We first derive the findings in Table A5.1 below and then it implies Table 5.

Table A5.1
Sensitivity analysis towards X_1, X_2, W_1, W_2 (With respect to the physical meanings of the parameters, we consider the case when W_1 and W_2 are positive which means the platforms cannot be extremely risk averse).

	X_1	X_2	W_1	W_2
$\hat{\xi}_1\uparrow$	↑	↑	↓	↓
$\hat{\xi}_2\uparrow$	↑	↑	↓	↓
$V_1\uparrow$	↑	↑	↓	↓
$V_2\uparrow$	↑	↑	↓	↓
$(p_1 - b_1)\uparrow$	↑	↑	–	–
$(p_2 - b_2)\uparrow$	↑	↑	–	–

Proof of Theorem 5.1. Directly from Proposition 5.2 and Table 5. (Q.E.D.)

Proof of Proposition 5.3. : Note that comparing between $\Pi^{CON}_{TPF,i}(\alpha_1, \alpha_2)$[consignment] and $\Pi_{TPF,i}(\alpha_1, \alpha_2)$ [buyout], they exhibit the same form except the revenue. If we replace $\eta_i p_i = \overline{p}_i$, then we will see that the optimal product information disclosure levels under the consignment scenario will be expressed in the same format as the one under the basic model (i.e. buyout) with one parameter change in replacing p_i by $\overline{p}_i$. Since $0 < \eta_i < 1$, we have: $p_i > \overline{p}_i$ which implies $\alpha^{CON}_{i,TPF*} < \alpha_{i,TPF*}$. (Q.E.D.)

Proof of Theorem 5.2. Directly from Proposition 5.3. (Q.E.D.)

Proof of Proposition 5.4. *As* $\Pi_{PF}(\alpha_1, \alpha_2)$ is a concave function, solving the first order conditions yields $\alpha_{1,CPF*} = \frac{A_1 + A_2 B}{1 - B^2}$ and $\alpha_{2,CPF*} = \frac{A_2 + A_1 B}{1 - B^2}$. (Q.E.D.)

Proof of Proposition 5.5. Similar to the proof of Proposition 4.2. (Q.E.D.)

Proof of Theorem 5.3. From Proposition 5.4 and Proposition 5.5. (Q.E.D.)

Appendix(A4)

Remarks on the Demand Function:
Suppose the market faced by rental service provider i has a potential size of $\tilde{n}_i$, $i = 1, 2$. Consumers in market i have a heterogeneous valuation towards the rental service v_i, and v_i follows a probability density distribution function $f_i(v_i)$. Following the common assumption in the literature, we consider the case when $f_i(v_i)$ is a uniform distribution with support in 0 and 1, i.e. $f_i(v_i) = U(0,1)$. $f_i(v_i) = 1$ for any v_i is between 0 and 1. For $i = 1, 2$ and $i \neq j$, we have the demand faced by market i given as follows:

$$\tilde{D}_i(\alpha_i) = \tilde{n}_i \int_{p-\varphi(\alpha_i - c\alpha_j)}^{1} f_i(v_i)dv_i \tag{A1}$$

where p is the service price, $(\alpha_i - c\alpha_j)$ is the utility gained from the disclosed information (i.e. by having the product information disclosure from product i, compared to the product information disclosure level from the competitor's product j). φ is a coefficient added to scale the utility gained by product information disclosure, which represents the customers' unit valuation/willingness-to-pay for information disclosure.

It is easy to show that (A1) is equivalent to:

$$\tilde{D}_i(\alpha_i) = \tilde{n}_i(1 - p_i + \varphi(\alpha_i - c\alpha_j)). \tag{A2}$$

In the basic model, we consider the case when the two markets are symmetric, which means: $\tilde{n}_1 = \tilde{n}_2 = \tilde{n}$, and $p_1 = p_2 = p$, we have:

$$\tilde{D}_1(\alpha_1) = \tilde{n}(1 - p + \varphi(\alpha_1 - c\alpha_2)). \tag{A3}$$

$$\tilde{D}_2(\alpha_2) = \tilde{n}(1 - p + \varphi(\alpha_2 - c\alpha_1)). \tag{A4}$$

From (3.1) and (3.2), we have:

$$\tilde{D}_1(\alpha_1) = \lambda a + (1 - \lambda)a(\alpha_1 - c\alpha_2), \tag{A5}$$

$$\tilde{D}_2(\alpha_2) = \lambda a + (1 - \lambda)a(\alpha_2 - c\alpha_1), \tag{A6}$$

Mapping $\lambda a = \tilde{n}(1 - p)$, and $\tilde{n}\varphi = (1 - \lambda)a$, we have when: $\lambda = \frac{1-p}{1-p+\varphi}$, and $a = \tilde{n}(1 - p + \varphi)$ (A3) is the same as (A5) and (A4) is the same as (A6).

If $\tilde{n}_1 \neq \tilde{n}_2$, and $p_1 \neq p_2$, we will have the results in heterogeneous demand case (online supplementary appendix (A2)). (Q.E.D.)

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