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ORIGINAL RESEARCH

The provision strategy of blockchain service under the supply chain with downstream competition

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Abstract

The business activity is inseparable from the support of documental information flow. In the past, the commercial documents needed a lot of time to get to the point-to-point, which could lead to problems, such as insecurity or the relatively long time. With the emergence of new technologies, it is possible to change this information transmission method to enable fast and accurate dissemination. For considering the possibility of technology adoption, this study investigates the role of blockchain service in term of market size and file circulation time. Specifically, we construct a game-theoretic model to find the equilibrium strategy from a manufacturer and two competing retailers. From the perspective of equilibrium, we investigate the results for market effects, economic effects, service effects, and service efficiency, respectively. Moreover, we also analyze the service strategy of retailers providing service by manufacturer, time sensitivity, and competitive intensity, respectively. Based on the above analysis, this study has obtained an equilibrium to support the commercial practice. In summary, this study has two contributions. On the one hand, we analyze the impact of the technological investment in blockchain service on asymmetric market scale competition. This result extends the application scope of blockchain service in the market. On the other hand, this study discusses the impact of time value on technology investment in blockchain service. Therefore, through the discussion of our study, the results show the value of blockchain service in information exchanges.

Keywords Blockchain service · Service competition · Service efficiency · Time value of document transmission · Service strategy · Game theory

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1 Introduction

1.1 Background and motivation

In the transactional activity of modern business, the circulation of commercial documents, which plays an important role, is the carrier of information exchange. These documents record the transactional information, capital information, and authentication information in e-documents or in paper documents, which support efficient business activities, especially in the transnational commerce. For example, in the process of business in an FOB contract, the seller submits a set of documents to the goods for performing obligations. Correspondingly, the buyer should pay for goods based on the full documents (Yingle, 2020). According to the requirements of documental information, the documental delivery time is shorter and the settlement is more efficient for both parties. In other words, the firm's superior is that the high-level efficient circulation of documents reduces the time cost.

To improve the efficiency of business, in 2020, the Ministry of Transport of the People's Republic of China issued the "Guidelines on Promoting the Construction of New Types of Infrastructure in the Transport Sector" (Chinese government, 2020). This document shows that the application of blockchain technology need to build a highly integrated and efficient smart transportation infrastructure. This also represents that the government promotes the digital construction of documents, online business processing, full-chain supervision of dangerous goods, and visualization of the full-process logistics. This means that the blockchain technology tries to solve some existing problems in the process of traditional trade, including the long circulation time of documents, unsafe circulation processes, and the loss of circulation value, addressing a low efficiency in the settlement between the two parties (Ahmad et al., 2021; Jinse, 2021).

In fact, it can find the value of blockchain service from the existing practice. For example, in the field of shipping, the Shanghai International Port (Group) Co., Ltd. follows the equipment interchange receipt (EIR) and paperless packing list in order to fully realize paperless Bill of Lading. This part involves the avoiding human errors, improving efficiency, and accurately collecting information through the high-value paperless electronic EIR (Zhihu, 2018). In the field of retail supply chain, a part of the stakeholders still uses the paper documents and handwritten signatures, which uses for operating and clearing (CFLP, 2020). The existence of these paper documents restricts the development of smart commerce, resulting in paper documents that drag down the clearing cycle, carrier experience that drag down the goods cycle, and waste in cost management. The JD group uses the blockchain technology to realize the integration of documental flow and informational flow. Simultaneously, it uses technology of digital signature to resolve the problem of the unresponsive handles in the traditional environment. In this process, any abnormalities can be timely discovered to correct mistakes in time and upload new data to the chain in real-time. In summary, the blockchain technology improves many of the shortcomings in the delivery of traditional trade documents, improves the level of commercial services, increases the time value of documents, and ultimately enhances the operational strength of corporate finance (See Appendix for details of some examples about some blockchain and document cases in daily business activities). These practices have been accomplished with the support of the government.

With the blockchain service for firms, they can obtain the new superiority in the competitive environment. For example, in the retail sector, Wal-Mart relies on blockchain technology to improve operational efficiency and win the trust of consumers (Sohu, 2019). The similar firms include Kroger and Nestle, which have cooperated with IBM. This technology firm constructs a project to increase the efficiency. “Allowing all participants to share information quickly and confidently in a strong and trustworthy network”. It is hoped that increased transparency will promote more responsible behavior by all participants. In a word, from a perspective of practice, regardless of maritime or retail activities, the firms will have to face competing behaviors for blockchain service to obtain a commercial superiority, especially the firm with different market sizes. In this case, firm needs to consider how to choose the optimal method to satisfy the requirements of competitive market and consumer.

Existing practice shows the potential value of the application of blockchain technology. Comparing with existing studies, these is a research gap in the service competition between theoretical researches and practical applications. Specifically, although some research involves the blockchain application in supply chain management (Dorri et al., 2017; Choi et al., 2020b; Ghani et al., 2017), there are some limitations in the application of technology in information flow. Existing studies show the characteristics of blockchain technology, including decentralization, security, and flow quickly, it helps to understand the value of real-time transmission of information (Lieber, 2017; Kim & Shim, 2018; Saberi et al., 2019; Song et al., 2022; Niu et al., 2022). From the perspective of blockchain applications, the knowledge gap refers to the discussion of blockchain service to competing firms on different market sizes. It also helps to find the value of blockchain application for different firms by technical features of blockchain service. Therefore, our research helps to understand that blockchain technology facilitates the digitization and reduces the negative impact of information flow.

These existing commercial practice and theoretical researches show that competing enterprises are different from the service level and market scale. The supply chain members closest to consumers are the downstream enterprise, which has different service strategies to achieve the optimal selection. Therefore, in the environment of blockchain service, there is a gap between the blockchain service of upstream and downstream enterprises, especially the information activities of documents (e.g. real-time). This gap leads to some questions to ponder. For example, what is the equilibrium strategy for competing firms to provide the blockchain service under the specific condition? How to obtain the best strategic decisions? All these questions can play a positive role in the rational operation of firms.

1.2 Research questions and major findings

Based on the research motivation and research gap in practical activities, we construct a two-echelon supply chain of manufacturer and retailer by using a game-theoretical model to analyze the three questions from the provision strategy of blockchain service. The basic logic is that research finds the impact of market effect (e.g. product price and product quantity), strategy choice, and other factors before and after the service provision of blockchain technology. Specifically, the research questions are as follows.

First, from the perspective of competitive retailers, what are the changes in market effects, such as product price and product quantity under the influence of documental circulation time and market size?

Specifically, the result shows that the changes in market demand and price are affected by the circulation time of the documents and the market size. Intuitively, we believe that the firms can improve market prices and demand by using service and improving the positive influence of documental circulation time on price and demand in any conditions. However, this result may be one-side to our results. When the circulation time for documents or firm with small market size does not have a certain level, even if blockchain services are provided, the price and demand of firm cannot be reasonably promoted.

Second, from the perspective of economic effect and service efficiency, what is the equilibrium strategy for competing retailer to offer blockchain service, respectively?

Specifically, the result shows that the two retailers of blockchain service are equilibrium strategies under the condition of fixed competitive intensity. When the combination of relatively low market scale and short circulation time, the large retailer as a service provider is an equilibrium strategy. When the document is a long circulation time, the retailer's service strategy cannot improve the circulation time. Additionally, from the perspective of service efficiency and service value, the results show that the blockchain service of small retailer is more efficient. The blockchain service provides by large-scale retailers give full play to the advantages of core enterprises and reduce the loss of commercial value caused by time waste. From the perspective of consumer, the service behavior of competing retailers brings the greatest benefits.

Third, which is the equilibrium strategy for competing retailers on the blockchain service by the manufacturer? In addition, how does documental circulation time affect the equilibrium strategy?

Specifically, the results show that when the market size is small, the largest retailers change their service strategy from providing services to not providing services. The deep reason lies in the influence of the service effect produced by the service of upstream manufacturers. In this way, the services of upstream companies are transferred to downstream companies. In terms of homogeneity and heterogeneity of circulation time sensitivity, enterprises with competitive strength can find that it is the equilibrium strategy for services provision by both retailers.

1.3 Contribution statements and organization

We compare the existing literature and practical activities to find the research gap in blockchain service and supply chain management. To sum up, the contribution of this study has three aspects. First, while some studies consider the time factor in supply chain management (Ding et al., 2018; Xu et al., 2020; He et al., 2021), we consider the circulation time of the documents to highlight the real-time technical characteristics of the blockchain service environment (Saberi et al., 2019). Second, from the perspective of information flow, although some existing studies have considered the application of blockchain technology in supply chain management (Astill et al., 2019; Choi, 2020b), the existing literature absents the discussion of relationship between of the blockchain service and the strategic choices of competing firms. Our research enriches the research on blockchain technology in operations management. Third, we investigate the conditions for combining documental circulation by blockchain service. The results help to understand the commercial value of the information flow and the blockchain in trade activities.

The structure of the paper is as follows: Sect. 2 is a literature review; Sect. 3 introduces the basic model and model design; Sect. 4 conducts an analysis from the aspects of market effect, economic effect, service effect, and service efficiency. Finally, the relevant conclusions and management implications are presented in Sect. 5. In order to show the results more clearly, we show the equilibrium results and propositional proofs in the E-Appendix.

2 Literature review

2.1 Study of service provision

Our research is related to service provision, which involves a discussion of specific factors and optimal strategies. Specifically, from the perspective of factors, existing studies discuss product price, subsidy, or service preference. For example, Zhu et al., (2018) point the optimal strategy of price subsidy for general internet services provided by a high-value product freight service providers. The shippers' price is willing to pay depends on the amount of transportation and the security level of the investment. From the perspective of optimal choice, existing studies analyze the strategic or tactical method to service. For example, Zhang et al., (2021a,2021b) analyze the optimal selling strategy for providing information to omni-channel retailers in the case of the demand information and valuation uncertainty for new products. Sun et al., (2022) investigate the digital showroom strategy for dual-channel supply chain to achieve the channel coordination. Based on the above-mentioned, existing studies investigate the methods to service provision. From aspect of our research, this paper takes into account the role of blockchain service into the case of reducing time of documental circulation, which shows the features of the blockchain technology (Dai et al., 2017; Chang et al., 2019), such as accuracy and real-time. Meanwhile, this case also supports the case of maritime supply chain in the documental activities. This is different from the previous research results (Wu, 2012; Ding et al., 2018).

2.2 Study of blockchain and supply chain management

Our research is related to blockchain and supply chain management. In the blockchain activities of supply chain, supply chain management involves different links, including raw material supply management, manufacturing production management, distribution logistics, and terminal consumption (Saberi et al., 2019). Moreover, it expands some scopes of the application of blockchain service, including food traceability (Astill et al., 2019; Bumblauskas et al., 2020), information disclosure and privacy issues (Dorri et al., 2017; Choi et al., 2020b), smart contracts (Christidis & Devetsikiotis, 2016), and financial management (Treleaven et al., 2017; Choi, 2020a). Based on this method, the supply chain members increase the operational efficiency over traditional operation (Ghani et al., 2017), which better reflects the changes in information flow. It also resolves the problem of the information islands in the supply chain (Dominguez et al., 2018; Wang et al., 2019a, c). Through the operational manner by blockchain service, the stakeholders integrate information flow, capital flow, logistics, business flow, and technology flow to realize the high-level efficiency and low-level cost (Aydiner et al., 2019; Kamble et al., 2019; Wang et al., 2019b). Therefore, it is necessary for us to find the new solution for blockchain service based on the existing literature (Choi, 2019; Gurtu & Johny, 2019; Lahkani et al., 2020; Narwane et al., 2021; Wang et al., 2021; Song et al., 2022). In summary, existing studies do not consider the influence of commercial documents activities in the time process. In this study, we investigate the quantitative results of documental transfer time to find the optimal solution in the environment of blockchain technology.

2.3 Study of supply chain competition and cooperation

Our study is related to competition and cooperation in supply chain. For example, from the perspective of cooperation and supply chain structure, Zhang et al., (2021a, 2021b) investigate the two competitive platforms in the changes of product price and commission. From the perspective of supply chain contract, Tao et al., (2021) discuss the strategies about newsvendor models in different cases. Niu et al., (2022) investigate the optimal strategies in the case of information leakage by demand uncertainty and signal inference. From the perspective of the relationship between supply chain power and co-opetition, Zhu & He (2017) investigate the decision on product greenness from the supply chain structure, green product types, and competition types. Based on the above-mentioned, the existing literature analyzes the impacts of parameter in supply chain cooperation. Although our study is similar to the above literature, these discussions only slightly investigate the influence of circulation time and asymmetric competition. Therefore, this result could provide new implications for firms about technological competition.

2.4 Study of service efficiency

Our study is related to service efficiency. Some existing literature uses the other methods to find results of service efficiency, including function efficiency, ecological efficiency, or energy efficiency. For example, Zheng et al., (2018) use a DEA model to evaluate energy service efficiency in China and guide different regions to choose the most effective ecological and energy-saving measures. Xu & Yang (2021) examine the efficiency of port transportation by supporting blockchain technology. The relevant aspects (e.g. service efficiency) are different from our research. We use the proportional to investigate the retailers with different market capacities provide the blockchain services. By investigating the proportional relationship between service inputs and outputs, we obtain the service value from the economic efficiency of blockchain service. From the perspective of competing retailers, it is the best choice to provide an equilibrium strategy for blockchain services.

2.5 Knowledge gap

Based on the above-mentioned, we elaborate the significance from the realistic needs and research differences. From the perspective of realistic needs, we find that the blockchain service is gradually receiving more attention in different industries. When this service is used as a competitive advantage for firm, there is seldom the related discussion in the existing research. This case cannot be an all-round supported business practice. For making up this gap, our research analyzes the competitive cases based on existing practice, which helps to understand the temporal value of blockchain service in the case of competition. From the perspective of research differences, we summarize two aspects from the literature gap, such as asymmetric competition and reduction of documents circulation time, which help to understand the possibilities of actual activities of blockchain application within the scope of maritime industry or retail industry. Based on the above-content, we provide some management implications for the practice, including market effect, economic effect, service effect, and service efficiency. To better understand the position of this research among the existing studies, we summarize the Table 1 to show the research differences as below.

Table 1 The position of this paper in the research

Authors	Blockchain service	Competition	Service efficiency/provision	Asymmetry	Circulation time of factors
Nagurney et al. (2018); Sun et al. (2022); Niu & Mu (2020)		√	√		
Zhang et al.(2021a) (2021b); Niu et al. (2022)		√		√	
Choi (2019)	√		√		
He et al. (2021)		√			√
Pournader et al. (2020)	√				√
Song et al. (2022)	√	√	√		
Wang et al. (2021)	√	√	√		√
Our paper	√	√	√	√	√

3 Model

This section describes the basic setting of the model to explain the influences of competing retailers on the provision of blockchain services, including the supply chain structure, assumption, utility function, profit function, and decision sequence, respectively.

3.1 Modeling framework of supply chain structure

We construct the supply chain structure with a manufacturer and two retailers. Specifically, the manufacturer does not provide the blockchain service. The competitive retailers have two strategies, such as providing blockchain service (Y) or not providing blockchain service (N). Therefore, the results are shown in Fig. 1; Table 2. Based on the above-mentioned, we further explain the goal of the structure. Specifically, the firms need to find the new methods in order to increase the competitive superiority. Correspondingly, in our study, we use blockchain service to increase the firm's benefit through documents activities. In this case, the blockchain technology can reduce the circulation time in document activities through the characteristics of transparency and technical credibility, which also shows the potential time value of blockchain technology in the environment of competition.

Fig. 1 Supply chain structure of blockchain service provision

Table 2 Service provision strategy of blockchain technology

		Retailer 2	
		No provision (N)	Provision (Y)
Retailer 1	No provision (N)	NN (Scenario 1)	NY (Scenario 3)
	Provision (Y)	YN (Scenario 2)	YY (Scenario 4)

3.2 Model sssumption and parameter description

3.2.1 Model assumption

(1) We investigate four scenarios to explain the effect of competition at different sizes of retailers when the manufacturer without blockchain service, including NN, YN, NY, YY based on the Table 2, respectively.

(2) According to the existing literature (Huang et al., 2013; Yang et al., 2020), we set the market ratio of retailer 1 and retailer 2 as $A_1/A_2 = a$. The $A_i(i = 1, 2)$ means there is no basic demand for blockchain service. To highlight the discussion of main question, we set the $A_2 = 1$ in order to find the changes in demand of retailer 1. Moreover, the demand of retailer 1 is $A_1 = a(0 < a < 1)$. Based on the above-conditions, we can construct the utility function to show the consumers' utility (Cai, 2010). The result is shown as follows.

$$U = \sum_{i=1,2} \left(\alpha_i q_i - q_i^2/2\right) - bq_1q_2 - \sum_{i=1,2} p_i q_i \tag{1}$$

where $\alpha_i = A_i(1 + 1(i)s_i), i = 1, 2$. In this term, $1(i) = 0 or 1$ represents whether a competing retailer is using blockchain service. When the retailer provides the blockchain service, the term $1(i) = 1$; otherwise, the term $1(i) = 0$. In addition, the p_i, q_i, and b represent product price, product quantity, and competitive intensity, respectively. The $\sum_{i=1,2} \left(\alpha_i q_i - q_i^2/2\right) - bq_1q_2$ is utility of consumers with smooth and strictly concave (Huang et al., 2013). The bq_1q_2 means substitution between product 1 and product 2 with $b > 0$ as an indicator of substitutability. The last term of formula (1) refers to the expenditure cost of consumer needs. In a word, the basic logic of formula (1) is the net utility gain to the customer. With this formula, we can obtain the demand function in the condition of maximum net utility from the customer's blockchain service.

(3) To describe the circular time of the document activities, we use the term βt to find the influence of the circular time. In addition, the time-sensitivity coefficient is β, which represents the degree of time impact. Therefore, the term βt shows the value of documental activities in traditional business. In blockchain business, this technology allows the timely transmission of document information (Wang et al., 2019b; Pournader et al., 2020), which also shows the features of blockchain technology, such as transparency. This way can reduce the loss of documental cycle time. In the basic analysis, the time-sensitive for two retailers is the same (β) in order to indicate the value of blockchain technology in information activities. In the part of extension, we also investigate the influence of time sensitivity on the optimal strategy.

(4) For the service level of blockchain technology, we set the specific level of service as s_i^A ($i = 1, 2; A = NN; YN; NY; YY$). From the perspective of cost structure, we use the unit service cost (ks_i^A) and maintenance cost ($m\left(s_i^A\right)^2$) to describe the changes of blockchain technology based on the existing literature (Yang et al., 2020). In addition, to focus on the main question, we consider the unit cost of operation as $\frac{1}{2}s_i^A$ and maintenance cost as $\frac{1}{2}\left(s_i^A\right)^2$ based on the literature (Li et al., 2012; Khanjari et al., 2014; Chen et al., 2019; Liu et al., 2020; Niu et al., 2021). In other words, the cost efficiency of blockchain technology is at a medium level (Wang & Shin, 2015). Correspondingly, if a firm wants to provide blockchain service, it needs to pay the per service cost $\frac{s_i^{YY}}{2}$ and the investment cost $\frac{1}{2}\left(s_i^A\right)^2$. In other words, these parameters are the marginal cost as $1/2$ in the environment of blockchain service. Note that this assumption is consistent with the existing literature in order to explain the rationality of the conditional setting (Li et al., 2012; Khanjari et al., 2014; He et al., 2019). Furthermore, the structure is set in such a way that is does not change the main results.

(5) The model is set up to satisfy the rational person supposition, which obtains the maximum benefit or consumption experience, such as manufacturer and retailer.

3.2.2 Symbol description

We define the symbols from the decision variables, profit variables, parameters. The results are shown in Table 3.

3.3 Model description

3.3.1 Utility function and demand function

According to the description of the modeling framework, we can obtain the utility functions in Table 4. When a retailer provides blockchain service, the change in size is $(1 + s_i)$. According to the change of the quantity, we can obtain the quantity of product for each scenario.

3.3.2 Profit function

According to the model setting, we can obtain the profit function in Table 5.

Table 3 Parameter description

Decision variables			
q_i^A;$i=1,2;A=NN;YN;NY;YY$	Product quantity	s_i^A;$i=1,2;A=NN;YN;NY;YY$	The level of blockchain service
p_i^A;$i=1,2;A=NN;YN;NY;YY$	Retailer price	w_i^A;$i=1,2;A=NN;YN;NY;YY$	Wholesale price
Profit variables			
π_i^A;$i=1,2,p;A=NN;YN;NY;YY$	Profit function	U_i^A;$i=1,2,p;A=NN;YN;NY;YY$	Utility function
CS^A;$A=NN;YN;NY;YY$	Customer surplus		
Parameters			
b	The intensity of competition	$\beta_i;i=1,2$	Time sensitivity
t	The circulation time of the document	a	The market sizes ratio of retailer 1 and retailer 2

Table 4 Utility function

Scenario	Utility function
NN	$U^{NN}=aq_1^{NN}-\frac{\left(q_1^{NN}\right)^2}{2}+q_2^{NN}-\frac{\left(q_2^{NN}\right)^2}{2}-bq_1^{NN}q_2^{NN}-\left(p_1^{NN}q_1^{NN}+p_2^{NN}q_2^{NN}\right)$
YN	$U^{YN}=\left(1+s_1^{YN}\right)aq_1^{YN}-\frac{\left(q_1^{YN}\right)^2}{2}+q_2^{YN}-\frac{\left(q_2^{YN}\right)^2}{2}-bq_1^{YN}q_2^{YN}-\left(p_1^{YN}q_1^{YN}+p_2^{YN}q_2^{YN}\right)$
NY	$U^{NY}=aq_1^{NY}-\frac{\left(q_1^{NY}\right)^2}{2}+\left(1+s_2^{NY}\right)q_2^{NY}-\frac{\left(q_2^{NY}\right)^2}{2}-bq_1^{NY}q_2^{NY}-\left(p_1^{NY}q_1^{NY}+p_2^{NY}q_2^{NY}\right)$
YY	$U^{YY}=\left(1+s_1^{YY}\right)aq_1^{YY}-\frac{\left(q_1^{YY}\right)^2}{2}+\left(1+s_2^{YY}\right)q_2^{YY}-\frac{\left(q_2^{YY}\right)^2}{2}-bq_1^{YY}q_2^{YY}-\left(p_1^{YY}q_1^{YY}+p_2^{YY}q_2^{YY}\right)$

3.3.3 Decision sequence

According to setting of models, the four scenarios have different decision sequences. We give an example to demonstrate the decision-making process in Fig. 2. Specifically, the manufacturer has the highest priority in terms of price setting. If a blockchain service provision strategy exists, the service-level determination will have the second priority. Then, according

Table 5 Profit function

Scenario	The part of the supply chain	Profit function
NN	Manufacturer	$\pi_p^{NN} = w_1^{NN} q_1^{NN} + w_2^{NN} q_2^{NN}$
	Retailer 1	$\pi_1^{NN} = \left(p_1^{NN} - w_1^{NN} - \beta t\right) q_1^{NN}$
	Retailer 2	$\pi_2^{NN} = \left(p_2^{NN} - w_2^{NN} - \beta t\right) q_2^{NN}$
YN	Manufacturer	$\pi_p^{YN} = w_1^{YN} q_1^{YN} + w_2^{YN} q_2^{YN}$
	Retailer 1	$\pi_1^{YN} = \left(p_1^{YN} - w_1^{YN} - \frac{s_1^{YN}}{2}\right) q_1^{YN} - \frac{\left(s_1^{YN}\right)^2}{2}$
	Retailer 2	$\pi_2^{YN} = \left(p_2^{YN} - w_2^{YN} - \beta t\right) q_2^{YN}$
NY	Manufacturer	$\pi_p^{NY} = w_1^{NY} q_1^{NY} + w_2^{NY} q_2^{NY}$
	Retailer 1	$\pi_1^{NY} = \left(p_1^{NY} - w_1^{NY} - \beta t\right) q_1^{NY}$
	Retailer 2	$\pi_2^{YN} = \left(p_2^{NY} - w_2^{NY} - \frac{s_2^{NY}}{2}\right) q_2^{NY} - \frac{\left(s_2^{NY}\right)^2}{2}$
YY	Manufacturer	$\pi_p^{YY} = w_1^{YY} q_1^{YY} + w_2^{YY} q_2^{YY}$
	Retailer 1	$\pi_1^{YY} = \left(p_1^{YY} - w_1^{YY} - \frac{s_1^{YY}}{2}\right) q_1^{YY} - \frac{\left(s_1^{YY}\right)^2}{2}$
	Retailer 2	$\pi_2^{YY} = \left(p_2^{YY} - w_2^{YY} - \frac{s_2^{YY}}{2}\right) q_2^{YY} - \frac{\left(s_2^{YY}\right)^2}{2}$

to the optimal market quantity of competing retailers, the optimal market price corresponding to the two retailers is determined. Finally, a gap is performed. We construct the Stackelberg game model to obtain the basic model (see Appendix A). In addition, from the perspective of service efficiency, it analyzes the effect of service delivery.

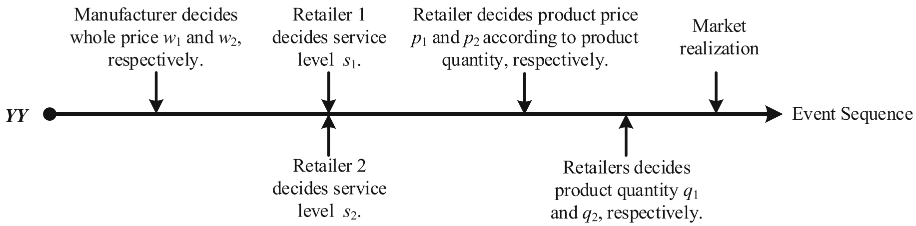


Fig. 2 Decision sequence

4 Model analysis

In this section, we analyze the market effect, economic effect, service efficiency, service value, and consumer surplus, respectively. Moreover, we give some management implications according to the analytical results.

4.1 Market effect of blockchain service

4.1.1 The quantity strategy

We investigate the changes of product quantity under different scenarios. Specifically, we compare the impact of market demand with that before and after the provision of blockchain services. The results are shown as Proposition 1.

Proposition 1 *(The Changes in the Quantity of Products on the Market)*

(1) the change in quantity R1 with R2 no change:
(a) when R2 does not provide service, $q_1^{NN} < q_1^{YN}$; (b) when R2 provides service, $q_1^{NY} < q_1^{YY}$;
(2) the change in quantity R2 with R1 no change:
(a) when R1 does not provide service, $q_2^{NN} < q_2^{NY}$; (b) when R1 provides service, $q_2^{YN} < q_2^{YY}$;
Proposition 1 discusses the changes in market demand. Specifically, the proposition shows the changes in the quantity of products. In fact, according to the existing economic theories and literature (Priyamvada et al., 2021; Wang et al., 2021), the investment behavior will promote economic development. In other words, it will also increase the product quantity studied in the literature. Therefore, based on the analysis of investment behavior, the firm (e.g. retailer in our study) considers to invest in blockchain technology to increase its competitive superiority in the market share. In other words, other technologies also can achieve the similar results. Combined with a competitive perspective, it also shows the same changing trend. When a fixed competitor chooses the render service, the service provision of blockchain will increase the product quantity, which generates higher than the quantity of non-service provision. In addition, this change in product quantity does not change with competitor's service strategy. Based on the existing literature, we find that the changes of product quantity are similar to Niu & Mu (2020). They consider the blockchain as quality verification with a multinational supply chain structure. In this study, the e-retailer has a higher order quantity in the case of blockchain service. This also explains that our research in the changes of product quantity is reasonable. Moreover, the Proposition 1' can be derived.

Proposition 1' *(Strategy of Product Quantity).*

Through the expansion of products quantity by blockchain technology, the firm can obtain a competitive superiority.

The proposition 1' shows the role of blockchain service in the changes of product quantity. However, this strategy will increase the competitive intensity due to the investment behavior of the firms. Therefore, in order to find out the different changes in market activities, we further analyze the changes in product price to find out the influence of file transfer time and competitive retailers.

4.1.2 The price strategy

We analyze the changes in product price at the highest price for every scenario. The result is shown in Fig. 3 and Proposition 2. Specifically, when the low-level circulation time of the document and market size of retailer 1, the product price of retailer 2 is higher than retailer 1 using blockchain service. In addition, when the market size of retailer 1 and retailer 2 are the same, the circulation time of documents can be relatively prolonged, which helps to improve the consumer experience through the blockchain service of competitive retailers.

Proposition 2 *(Market Price Strategy)*

The competitive retailers providing blockchain service can obtain the highest price in the case of converging market size. In addition, when the market interval ratio is low, the party with the larger market interval decides a higher market price than other scenarios. The documental circulation time is longer, the service efficiency is weaker.

From Fig. 3 and Proposition 2, we can find the changes in the price strategy. Specifically, when the manufacturer does not provide blockchain service, its behavior of production doesn't impact the product price, which leads to marginal effect. This case is also consistent with classical economic theories and the existing literature (Fan et al., 2022). Moreover, when two competitive retailers provide blockchain service, the retailer with the large market size has a negative effect of prolonging documentability due to the circulation time. In other words, through providing the blockchain service, the firm can obtain an effective way to obtain higher benefits per unit of product. When the party with the smaller market size (R1) provides blockchain technology, the highest price strategy is R2 for providing the services unless certain market capacity conditions are met. Besides, the circulation time is longer, the firm's benefit of blockchain is worse. When the circulation time reaches a threshold, the competing retailers without blockchain service will set the higher product prices.

From the perspective of firms, if retailers provide the blockchain service, they can obtain the product quantity. To explain this case clearly, we give two examples in order to elaborate the Fig. 3 and Proposition 2. For example, from the report of Deloitte, supplier adopts the blockchain service in order to find a reasonable segment of product market in the fresh food supply chain. It obtains a higher price when the quality of the product is higher (Atimescn, 2021). Moreover, the Spiceworks, as a survey company, finds that the large firms are 10 times more likely than small companies to adopt emerging technologies, including blockchain, artificial intelligence, and the Internet of Things (Shilian, 2021). In other words, the different size of enterprise also affects the choice of blockchain strategy. Based on the above-mentioned, the existing examples can demonstrate the rational results of our study. Therefore, we can

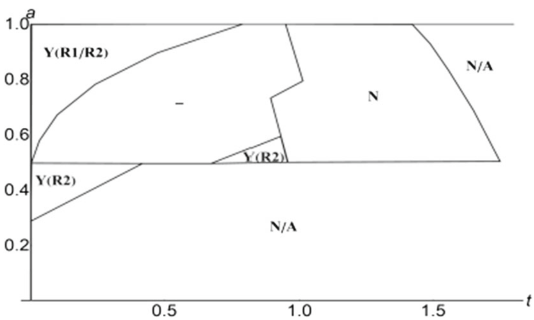


Fig. 3 Maximum price strategy.Defined symbol$O(C(i))$, Where$O = Y,N,-$ represents the provision of blockchain services, non-provision of services, and uncertain policy, respectively.

obtain the two aspects of management implication. On the one hand, the firm should consider the adoption of blockchain service in order to obtain higher price based on their own market size and the circulation time of documents. On the other hand, although the highest price helps to increase the unit benefit, the competitive intensity will be increase in the end-market. The firm needs to consider this reason to rationalize the price.

4.2 Economic effect of blockchain service

4.2.1 The equilibrium strategies of the retailer

By analyzing the profits of competing retailers, we can obtain strategy for different cases. Specifically, from the perspective of competitive retailers, we can obtain Proposition 3 and Fig. 4.

Proposition 3 *(Economic Effect of the Retailer)*

(1) the change in profit of R1 with R2 unchanged:

(a) when R2 does not provide service, $\pi_1^{NN} < \pi_1^{YN}$; (b) when R2 provides service, $\pi_1^{NY} < \pi_1^{YY}$;

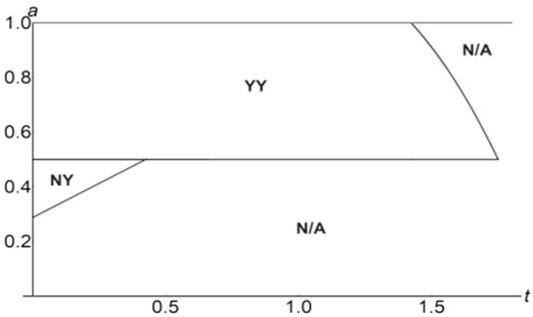
(2) the change in profit of R2 with R1 unchanged:

(a) when R1 does not provide service, $\pi_2^{NN} < \pi_2^{NY}$; (b) when R1 provides service, $\pi_2^{YN} < \pi_2^{YY}$;

The Proposition 3 and Fig. 4 show the changes in profits with competing retailers. Specifically, when one retailer chooses a fixed strategy, another retailer's service could help increase the profit of the enterprise. Moreover, through the integration of profit with different results, we can obtain the equilibrium, such as provision of blockchain with both retailers or large-scale retailers. This result is similar to the existing literature (Debo and Li, 2020). This is because the large firm has financial support for blockchain service. In addition, if a strategy YY exists, it represents the value of competition in the market. In terms of documents circulation time, the blockchain service cannot be redeemed for a long time. In other words, if the document circulates for a long time, it is worthless.

Based on the above analysis, we can give two aspects of management implications. On the one hand, from the perspective of market size (a), the competitive retailers can consider increasing their service to obtain a competitive superiority. In other words, the retailer should consider the change of profit. This is because part of the retailer's profit will be converted into the investment cost of blockchain technology, which reduces the profit. Besides, while both companies provide blockchain service with increased competitive intensity, the profits

Fig. 4 The competitive retailer services provide an equilibrium strategy



will get from competitive benefits of similar size. On the other hand, from the perspective of circulation time of document (t), the longer the document circulation time, the lower the time value, and the smaller the positive impact of time savings. To support this result, we give an example to explain this point. For example, the low-level efficient circulation of document leads to an increased pressure on the capital occupation in the international trade, resulting in a less efficient turnover in the international trade. This situation also reduces the operational efficiency.

4.2.2 The equilibrium strategies of the manufacturer

The analysis of the manufacturer's profit allows us to obtain strategies for different cases. Specifically, we can obtain Fig. 5 and Proposition 4.

Proposition 4 *(Economic Strategy)*

a. From the perspective of manufacturer, the optimal strategy is for both firms to provide the blockchain service.
b. When the circulation time of document is short and the smaller retailers are specific conditions, the economic strategy is to provide blockchain service for two firms. When smaller retails do not meet the specific condition of market size, the economic strategy is to provide blockchain service to large-scale companies.

The Fig. 5 and Proposition 4 show the optimal strategy and equilibrium strategy. Specifically, from the perspective of manufacturer, it benefits from competitive activities with retailers. This is because the investment in blockchain service increases the quantity and price of product. The manufacturer obtains more production opportunities. Moreover, from the equilibrium perspective, the firms can have two strategies, such as NY and YY. This means that the firms can choose the different strategies according to the changes of market size and circulation time of documents, achieving a triple-win result. Therefore, we can provide some management implications. On the one hand, the firms use a triple-win approach to obtain the benefits. However, it also leads to an increase in the intensity of competition in the case of YY. In other words, this way leads to duplication of investments. In this case, the firm needs to consider the optimal strategy according to the changing market conditions. On the other hand, the firms also need to consider the influence of circulation time of the documents on the optimal strategy. If the circulation time is longer, the need for the firm to choose the blockchain service to improve its benefits due to the ambiguity of the results of blockchain service.

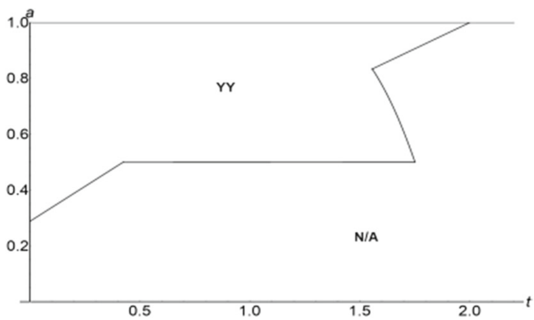
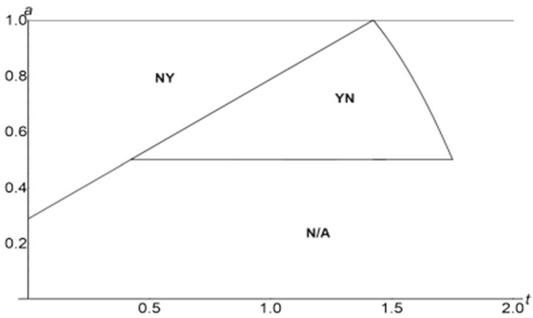


Fig. 5 Equilibrium strategy for manufacturer

Fig. 6 The service effect of blockchain equilibrium strategy



4.3 Service effect of blockchain service

In this section, we analyze the changes in service effects by using blockchain technology. Specifically, we discuss the service quality when the retailers provide blockchain services to illustrate the impact of service effects. The results are shown in Fig. 6 and Proposition 5.

Proposition 5 *(Service Strategy)*

The service strategy has two cases according to the condition of documents circulation and market size, such as strategies NY and YN.

Figure 6 and Proposition 5 show the result of service quality in the three cases with blockchain service. Specifically, the optimal strategies are NY and YN. When the circulation time of documents meets certain constraints, the retailer with the large market size provides the high-level blockchain service. When the circulation time of document meets a relatively long condition, the retailer with a smaller market size provides the high-level blockchain service. In fact, this is because the firm obtains a competitive superiority through the blockchain service, especially for longer document circulation times. Moreover, in conjunction with the discussion of benefits, the strategy with the highest level of blockchain service provision is not necessarily the most profitable strategy. In other words, the firm should consider the optimal service intensity to obtain the optimal benefit. This way can reduce unnecessary investments and realize the optimal investment in blockchain service. Based on this result, we can find that the existing literature is similar to this result (Yang et al., 2020). This result provides explanation about service advantage.

4.4 The efficiency and value of blockchain services

In this section, we investigate the value of service efficiency and service value. On the one hand, we define the formula to show the service efficiency. On the other hand, we discuss the value of access to blockchain services in terms of document circulation time.

4.4.1 The efficiency of blockchain service

According to the existing literature (Stefaniec et al., 2020; Zhao et al., 2019), we define that the formula (2) represents the service efficiency based on the return on investment (ROI) of the inputs and outputs. This index describes the ratio of return from blockchain investment during the operational life. When the ROI is higher, the economic performance is better.

Based on this method, we can obtain the Proposition 6.

$$ROI = \frac{Profit}{Total\ investment\ cost} \times 100\% \tag{2}$$

Proposition 6 *(Economic Efficiency of ROI)*

From the perspective of ROI, the service efficiency of small retailer (R1) is higher than the large retailer (R2) by using blockchain technology.

Proposition 6 shows the results of ROI. Specifically, the result shows that the smaller retailer has an efficient superiority. In other words, this doesn't mean that the efficiency is the same in the case of two retailers that tend to have the same market size. The firm obtains the key competitive advantage through enhancing the vitality of firm (Jiemian, 2017). If a firm uses the market scale to obtain the market share without a service strategy, it will lose its own market share. From the perspective of practical business, Shandong Zhishun Industries and Commerce Co. Ltd (ZIC), as an unknown and small firm in China, is focusing on providing technical services in conjunction with ZhuBaJie (as a service website). ZIC invests its costs in channel expansion to obtain a lot of service profit. After three months, the manager finds the input-output ratio is 1:10, which means a relatively high profit of ratio (Yesky, 2021). The standpoint and practice are consistent with the general cognition. In other words, the small retailers have a more efficient decision-making system than larger enterprises (Small business, 2021). In summary, when a firm chooses the strategy with the best economic effect, it is not necessarily the most efficient in its service strategy.

4.4.2 The accessible value of transmission efficiency

We define the formula (3) to represent the relationship between traditional documental activity and blockchain service[1]. This index shows the accessible value of the documents using blockchain service. The results are shown in Proposition 7.

$$Value\ loss\ ratio = \frac{TOTLE\ TIME\ VALUE}{PROFIT} \times 100\% \tag{3}$$

Proposition 7 *(Accessible Value of Blockchain Service)*

(a) The loss of value caused by time loss:

Value loss ratio (both no investment) < Value loss ratio (R1 no investment) < Value loss ratio (R2 no investment);

(b) The option values of the blockchain:

Accessible value (both investment) > Accessible value (R2 investment) > Accessible Value (R1 investment).

Proposition 7 shows the relationship between the loss of time value in documental circulation and the option values of the blockchain. Specifically, this result shows the value of blockchain service. When the large retailer does not provide services, the loss of benefits reaches a maximum. The reason for this is that large firm has an impact on the product quantity in the market. In other words, it leads to reduce the technical vitality. Correspondingly,

[1] The idea of the blockchain approach to modeling the value of transmission efficiency options is derived from the DEA model. The purpose is to find the relationship between the time value and blockchain service. Therefore, we consider both sides of documental circulation in terms of value loss and blockchain service benefits. In addition, we construct the formula (3) similar to the input-output model of DEA, which helps to understand the value of blockchain service.

the retailers provide the blockchain service to reduce the circulation time of documents. This result can find in the value of blockchain in practical business (Shou, 2019). For example, in 2019, Xi'an Branch of China Merchants Bank completed an export accounts receivable trade financing business using the cross-border business blockchain service platform, with a financing amount of USD 307,000. The verification time of the documents was reduced from several days to within 10 mins through the verification of the blockchain platform. This function shows the accessible value of blockchain for documental circulation with short times. In summary, the documental transmission is the higher-level efficiency and the value loss ratio is medium. It helps to understand the role of the relationship between efficiency and value of blockchain services.

4.5 Customer surplus of blockchain service

In this section, we investigate the customer surplus of blockchain service. Specifically, we can obtain the result from formula (1). The result is shown in Proposition 8.

Proposition 8 *(Customer Surplus)*

$$CS^{NN} < CS^{YN} < CS^{NY} < CS^{YY}$$

Proposition 8 shows the changes of consumers' interests in different scenarios. Specifically, the strategy YY is higher than other strategies. The reason is value of blockchain in a competitive retailers, which brings a technological experience to the consumers. Therefore, we can provide some management implications. On the one hand, if there is the possibility to provide service both firms, they can obtain the benefits, which realize the balance of benefits. On the other hand, the firm should consider the comprehensive influence of profit, service efficiency and consumer interests to achieve an equilibrium strategy under multi-objective conditions.

4.6 Retailer's service strategy with manufacturer provision service

In this section, we investigate the market response from manufacturers through blockchain service, which extends the basic analysis. We briefly give the results of the discussion. The details can refer the E-appendix. The results are shown in Fig. 7.

Figure 7 shows the equilibrium strategy of competing retailers in the case of manufacturer's blockchain service. Specifically, the strategy NY changes the NN strategy. In addition, the documental circulation time expands specific value (from 1.5 units to 2 units) due to the

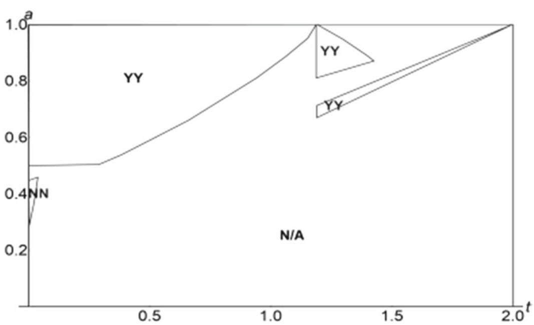


Fig. 7 The equilibrium strategy of competitive retailers in the case of manufacturer's blockchain service

influence of upstream manufacturers' services. When the retailer chooses the blockchain service, it leads to a double marginal effect, which also increases the product quantity. Moreover, this result also leads to an increase in the circulation time of documents. That is to say that the improvement of service intensity will increase the circulation time of documents and improve the service level. Based on the above analysis, we can provide some management implications. On the one hand, firms need to consider the changes in strategies by affecting the manufacturer's blockchain service according to specific conditions. On the other hand, from the perspective of documental circulation time, blockchain service will extend the document circulation time in the case of manufacturer's blockchain service. Specifically, this result shows that the circulation time of document in blockchain service will be prolonged. If we consider the change of time in Figs. 4 and 7, we can find the maximum time for the effective selection strategy about 1.8-unit in Fig. 4 into increase the 2.0-unit in Fig. 7. Besides, this result is based on the blockchain service adopted by the manufacture, which changes the blockchain's service strategy in different retailers. In this way, we can justify this result. Therefore, the firms should consider the strategies of upstream firm in order to determine a reasonable technological solution.

4.7 Time value of the transfer document

In this section, we investigate the influence of time heterogeneity, which extends the basic analysis. We briefly give the results of the discussion. The details can refer the E-appendix. The results are shown in below.

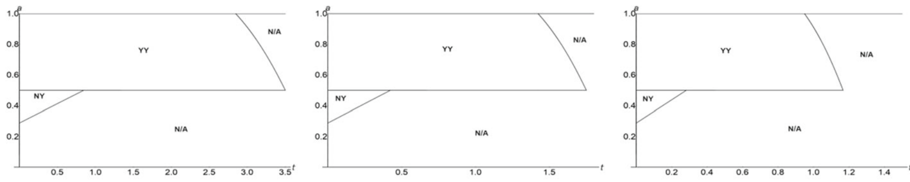
4.7.1 Time sensitivity consistency

In this part, we investigate the same sensitivity in the documental circulation time. The result is shown as Proposition 9 and Fig. 8.

Proposition 9 *(Strategy of Homogeneous Time-Sensitivity)*

The time-sensitivity of documental circulation is low and the document circulation time is short. In addition to the time dimension, the equilibrium strategy is the strategy selection that does not change in Fig. 8.

Proposition 9 and Fig. 8 show the changes of the equilibrium strategy for the same time sensitivity. Specifically, the same time sensitivity will not affect the basic choice of the equilibrium strategy. In this case, the firm needs to focus on the changes in the maximum circulation time of the documents. In other words, from the perspective of time, the firm can consider the service provision strategies based on the importance of documents.



(a) $\beta = 0.25$ (b) $\beta = 0.50$ (c) $\beta = 0.75$

Fig. 8 Equilibrium strategy selection under the same time sensitivity changes

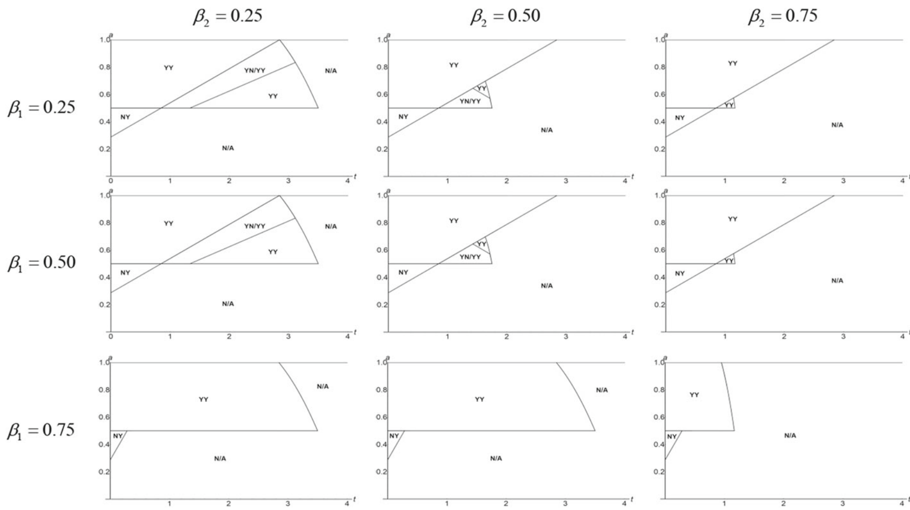


Fig. 9 Equilibrium strategy selection under different time-sensitivity changes

4.7.2 Time sensitivity inconsistency

In this part, we investigate the heterogeneous time-sensitive in document circulation time. The result is shown as Fig. 9.

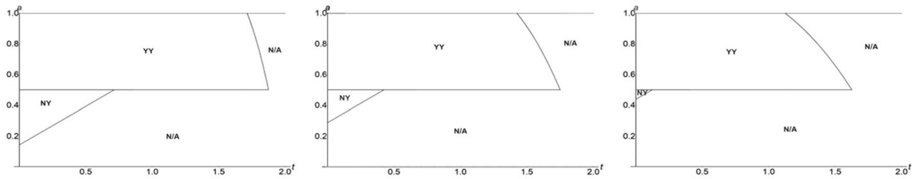
Figure 9 shows the influence of heterogeneous time sensitivity on the choice of equilibrium strategies. Specifically, when the time-sensitivity of the two retailers is at a low to medium level, the choice of potential service strategies shows different performance trends. When the time-sensitivity is high, the available service strategies change in both cases. This is because it is influenced by the market size of the retailers. Although manufacturer has the priority in the highly competitive supply chain, they have more control over the market than other companies. However, for retailers with fierce competition, if the market size is fixed, R2's share of the overall market will determine the capacity ratio of the service strategy. Therefore, when R2's documental circulation sensitivity reaches the pinnacle, the decision-making power affects the overall decision-making in the downstream market. While the retailer's decision-making in the small market (R1) will affect the overall decision-making power to a certain extent, the retailer's influence on the market in the large market is "incompetent".

Based on the above analysis, we provide the management implications. When the heterogeneous documental circulation time exists, the retailers of small market scales should follow the rules of large retailer. Therefore, the firm adopts the blockchain service, which helps to enhance the consistency of market strategy choices.

4.8 The influence of competition intensity on equilibrium strategy

In this section, we investigate the influence of competitive intensity, which extends the basic analysis. We briefly give the results of the discussion. The details can refer the E-appendix. The results are shown in Fig. 10.

Figure 10 shows that the influence of changes in market competition on the service strategies of competing retailers. Specifically, as the intensity of competition increases, the available



(a) $b = 0.25$ (b) $b = 0.50$ (c) $b = 0.75$

Fig. 10 Influence of Market Competition Changes on Service Strategy of Competitive Retailers

range (or area) for the new NY and YY strategies decreases. In other words, although competitive intensity reduces the available area, it does not change the results of the basic discussion. Therefore, when retailers pay attention to the competitive intensity, the more substitutability there is, the more likely firms are to adopt blockchain to accommodate literature circulation times. While retails with a smaller market scope adopt the NY strategy when the market range is low, the competitive intensity is increasing, and this strategic choice is much less likely. Therefore, when the retailer's market capacity tends to be consistent, the firm chooses the YY strategy in order to achieve equilibrium. From this point of view, retailers should pay attention to the intensity of competition between the two enterprises to improve service levels, increase market share, and finally achieve the effect of market revenue balance.

4.9 Discussion the main results

In this section, we discuss the main propositions in order to summarize the main insights. Specifically, we investigate the role of blockchain service in document circulation time to show the transparency features. In this study, we find the strategies in terms of market effect, economic effect, service effect, service efficiency, and service value, respectively. Moreover, we also briefly discuss the equilibrium results of equilibrium strategy under the manufacturer provide service, the sensitivity of documents to circulation time, and the intensity of competition, respectively. These results provide the solutions for strategy selection. The main discussions are shown in below.

Firstly, from the perspective of market effects, the blockchain service increases the price and quantity of products based on the changes in market size and documents circulation time. Secondly, from the perspective of equilibrium, the equilibrium is the blockchain service provided by all retailers or larger retails. This method helps to realize the consistency in decision-making. Thirdly, from the perspective of the value of blockchain service, this study shows that the firm needs to consider the necessity of document circulation time for the intensity of the service. In addition, the boat is small enough to turn around. In other words, smaller firm has a higher service efficiency, which reduces the influence of bloated structure of large organizations. Moreover, two retailers bring a good consumption experience through investing in blockchain technology. Finally, through the discussion of different conditions, the main results are consistent with the basic discussion results. Therefore, the firm should pay attention to the choice of strategies under different conditions to achieve a balanced result in decision-making among enterprises.

5 Conclusions, management implications, theoretical implications, and Future Research

5.1 Conclusion

The circulation time of documents will affect the efficiency of commercial activities. The blockchain technology can increase the trust and speed of information flow in circulation of documents through its transparency. However, blockchain service require financial support, especially since the firms of different sizes have different attitudes toward technology provision. Therefore, this study discusses the influence of circulation time of documents through the support of blockchain technology in order to find the optimal strategy from the changes of document circulation time and market size of firms. Specifically, this paper constructs a game-theoretical model for competing retailers with different market size. The main discussions are as follows.

Firstly, we consider that the market effect composed of product quantity and price in order to find the optimal strategy. The result shows the changes in market effect supported by blockchain technology are reasonable as the circulation time documents and the market size of firms change.

Secondly, we consider the changes of economic effect. The result shows that the equilibrium strategies are YY and NY. That means that the equilibrium is a blockchain service provided by all retailers or larger retailers. Moreover, it is a good choice for small retailers to provide blockchain services due to its higher efficiency. Surely, competitive retailers provide the blockchain service, which improves the service experience of consumers and reduces the loss of time value of circulation documents.

Finally, the study also investigates that the impact of manufacturer's service provision on retailers' service strategies, time sensitivity, and competitive intensity, respectively. The stable results are verified by a basic discussion.

5.2 Management implications

Commercial information is inseparable from the documental support. The value of information can only be realized if the rapid circulation of relevant information is achieved. Blockchain technology, as a new technology, supports the secure, trustworthy, and rapid circulation of information through the feature of transparency and trust. Therefore, based on the result of this study, we can provide some management implications to support the business decision-marking.

Firstly, from the perspective of time value, the firm needs to consider the value of blockchain over time changes. If the existing documents are in circulation for a longer period of time, there is less need to adopt blockchain service due to the unobvious effect of time variation. In other words, the blockchain service is a way to improve the service experience in documental activities.

Secondly, from the perspective of multiple effects, the firm consider providing the blockchain service in order to achieve a balance of benefits. Moreover, it also increases the service experience for consumers. In addition, the small firms can actively play a role in building blockchain service to satisfy a high-level efficient requirement.

Finally, from the perspective of competitive intensity, firm needs to consider the influence of competitive intensity on the environment of blockchain service. In other words, this result leads to a change in the timing of documental activities. This way helps to increase the business efficiency and to obtain the equilibrium strategy from the economic effect.

5.3 Theoretical implications

In this study, we investigate the role of blockchain service in documental activities. Our study extends the current body of knowledge. Specifically, on the one hand, we analyze the impact of technological investments of blockchain service on asymmetric competition in the market size. This result extends the application scope of blockchain service in the market. On the other hand, we investigate the time value of blockchain service in documental activities. Although the existing literature includes a discussion of time in supply chain management (Astill et al., 2019; Choi, 2020b), there is no discussion of the impact of the time value of blockchain service on technology investments. In addition, we construct a game-theoretical model with the feature of blockchain service. Based on the above analysis, we can obtain the optimal results to support the practice of using blockchain service in documental activities. In summary, our study extends the current body of knowledge on blockchain service, market competition, and way of documental transmission in the supply chains.

5.4 Future research

This study investigates the blockchain service provision solution for competing retailers when the revenue is balanced. However, this study does not consider the influence of new equilibrium when the both firms provide competing state blockchain service. In other words, we can obtain the new results from the sequential game in order to find a new equilibrium. Correspondingly, the new proposition is that it is conditional for firms with different sizes to introduce blockchain services. This is a necessary condition to pay attention to the change in the competitive intensity. Besides, our study does not consider the contracts to coordinate business relationships. Correspondingly, the new proposition is that through the cooperation of firms, they can obtain the optimal results in terms of competitive intensity and coordination level in order to reduce the repetitive investments.

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Supporting Information.

We have submitted an electronic appendix that provides supporting information for this study.

References

Ahmad, R. W., Hasan, H., Yaqoob, I., Salah, K., Jayaraman, R., & Omar, M. (2021). Blockchain for aerospace and defense: Opportunities and open research challenges. *Computers & Industrial Engineering*, *151*, 106982. https://doi.org/10.1016/j.cie.2020.106982

Astill, J., Dara, R. A., Campbell, M., Farber, J. M., Fraser, E. D. G., Sharif, S., & Yada, R. Y. (2019). Transparency in food supply chains: a review of enabling technology solutions. *Trends in Food Science & Technology, 91*, 240–247. https://doi.org/10.1016/j.tifs.2019.07.024

Atimescn (2021). Will Blockchain make products more expensive or cheaper?. http://atimescn.com/TechnologyView-10278.html. Accessed on 2021-01-24

Aydiner, A. S., Tatoglu, E., Bayraktar, E., & Zaim, S. (2019). Information system capabilities and firm performance: opening the black box through decision-making performance and business-process performance. *International Journal of Information Management*, *47*, 168–182. https://doi.org/10.1016/j.ijinfomgt.2018.12.015

Bumblauskas, D., Mann, A., Dugan, B., & Rittmer, J. (2020). A Blockchain use case in food distribution: do you know where your food has been? *International Journal of Information Management*. https://doi.org/10.1016/j.ijinfomgt.2019.09.004

Cai, G. (George) (Ed.). (2010). Channel selection and coordination in dual-channel supply chains. Journal of Retailing. 86(1), 22–36. https://doi.org/10.1016/j.jretai.2009.11.002

CFLP (2020). JD Logistics - Trusted document signing platform based on blockchain. http://www.chinawuliu.com.cn/xsyj/202005/22/504824.shtml. Accessed on 2020-09-25.

Chang, S. E., Chen, Y. C., & Wu, T. C. (2019). Exploring blockchain technology in international trade. *Industrial Management & Data Systems*, *119*(8), 1712–1733. https://doi.org/10.1108/IMDS-12-2018-0568

Chen, X., Wu, S., Wang, X., & Li, D. (2019). Optimal pricing strategy for the perishable food supply chain. *International Journal of Production Research*, *57*, 2755–2768. https://doi.org/10.1080/00207543.2018.1557352

Chinese, & Government (2020). Guidance of the Ministry of Transport on Promoting the Construction of New Infrastructure in the Field of Transportation. http://www.gov.cn/zhengce/zhengceku/2020-08/06/content_5532842.htm. Accessed on 2020-09-24.

Choi, T. M. (2019). Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains. *Transportation Research Part E: Logistics and Transportation Review*, *128*, 17–29. https://doi.org/10.1016/j.tre.2019.05.011

Choi, T. M. (2020a). Supply chain financing using blockchain: Impacts on supply chains selling fashionable products. *Annals of Operations Research*. https://doi.org/10.1007/s10479-020-03615-7

Choi, T. M., Feng, L., & Li, R. (2020b). Information disclosure structure in supply chains with rental service platforms in the blockchain technology era. *International Journal of Production Economics*, *221*, 107473. https://doi.org/10.1016/j.ijpe.2019.08.008

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the Internet of Things. *Ieee Access : Practical Innovations, Open Solutions*, *4*, 2292–2303. https://doi.org/10.1109/ACCESS.2016.2566339

Dai, J., & Vasarhelyi, M. A. (2017). Toward blockchain-based accounting and assurance. *Journal of Information Systems*, *31*(3), 5–21. https://doi.org/10.2308/isys-51804

Debo, L., & Li, C. (2021). Design and pricing of discretionary service lines. *Management Science*, *67*(4), 2251–2271. https://doi.org/10.1287/mnsc.2020.3670

Ding, Y., Gao, X., Huang, C., Shu, J., & Yang, D. (2018). Service competition in an online duopoly market. *Omega*, *77*, 58–72. https://doi.org/10.1016/j.omega.2017.05.007

Dominguez, R., Cannella, S., Barbosa-Póvoa, A. P., & Framinan, J. M. (2018). OVAP: A strategy to implement partial information sharing among supply chain retailers. *Transportation Research Part E: Logistics and Transportation Review*, *110*, 122–136. https://doi.org/10.1016/j.tre.2017.12.016

Dorri, A., Steger, M., Kanhere, S. S., & Jurdak, R. (2017). Blockchain: A distributed solution to automotive security and privacy. *IEEE Communications Magazine*, *55*(12), 119–125. https://doi.org/10.1109/MCOM.2017.1700879

Fan, X., Chen, K., & Chen, Y. J. (2022). Is Price Commitment a Better Solution to Control Carbon Emissions and Promote Technology Investment? *Management Science*. https://doi.org/10.1287/mnsc.2022.4365

Ghani, M. A., NMA, E., Kucukvar, G., M., et al. (2017). From green buildings to green supply chains: An integrated input-output life cycle assessment and optimization framework for carbon footprint reduction policy making. *Management of Environmental Quality: An International Journal*, *28*(4), 532–. https://doi.org/10.1108/MEQ-12-2015-0211

Gurtu, A., & Johny, J. (2019). Potential of blockchain technology in supply chain management: A literature review. *International Journal of Physical Distribution & Logistics Management*, *49*(9), 881–900. https://doi.org/10.1108/IJPDLM-11-2018-0371

He, Q., Wang, N., Yang, Z., He, Z., & Jiang, B. (2019). Competitive collection under channel inconvenience in closed-loop supply chain. *European Journal of Operational Research*, *275*(1), 155–166. https://doi.org/10.1016/j.ejor.2018.11.034

He, P., Wang, Z., Shi, V., & Liao, Y. (2021). The direct and cross effects in a supply chain with consumers sensitive to both carbon emissions and delivery time. *European Journal of Operational Research*, *292*(1), 172–183. https://doi.org/10.1016/j.ejor.2020.10.031

Huang, J., Leng, M., & Parlar, M. (2013). Demand functions in decision modeling: a comprehensive survey and research directions. *Decision Sciences*, *44*(3), 557–609. https://doi.org/10.1111/deci.12021

Jinse (2021). Blockchain- drive electronic signature realize the complete online preservation. https://www.jinse.com/news/blockchain/989814.html. Accessed on 2021-01-26.

Kamble, S., Gunasekaran, A., & Arha, H. (2019). Understanding the blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*, *57*(7), 2009–2033. https://doi.org/10.1080/00207543.2018.1518610

Khanjari, N. E., Iravani, S., & Shin, H. (2014). The impact of the manufacturer-hired sales agent on a supply chain with information asymmetry. *Manufacturing & Service Operations Management*, *16*(1), 76–88. https://doi.org/10.1287/msom.2013.0452

Kim, K. H., & Shim, J. H. (2018). Application and policy direction of blockchain in logistics and distribution industry. *The Journal of Industrial Distribution & Business*, *9*(6), 77–85. https://doi.org/10.13106/ijidb.2018.vol9.no6.77

Lahkani, M. J., Wang, S., Urbański, M., & Egorova, M. (2020). Sustainable B2B e-commerce and blockchain-based supply chain finance. *Sustainability*, *12*(10), 3968. https://doi.org/10.3390/SU12103968

Li, K., Mallik, S., & Chhajed, D. (2012). Design of extended warranties in supply chains under additive demand. *Production and Operations Management*, *21*(4), 730–746. https://doi.org/10.1111/j.1937-5956.2011.01300.x

Lieber, A. (2017). *Trust in Trade: Announcing a new blockchain partner*. IBM Blockchain.

Liu, P., Long, Y., Song, H. C., & He, Y. D. (2020). Investment decision and coordination of green agri-food supply chain considering information service based on blockchain and big data. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2020.123646

Nagurney, A., Shukla, S., Nagurney, L. S., & Saberi, S. (2018). A game theory model for freight service provision security investments for high-value cargo. *Economics of Transportation*, *16*, 21–28. https://doi.org/10.1016/j.ecotra.2018.09.002

Narwane, V. S., Raut, R. D., Mangla, S. K., Dora, M., & Narkhede, B. E. (2021). Risks to Big Data Analytics and Blockchain Technology Adoption in Supply Chains. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04396-3

Niu, B., & Mu, Z. (2020). Sustainable efforts, procurement outsourcing, and channel co-opetition in emerging markets. *Transportation Research Part E: Logistics and Transportation Review*, *138*, 101960. https://doi.org/10.1016/j.tre.2020.101960

Niu, B., Mu, Z., Cao, B., & Gao, J. (2021). Should multinational firms implement blockchain to provide quality verification? *Transportation Research Part E: Logistics and Transportation Review.* https://doi.org/10.1016/j.tre.2020.102121

Niu, B. Z., Dai, Z. P., & Chen, L. (2022). Information leakage in a cross-border logistics supply chain considering demand uncertainty and signal inference. *Annals of Operations Research*, *309*, 785–816. https://doi.org/10.1007/s10479-020-03866-4

Pournader, M., Shi, Y., Seuring, S., & Koh, S. C. L. (2020). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *International Journal of Production Research*, *58*, 2063–2081. https://doi.org/10.1080/00207543.2019.1650976

Priyamvada, R., Khanna, A., et al. (2021). An inventory model under price and stock dependent demand for controllable deterioration rate with shortages and preservation technology investment: revisited. *OPSEARCH*, *58*, 181–202. https://doi.org/10.1007/s12597-020-00474-5

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, *57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Sohu (2019). The latest application of Blockchain in retail industry. https://www.sohu.com/a/359491857_100256004. Accessed on 2020-09-25.

Shilian (2021). Large companies are 10 times more likely than small companies to adopt blockchain technology. http://www.shilian.com/kuaixun/11414.html. Accessed on 2021-01-24.

Shou (2021). Blockchain will be the next "breakout point" for financial payments. https://www.sohu.com/a/315291541_100128500. Accessed on 2021-01-24.

Small businesses (2021). The advantages of a small retailer. https://smallbusiness.chron.com/advantages-small-retailer-19116.html. Accessed on 2021-03-19.

Stefaniec, A., Hosseini, K., Xie, J., & Li, Y. (2020). Sustainability assessment of inland transportation in China: A triple bottom line-based network DEA approach. *Transportation Research Part D: Transport and Environment*, *80*, 102258. https://doi.org/10.1016/j.trd.2020.102258

Song, Y., Liu, J., Zhang, W., & Li, J. (2022). Blockchain's role in e-commerce sellers' decision-making on information disclosure under competition. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04276-w

Sun, Y., Wang, Z., Yan, S., & Han, X. (2022). Digital showroom strategies for dual-channel supply chains in the presence of consumer webrooming behavior. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04475-5

Tao, F., Xie, Y., Wang, Y. Y., Lai, F., & Lai, K. K. (2021). Contract strategies in competitive supply chains subject to inventory inaccuracy. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-03969-6

Treleaven, P., Brown, R. G., & Yang, D. (2017). Blockchain technology in finance. *Computer (Long Beach Calif)*, *50*(9), 14–17. https://doi.org/10.1109/MC.2017.3571047

Wang, J., & Shin, H. (2015). The impact of contracts and competition on upstream innovation in a supply chain. *Production and Operations Management*, *24*(1), 134–146. https://doi.org/10.1111/poms.12218

Wang, J., Liu, J., Wang, F., & Yue, X. (2021). Blockchain technology for port logistics capability: Exclusive or sharing. *Transportation Research Part B: Methodological*, *149*, 347–392. https://doi.org/10.1016/j.trb.2021.05.010

Wang, J., Bi, L., Wang, L., Jia, M., & Mao, D. (2019a). A mining technology collaboration platform theory and its product development and application to support china's digital mine construction. *Applied Sciences*, *9*(24), 5373. https://doi.org/10.3390/app9245373

Wang, Y., Han, J. H., & Beynon-Davies, P. (2019b). Understanding blockchain technology for future supply chains: A systematic literature review and research agenda. *Supply Chain Management*, *24*(1), 62–84. https://doi.org/10.1108/SCM-03-2018-0148

Wang, Y., Jiang, R., Xie, J., Zhao, Y., Yan, D., & Yang, S. (2019c). Soil and water assessment tool (SWAT) model: A systemic review. *Journal of Coastal Research*, *93*(sp1), 22–30. https://doi.org/10.2112/SI93-004.1

Wu, C. H. (2012). Price and service competition between new and remanufactured products in a two-echelon supply chain. *International Journal of Production Economics*, *140*(1), 496–507. https://doi.org/10.1016/j.ijpe.2012.06.034

Xu, X., Zhang, M., & He, P. (2020). Coordination of a supply chain with online platform considering delivery time decision. *Transportation Research Part E: Logistics and Transportation Review*, *141*, 101990. https://doi.org/10.1016/j.tre.2020.101990

Xu, X., & Yang, Y. (2021). Analysis of logistics port transportation efficiency evaluation based on the block chain technology. *Annals of Operations Research*. https://doi.org/10.1007/s10479-021-04379-4

Yang, X., Cai, G., Ingene, C. A., & Zhang, J. (2020). Manufacturer strategy on service provision in competitive channels. *Production and Operations Management*, *29*(1), 72–89. https://doi.org/10.1111/poms.13089

Yesky (2021). Can small businesses also achieve high production ratios?. http://news.yesky.com/hotnews/342/725623342.shtml. Accessed on 2021-03-18.

Yingle (2020). Important of trade document. http://s.yingle.com/l/gj/503648.html. Accessed on 2020-09-26.

Zhang, J., Cao, Q., & He, X. (2021a). Competitor referral by platforms. *Annals of Operations Research, 10*, 25. https://doi.org/10.1007/s10479-021-04020-4

Zhang, W., He, Y., Gou, Q., & Yang, W. (2021b). Optimal advance selling strategy with information provision for omni-channel retailers. *Annals of Operations Research*. https://doi.org/10.1007/s10479-020-03896-y

Zhao, L., Zha, Y., Zhuang, Y., & Liang, L. (2019). Data Envelopment Analysis for sustainability evaluation in china: tackling the economic, environmental, and social dimensions. *European Journal of Operational Research*, *275*, 1083–1095. https://doi.org/10.1016/j.ejor.2018.12.004

Zheng, S., Lam, C. M., Hsu, S. C., & Ren, J. (2018). Evaluating efficiency of energy conservation measures in energy service companies in China. *Energy Policy*, *122*, 580–591. https://doi.org/10.1016/j.enpol.2018.08.011

Zhihu (2018). "Threshold" in the construction of electronic document platform. https://zhuanlan.zhihu.com/p/102790781. Accessed on 2020-09-24

Zhu, H., Ouahada, K., & Nel, A. (2018). Optimal price subsidy for universal internet service provision. *Sustainability*, *10*(5), 1576. https://doi.org/10.3390/su10051576

Zhu, W., & He, Y. (2017). Green product design in supply chains under competition. *European Journal of Operational Research*, *258*(1), 165–180. https://doi.org/10.1016/j.ejor.2016.08.053