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Research Article

Decision-Making and Coordination of a Three-Stage Book Supply Chain considering Big Data Information Cost

Pan Liu

Economics & Management College, Henan Agricultural University, NongYe Road 63, Zhengzhou, Henan, China

Correspondence should be addressed to Pan Liu; hnycliupan@163.com

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In the Big Data era, Big Data Information (BDI) has been used in the book supply industry. Data Company as an important BDI supplier should be included in a book supply chain. Thus, to explore the investment decision-making problems of BDI and its effects on the coordination and pricing rules of book supply chain, a three-stage book supply chain with one book publisher, one retailer, and one Data Company was chosen. Meanwhile, four benefit models about BDI investment were proposed and analyzed in the environments of symmetry information and asymmetric information. A revenue sharing contract was used to achieve book supply chain coordination. Findings: whether the book publisher and the retailer were suitable to invest in BDI, it was influenced by the cost improvement coefficient. With the ascent of the cost improvement coefficient, benefits of supply chain members will reduce, and, in different investment models, their prices show different change trends with the cost improvement coefficient.

1. Introduction

With the popularity of the Internet and mobile Internet and the rapid development of Internet of Things (IoT) and Cloud, global data are growing quickly. At the same time, the development of Cloud and virtual storage provide a chance for reducing the storage cost of Big Data [1, 2]. All of these are a chance for the appliance and growth of Big Data. Hence, the era of Big Data has arrived. Under the Big Data background, data are called as the essential raw materials in the society of information economy [3] and have penetrated into every industry, which affects the development and change of an industry. In the book publishing industry, Big Data is also changing it.

Hence, many book publishers and retailers start to obtain and apply Big Data. Existing researches have explored the merits of Big Data usage, and they demonstrate that enterprises can find a good benefit model and business model with the aid of applying Big Data [4]. Furthermore, using Big Data can also assist companies in improving the production capacity and efficiency and then acquire more benefits [5]. But for traditional book publishers, they do not have adequate skill to handle such complex and huge data. Thus, numerous publishers begin to outsource their Big Data engineering. The general approach is to purchase related Big Data information (BDI) from the relevant Data Company. Following this tendency growth, the ranking of Data Company in book supply chain will become increasingly crucial. This transform will cause the change of book supply chain framework; i.e., Data Company should be involved in the book supply chain as a chain member.

In the background of Big Data, for Data Company, to obtain more worthy BDI, extra money using in Big Data technology and equipment should be paid. Furthermore, for book publishers, applying BDI will also add their extra expenditure on gaining the relevant BDI. In this study, BDI in a book publisher contains the external and internal sections (the external BDI mainly refers to consumer preference information) and is chosen as the study object. For a book supply chain, their upstream and downstream members want to know how to balance the change between costs and revenues. From the angle of whole book supply chain, how to obtain the maximum profit and how to coordinate the supply chain are also crucial problems to be solved. At the same time, based on our actual investigation in a book publisher of Chongqing, China, the investment models of BDI are distinct

in different supply chains. Moreover, most enterprises have no idea if the investment model they applied is good and which investment model is beneficial.

Aims of this paper are to explore the investment decision-making and coordination rules of a three-stage book supply chain considering Data Company. For a three-stage book supply chain with one Data Company, one retailer, and one book publisher, there may be four BDI investment models: (1) Data Company invests in Big Data to gain valuable BDI needed by the retailer and the book publisher, but the retailer and the book publisher do not invest and buy the related BDI from Data Company; (2) Data Company invests in Big Data to gain valuable BDI needed by the retailer and the book publisher, and the retailer and the book publisher invest and buy BDI, respectively; (3) Data Company invests in Big Data to gain valuable BDI needed by the retailer and the book publisher, and the retailer and the book publisher invest BDI jointly and share BDI's costs. In the three-stage book supply chain, the retailer as the downstream member is close to market and may obscure market demand information. If the book publisher does not take measures, it will face information asymmetry. Information asymmetry influences the performance of supply chain. Thus, in the information asymmetry background, what kind of effects of BDI investment will bring to chain members' benefits? How should chain members make an investment decision? How should the players balance profits and costs? The main problem is to study the investment decision-making and coordination rules of the three-stage book supply chain.

Even though many efforts have been done to discuss the investment decision-making and coordination problem of supply chain, they are centered on a two-stage supply chain. Researches focus on a three-stage book supply chain considering that Data Company is shortage; hence, in this paper, we will make up this gap. Thus, in this study, firstly, the importance of Data Company in a book supply chain will be discussed, and then researches on the investment decision-making and coordination problems of book supply chain in the Big Data era will be described. According to utility function theory, the demand function will be built. Then, four benefit models are developed and analyzed in the information asymmetry situation and the information symmetry situation. The results offer a theoretical guidance for Data Company, retailer, and book publisher investing and using Big Data. At the same time, it is a new development of book supply chain management theory in the Big Data era.

2. Literature Review

2.1. Big Data and Book Supply Chain Management

2.1.1. Big Data and BDI. Currently, Big Data have aroused strong attention from all around the world and are thought to be "the fourth paradigm of science" [6, 7]. However, the definition of large data has not yet reached a consensus. "Comparison definition, attribute definition, and system definition" are thought to be important among related definitions. The first definition (comparison definition) is from the cognition to Big Data processing capacity. In this definition, Big Data are described as surpassing the abilities of a traditional database software tool in data analysis, storage, collection, and management [8–11]. In addition, Wikipedia [12] also stressed that the analysis time of data surpasses the acceptable time. The second definition (attribute definition) is from the International Data Center (IDC). In this definition, the technology of Big Data was thought to create a new age of technology [13]. To extract precious information from such large and miscellaneous data, it was designed. This definition reflects the "4V" nature of Big Data (Volume, Value, Velocity, and Variety) [8, 14]. The last one (system definition) comes from National Institute of Standards and Technology (NIST). In this definition, data analysis methods are emphasized, and the capacity, representation, and gaining speed of Big Data exceed the data ability of traditional typical method, and new method needs to be designed to increase processing capability [15]. In different areas, the definition of Big Data is also given [16]. McAfee A. [5] defined the Big Data from the angle of supply chain. They thought Big Data are methods and decision maker can use this method to improve operation visualization and performance evaluation method to make optimal decision.

We should understand the meaning of "information" before describing BDI. In the information science area, Deschamps [17] proposed the new concept of information. But in different industries definitions are different. The field of communication as a pioneer in information research has also given the concept of information. In this field, information is defined as data, signal, and the final product of data processing [18]. "Data" are the physical symbols containing or recording information and arranging based on certain rules [19]. "Information" is to put the data in a certain context and then explain the meaning of it [20]. In the Big Data environment, aims of companies gaining Big Data are to extract valuable information [21]. This valuable information is called BDI in this paper. In addition, Liu & Yi [22] propose some new nature of information in the Big Data environment: (1) the update speed of information is more real-time; (2) its potential value is greater; (3) data processing and analysis technologies exceed the ability of the general corporate IT department.

2.1.2. Application of Big Data in Book Supply Chain Management. BDI can help optimize the pricing factors that upstream and downstream members considered, such as improving the efficiency of the publishing industry and reducing production costs [23]; the speed characteristics of Big Data are vital to weaken the bullwhip effect [24] and reduce book inventory. Thus, the implementation of Big Data in book supply chain also is discussed. But most of them concentrate on the qualitative researches, and the quantitative researches through building mathematical models are few.

In qualitative aspect, a large number of researchers have debated the implementation of Big Data in book supply chain. Particularly, in the book marketing field and the book theme selection decision area, many efforts were obtained. For example, timely and accurately feedback market demand information can increase sales of both offline and online book stores [25, 26]. Impacts, suggestions, and challenges

that Big Data bring to the book publishing and sale also were discussed (Zhang et al., 2012; see [27]), and book recommendation system based on Big Data [28] also was proposed. In addition, some researchers also discussed the price or pricing of book in the Big Data era. For example, the Hachette Publishing Group from France, based on readers' demand, though tracking the data about book pricing history and sales information, can grasp the price of book products timely and accurately and then adjusts the book sales price more realistically [29]. Liu [30] proposes to develop optimal e-book prices based on Big Data technology.

However, in quantitative aspects, there are few documents to explore decision-making and coordination problems based on the game theory in the Big Data environment. But in the traditional environment, some researches explored decision-making and coordination issues of upstream and downstream members, and these researches provide brace for our research. For instance, Ren et al. [31] discussed the coordination model of book supply chain considering Vendor Managed Inventory System (VMI). Främling [32] explored the condition that it is useful for publisher to tag books based on RFID technology. Hua et al. [33] explored distribution channel choice strategies of upstream and downstream members under single and dual distribution channels. Li & Liu [34] discussed the pricing strategies of e-book and p-book under wholesale model and agency model. Li et al. [35] researched the pricing and launch strategies of publisher and seller under the royalty model and buyout model considering launch strategy and lag launch strategy. Considering decentralized and centralized channels, Lu et al. [36] analyzed the pricing strategies of book supply chain members when they sell p-book and e-book under different models (wholesale mode and agency model). However, the above researches do not consider the effect of BDI input on decision-making and coordination of book supply chain.

Considering the influences of Big Data usage on decision-making and coordination in other areas have also appeared, and these researches also provide brace for our research. For example, Liu et al. explored the investment decision-making and coordination of supply chain on BDI in the information symmetry circumstance and the asymmetry circumstance [22], and a revenue sharing contract was applied to coordinate the supply chain. Moreover, the investment conditions of BDI in both decentralized and centralized conditions were also discussed [37]. Based on a three-stage supply chain with Data Company, BDI investment and coordination issues were discussed [38]. In addition, pricing issues of supply chain considering effects of big data on channel power [39] and effects of the forecast accuracy of Big Data [40] were also explored. In the Big Data environment, based on a closed-loop supply chain, effects of private information leakage on members' coopetition connection were discussed [41]. Cheng, Kuang, Shi, & Dong [42] explored that when the manufacturer implemented the sustainable investment, whether the retailer should utilize Big Data technology.

In summary, it can be found that efforts on usage of Big Data in book supply chain management have been obtained. But there are still some shortages: (1) decision-making and coordination issues of book supply chain in the Big Data environment are not discussed based on game theory angle. (2) Although the importance of Data Company was emphasized in supply chain, Data Company was not considered in the discussion process of the investment decision-making and coordination of book supply chain. (3) Whether the revenue sharing contract can achieve the supply chain coordinate was not discussed in a three-stage book supply chain. Thus, to make up this gap and abound with the theory of Big Data usage in book supply chain management, decision-making and coordination issues of book supply chain will be explored considering BDI.

2.2. Importance of Data Company in Book Supply Chain. In the age of Big Data, data-driven supply chain has appeared [43]. In the data-driven supply chain, data as the driven power and primary stuffs of supply chain operation are getting increasing attentions. But for most enterprises, analyzing so enormous and intricate data is a huge challenge. Thereby, Data Company owning Big Data analysis capacity is becoming increasingly crucial. Reasons are as follows: (1) The IT department of the traditional company is powerless in applying Big Data due to the nature of Big Data [13, 44]. According to the prediction of IDC, to 2020, the amount of global digital information will be 44 times today and most of them are unstructured [13]. Furthermore, the update speed of these data is very fast, and it also brings great challenges for the IT department of traditional enterprises [19]. Extracting the latent value of Big Data requires professional IT companies [45]. (2) Data Company has skills to increase data quality and protect data security [37]. The quality of data will influence the final value of Big Data and affect Big Data application in supply chain [46]. The unreliability is frequently caused by consumer privacy protection behavior [19]. Meanwhile, Big Data storage is also a challenge for traditional manufacturing companies [47]. Data Company owning the skill to safeguard consumer privacy will get more trust of consumers and they will provide their personal information to the Data Company.

Totally, by contrast, Data Company has the unparalleled merits than the IT department of the traditional book enterprises in the aspects of Big Data collection, storage, and analysis. Currently, Data Company plays a significance role in providing BDI to book upstream and downstream members.

Therefore, exploring the investment decision-making problem of book supply chain should consider the Data Company. Moreover, it is also essential for Data Company to make good decision in investing in Big Data.

3. Model Establishment

In the age of Big Data, following the growth of consumer living standards, the heterogeneity demands of readers are growing. For book publishers, obtaining the accurate and timely consumer preference information becomes increasingly important. At the same time, nature of Big Data can satisfy the book publishers' demand on this information. For retailers, they need consumer demand information to order and sale. Hence, for book publishers and retailers, the general way to get consumer demand information is to buy it from

Data Company. Based on this preference information, book publisher can design and produce books to satisfy reader demand. For Data Company, to gain more benefits from selling consumer BDI, it should invest in new data analysis technology. Thus, in this research, how book upstream and downstream members balance the relationships between BDI costs and benefits is the main problem we need to explore.

3.1. Parameter Description. p^k is the retail price of the book in different models. Here, $k = \{ND, DR, DM, DS\}$. *ND* model stands for the benefit model that Data Company invests in the Big Data and the retailer and the book publisher do not invest in or buy the related BDI from Data Company. *DR* model presents the benefit model that Data Company invests in Big Data and the retailer invests in or buys BDI from Data Company. *DM* model stands for the benefit model that Data Company invests in Big Data and the book publisher invests in or buys BDI from Data Company. *DS* model presents the benefit model that Data Company invests in Big Data and the retail and the book publisher invest in BDI jointly and share BDI's costs.

p_b^k is the BDI retail price in different models. α^k stands for the value discount factor and is influenced by the precision of consumer preference information.

c_b presents the information production cost of the Data Company. c_{ib} stands for the added cost of the Data Company because of using Big Data technology to gain BDI.

c stands for the book production cost.

w^k is the wholesale price of the book in different model.

c_{vr} stands for the inventory cost of retailer when the book is p-book, and if it is e-book, c_{vr} can be ignored.

c_r presents the sale cost of retailer.

c_{vd} is the inventory cost of book publisher when the book is p-book, and if it is e-book, c_{vr} can be ignored.

c_d stands for the sale cost of book publisher.

λ^k is the price impact coefficient of Data Company in different models.

θ is "the industry cost improvement coefficient. Analyzing the external BDI and the internal information of a company and using it in the company can help reduce the company's cost" [22].

3.2. Demand Function and Model Assumptions

3.2.1. Demand Function. In the environment of Big Data, to win more competition merits, book publisher will buy consumer preference information from Data Company and designs and produces book to satisfy consumer demand. Based on utility function theory, let $U = \alpha v - p$; here, $v \in [0, 1]$. The market demand formula is shown as follows.

$$Q^k = 1 - \frac{p^k}{\alpha^k} \tag{1}$$

Generally, both charging by service hours and charging by message number are the benefit models of Data Company. Certainly, both the two benefit models have been used. In this research, the benefit model charging by message number will be chosen. When the book publisher gains this consumer demand information, it can design and produce book (p-book or e-book). Assume that the total amount of consumer information is D. There is $\gamma = Q/D$, and here $\gamma \in [0, 1]$. To simplify the calculation, we set $\beta = 1/\gamma$, $D = \beta Q$, and β presents the consumer preference information conversion coefficient, in different models; it can express β^k.

3.2.2. Model Assumptions. (1) Book publisher and retailer gain consumer demand BDI from Data Company. Moreover, Data Company charges by number of messages. Based on our actual investigation in a book publisher of Chongqing, China, most companies have no ability to extract its internal BDI. Thus, in this paper, we assume that the retailer and the book publisher do not use the internal BDI and they use the traditional information saved at ERP software, MRP software, etc.

(2) Book publisher has sufficient production capacity. Upstream and downstream members are completely rational and risk neutral.

(3) Information gained from Data Company is about one type of book. Book publisher designs and produces this type of book according to consumer preference information, and, here, the book can be the print book (p-book) or can be the electronic book (e-book). Furthermore, the market is completely monopolized.

(4) Assume that if the book publisher produces book according to consumer preference information, the value discount factors and the consumer preference information conversion coefficient in different models are equal. Namely, $\alpha^{ND} = \alpha^{DR} < \alpha^{DM} = \alpha^{DS} = \alpha^C$ and $\beta^{ND} = \beta^{DR} < \beta^{DM} = \beta^{DS}$.

4. Investment Decision-Making of Supply Chain in the Information Symmetric Environment

4.1. Benefit Model of the ND Model. In the ND model, the Data Company has not used Big Data technology to extract information; thus, the accuracy of consumer preference information is low. If the book publisher purchases consumer preference information from the Data Company and then produces books (e-book or p-book) according to this information, the production cannot meet the needs of consumers well. Thus, $Q^{ND} < Q^{DR}$, $\beta^{ND} > \beta^{DR}$.

In reality, the game orders among supply chain members may have the following situations: (1) the book publisher is the leader of this game, and the Data Company and the retailer are the follower; (2) the Data Company is the leader, and the book publisher and the retailer are the follower; (3) the retailer is the game leader, and the book publisher and the Data Company are the game follower. However, in the Big Data environment, based on our actual investigation in a book publisher of Chongqing, China, Data Company often sets its BDI retail price first, and then the book publisher obtains BDI from the Data Company. Based on these BDI, the book publisher produces new p-book and then sells them to the retailer. The retailer sets the p-book retail price based on the wholesale price. Thus, to simplify the calculation, in

this section, we choose the second game order (the Data Company is the leader, and the book publisher and the retailer are the follower) to start our research.

In the ND model, the benefit functions of the Data Company, the book publisher, and the retailer are shown in functions (2), (3), and (4), respectively.

$$\pi_b^{ND} = \left(p_b - c_b\right)\beta^{ND}Q^{ND} \tag{2}$$

$$\pi_r^{ND} = \left(p^{ND} - w^{ND} - c_{vr} - c_r\right)Q^{ND} \tag{3}$$

$$\pi_d^{ND} = \left(w^{ND} - p_b - c - c_{vd} - c_d\right)Q^{ND} \tag{4}$$

$$\pi_t^{ND} = \pi_b^{ND} + \pi_d^{ND} + \pi_r^{ND} \tag{5}$$

Based on formulas (2), (3), and (4), we get Proposition 1.

Proposition 1. *The optimal prices and benefits of book supply chain members are shown in formulas (5) and (6).*

$$\begin{aligned}&\left(p_b^*, w^{ND*}, p^{ND*}, Q^{ND*}\right)\\ &= \left(\frac{\left(\alpha^{ND} - c - c_d - c_r - c_{vr} - c_{vd} + c_b\right)}{2},\right.\\ &\frac{\left(3\alpha^{ND} + c + c_b + c_d + c_{vd} - 3c_r - 3c_{vr}\right)}{4},\\ &\frac{\left(7\alpha^{ND} + c + c_b + c_d + c_r + c_{vd} + c_{vr}\right)}{8},\\ &\left.\frac{\alpha^{ND} - c - c_b - c_d - c_r - c_{vr} - c_{vd}}{8\alpha^{ND}}\right)\end{aligned} \tag{6}$$

$$\begin{aligned}&\left(\pi_b^{ND*}, \pi_d^{ND*}, \pi_r^{ND*}\right)\\ &= \left(\frac{\beta^{ND}\left(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr}\right)^2}{16\alpha^{ND}},\right.\\ &\frac{\left(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr}\right)^2}{32\alpha^{ND}},\\ &\left.\frac{\left(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr}\right)^2}{64\alpha^{ND}}\right)\end{aligned} \tag{7}$$

Proof. According to reverse method, firstly, the first order partial derivative of π_r^{ND} with respect to p^{ND} is calculated, and then let $\partial\pi_r^{ND}/\partial p^{ND} = 0$. We get $p^{ND}(w^{ND}) = (\alpha^{ND} + c_r + c_{vr} + w^{ND})/2$, and then put $p^{ND}(w^{ND})$ into formula (4). $\pi_d^{ND}(w^{ND})$ is got. Then, calculate the first order partial derivative of $\pi_d^{ND}(w^{ND})$ with respect to w^{ND}, and let $\partial\pi_r^{ND}/\partial p^{ND} = 0$. We get $w^{ND} = (\alpha^{ND} + c + c_d + c_{vd} - c_r - c_{vr} + p_b)/2$, and then put it into formula (2). Based on these, we get $p_b^* = (\alpha^{ND} - c - c_d - c_r - c_{vr} - c_{vd} + c_b)/2$. Then, $w^{ND*} = (3\alpha^{ND} + c + c_b + c_d - 3c_r + c_{vd} - 3c_{vr})/4$ and $p^{ND*} = (7\alpha^{ND} + c + c_b + c_d + c_r + c_{vd} + c_{vr})/8$. According to p_b^*, w^{ND*}, and p^{ND*}, we get Q^{ND*}, π_b^{ND*}, π_d^{ND*}, and π_r^{ND*}. Therefore, Proposition 1 is proved. □

Due to $Q^{ND*} > 0$, we get formula (8).

$$\alpha^{ND} > c + c_b + c_d + c_r + c_{vr} + c_{vd} \tag{8}$$

4.2. Benefit Model of the DM Model. In the DM model, the book publisher gains the related BDI from Data Company. By the comprehensive utilization of BDI and its internal data, inventory cost and sale cost of the book publisher can be improved. However, in the decentralized decision, the retailer can gain the market demand information from the book publisher; namely, information is symmetric between the book publisher and the retailer.

The benefit functions of the Data Company, the book publisher, and the retailer are shown in functions (9), (10), and (11), respectively.

$$\pi_b^{DM} = \left(p_b^{DM} - c_{ib} - \theta c_b\right)\beta^{DM}Q^{DM} \tag{9}$$

$$\pi_r^{DM} = \left(p^{DM} - w^{DM} - c_{vr} - c_r\right)Q^{DM} \tag{10}$$

$$\pi_d^{DM} = \left(w^{DM} - p_b^{DM} - \theta c - \theta c_{vd} - \theta c_d\right)Q^{DM} \tag{11}$$

$$\pi_t^{DM} = \pi_b^{DM} + \pi_d^{DM} + \pi_r^{DM} \tag{12}$$

Based on formulas (9), (10), and (11), we get Proposition 2.

Proposition 2. *The optimal prices and benefits of supply chain members are shown in formulas (13) and (14) (the proof process is similar to Section 4.1, and, here, we will not elaborate this calculation process).*

$$\begin{aligned}&\left(p_b^{DM*}, w^{DM*}, p^{DM*}, Q^{DM*}\right)\\ &= \left(\frac{\alpha^{DM} - \theta c - \theta c_d + c_{ib} - c_r - c_{vr} + \theta c_b - \theta c_{vd}}{2},\right.\\ &\frac{3\alpha^{DM} + \theta c + \theta c_b + \theta c_d + c_{ib} - 3\left(c_r + c_{vr}\right) + \theta c_{vd}}{4},\\ &\frac{7\alpha^{DM} + \theta c_b + c_{ib} + \theta c + \theta c_d + \theta c_{vd} + c_r + c_{vr}}{8},\\ &\left.\frac{\alpha^{DM} - \theta c_b - c_{ib} - c_r - c_{vr} - \theta c - \theta c_d - \theta c_{vd}}{8\alpha^{DM}}\right)\end{aligned} \tag{13}$$

$$\begin{aligned}&\left(\pi_b^{DM*}, \pi_d^{DM*}, \pi_r^{DM*}\right)\\ &= \left(\frac{\beta^{DM}\left[\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}\right]^2}{16\alpha^{DM}},\right.\\ &\frac{\left[\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}\right]^2}{32\alpha^{DM}},\\ &\left.\frac{\left[\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}\right]^2}{64\alpha^{DM}}\right)\end{aligned} \tag{14}$$

Due to $Q^{DM*} > 0$, we get formula (15).

$$\alpha^{DM} > \theta c_b + c_{ib} + c_r + c_{vr} + \theta c + \theta c_d + \theta c_{vd} \tag{15}$$

4.3. Decision Analyses of Supply Chain Members

Proposition 3. *When the added cost of the Data Company using in analyzing Big Data is $c_{ib} \in (0, \min\{\tau_3, \tau_4\})$, implementing Big Data plan can make the book publisher and the Data Company gain more benefits, the Data Company will invest in Big Data.*

Proof. To research the investment condition of the Data Company and the book publisher, benefits should be compared before and after investing in BDI. From the angle of whole supply chain, investors' benefits after investment should be higher than before investment. Assume that the change value of the retailer is $\Delta\pi_d$ before and after applying BDI. $\Delta\pi_d = \pi_d^{DM*} - \pi_d^{ND*} = [\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}]^2/32\alpha^{DM} - (\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})^2/64\alpha^{ND}$. When $c_{ib} < \alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - \theta c_b + c_r + c_{vr} - \sqrt{\alpha^{DM}/2\alpha^{ND}}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})$ can be met, $\Delta\pi_d > 0$. We call this condition τ_3. Assume that the change value of the Data Company is $\Delta\pi_{b2}$ before and after applying Big Data. $\Delta\pi_{b2} = \pi_b^{DM*} - \pi_b^{ND*} = \beta^{DM}[\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}]^2/16\alpha^{DM} - \beta^{ND}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})^2/16\alpha^{ND}$. When $c_{ib} < \alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - \theta c_b + c_r + c_{vr}\sqrt{\beta^{ND}\alpha^{DM}/\beta^{DM}\alpha^{ND}}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})$ can be met, $\Delta\pi_{b2} > 0$. We call this condition τ_4.

According to functions (13) and (14), Property 4 was obtained and the analysis process can be seen in the appendix. □

Property 4. (1) $\partial p^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})/8 > 0$, $\partial w^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})/4 > 0$, $\partial p_b^{DM*}/\partial\theta = (c_b - c - c_d - c_{vd})/2$

(2) $\partial\pi_r^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})[c_{ib} - \alpha^{DM} + c_r + c_{vr} + \theta(c + c_b + c_d + c_{vd})]/32\alpha^{DM} < 0$,

$\partial\pi_d^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})[c_{ib} - \alpha^{DM} + c_r + c_{vr} + \theta(c + c_b + c_d + c_{vd})]/16\alpha^{DM} < 0$,

$\partial\pi_b^{DM*}/\partial\theta = \beta(c + c_b + c_d + c_{vd})[c_{ib} - \alpha^{DM} + c_r + c_{vr} + \theta(c + c_b + c_d + c_{vd})]/8\alpha^{DM} < 0$.

According to (1) in the Property 4, with the ascent of the cost improvement coefficient θ, the wholesale price and the retail price of book will add. In addition, about the changes of θ, the optimal wholesale price of book will have a bigger fluctuation than the optimal retail price of book. Perhaps it is because, in the DM model, the book publisher has used BDI to improve its costs and then can set a lower wholesale price. However, with the ascent of the cost improvement coefficient θ, the change trends of the retail price of the Data Company are uncertain. When $c_b - c - c_d - c_{vd} > 0$, with the ascent of the cost improvement coefficient θ, the retail price of the Data Company will add; in contrast, it will reduce.

According to (2) in Property 4, with the ascent of the cost improvement coefficient θ, revenues of supply chain members will reduce. It demonstrates that when the optimization amplitude of the costs through using BDI (i.e., the cost improvement coefficient θ is small) is bigger, revenues of supply chain members are also bigger. Thus, for decision makers, if they want to gain more benefits through using BDI, they should try their best to excavate the value of BDI to reduce the value of θ. In addition, about the changes of θ, the revenue of the Data Company will have a bigger fluctuation than benefits of the retailer and the book publisher.

5. Investment Decision-Making of Supply Chain in the Information Symmetric Environment

In the environment of Big Data, to produce books needed by consumers, the traditional book publisher has to gain consumers' preference information from Data Company. With this trend growth, Data Company will become an important part of book supply chain. In this circumstance, if supply chain members want to get more benefits, how should they invest in BDI? How should the players balance profits and costs? These problems are important for book supply members.

To solve the above problems and make up the theoretical research gap, a supply chain with one book publisher, one retailer, and one Data Company was chosen. Based on the utility function theory, the demand function was built. Then, the benefit functions of the book publisher, the retailer, and the Data Company were constructed in the aforementioned models.

5.1. Benefit Model of the DR Model. In the DR model, the retailer obtains the related BDI from Data Company. Through the comprehensive utilization of BDI and its internal data, inventory cost and sale cost of the retailer can be improved. However, in the decentralized decision, the book publisher cannot gain the market demand information from the retailer; namely, information is asymmetric between the book publisher and the retailer.

The benefit functions of the Data Company, the book publisher, and the retailer are shown in functions (16), (17), and (18), respectively.

$$\pi_b^{DR} = \left(p_b^{DR} - c_{ib} - \theta c_b\right)\beta^{DR}Q^{DR} \tag{16}$$

$$\pi_r^{DR} = \left(p^{DR} - w^{DR} - p_b^{DR} - \theta c_{vr} - \theta c_r\right)Q^{DR} \tag{17}$$

$$\pi_d^{DR} = \left(w^{DR} - p_b^{ND} - c - c_{vd} - c_d\right)Q^{DR} \tag{18}$$

$$\pi_t^{DR} = \pi_b^{DR} + \pi_d^{DR} + \pi_r^{DR} \tag{19}$$

Based on formulas (16), (17), and (18), we get Proposition 5.

Proposition 5. *The optimal prices and benefits of supply chain members are shown in formulas (20) and (21), respectively (the proof process is similar to Section 4.1, and, here, we will not elaborate this calculation process).*

$$\left(p_b^{DR*}, w^{DR*}, p^{DR*}, Q^{DR*}\right) = \left(\frac{\alpha^{DR} - c - c_d + 2c_{ib} + (1-2\theta)\left(c_r + c_{vr} - c_b\right) - c_{vd}}{4},\right.$$
$$\frac{5\alpha^{DR} + 3c + (3-2\theta)c_b + 3c_d - 2c_{ib} - (3+2\theta)\left(c_r + c_{vr}\right) + 3c_{vd}}{8},$$
$$\frac{15\alpha^{DR} + (2\theta+1)c_b + 2c_{ib} + c + c_d + c_{vd} + (2\theta-1)\left(c_r + c_{vr}\right)}{16},$$
$$\left.\frac{\alpha^{DR} - (1+2\theta)c_b - 2c_{ib} + (2\theta-1)\left(c_r + c_{vr}\right) - c - c_d + c_{vd}}{16\alpha^{DR}}\right) \tag{20}$$

$$\left(\pi_b^{DR*}, \pi_d^{DR*}, \pi_r^{DR*}\right) = \left(\frac{\beta^{DR}\left[\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)\left(c_r + c_{vr}\right)\right]^2}{64\alpha^{DR}},\right.$$
$$\frac{\left[\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)\left(c_r + c_{vr}\right)\right]^2}{128\alpha^{DR}},$$
$$\left.\frac{\left[\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)\left(c_r + c_{vr}\right)\right]^2}{256\alpha^{DR}}\right) \tag{21}$$

Due to $Q^{DR*} > 0$, we get formula (22).

$$\alpha^{DR} > (1+2\theta)c_b + 2c_{ib} - (2\theta-1)\left(c_r + c_{vr}\right) + c + c_d - c_{vd} \tag{22}$$

5.2. Decision Analyses of the Retailer and Data Company

Proposition 6. *When the added cost of the Data Company using in analyzing Big Data is $c_{ib} \in (0, \{\tau_2\})$, implementing Big Data plan can make the retailer and the Data Company gain more benefits.*

Proof. To research the investment condition of the Data Company and the retailer, benefits should be compared before and after investing in BDI. From the angle of the whole supply chain, investors' benefits, after investment, should be higher than before investment. Assume that the change value of the retailer is $\Delta\pi_r$ before and after applying BDI. $\Delta\pi_r = \pi_r^{DR*} - \pi_r^{ND*} = [\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)(c_r + c_{vr})]^2/256\alpha^{DR} - (\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})^2/64\alpha^{ND}$. When $c_{ib} < [\alpha^{DR} - c - c_d - c_{vd} - (1+2\theta)c_b + (1-2\theta)(c_r + c_{vr})]/2 - \sqrt{\alpha^{DR}}/\sqrt{\alpha^{ND}}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})$, $\Delta\pi_r > 0$. We call this condition τ_1. Assume that the change value of the Data Company is $\Delta\pi_{b1}$ before and after applying Big Data. $\Delta\pi_{b1} = \pi_b^{DR*} - \pi_b^{ND*} = [\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)(c_r + c_{vr})]^2\beta^{DR}/64\alpha^{DR} - \beta^{ND}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})^2/16\alpha^{ND}$. When $c_{ib} < [\alpha^{DR} - c - c_d - c_{vd} - (1+2\theta)c_b]/2 + (1-2\theta)(c_r + c_{vr})/2 - \sqrt{\alpha^{DR}\beta^{ND}/\beta^{DR}\alpha^{ND}}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})$, $\Delta\pi_{b1} > 0$. We call this condition τ_2.

Because $\beta^{ND} > \beta^{DR}$, we get $\tau_1 > \tau_2$. Thus, the threshold of c_{ib} should meet the condition τ_2. Based on τ_2, we can get that c_{ib} has a negative relationship with the industry cost improvement coefficient θ.

According to functions (20) and (21), Property 7 was obtained and the analysis process is similar to Property 4, and we will not repeat here. □

Property 7. (1) $\partial p^{DR*}/\partial\theta = (c_b + c_d + c_{vd})/8 > 0$, $\partial w^{DR*}/\partial\theta = -(c_b + c_d + c_{vd})/4 < 0$, $\partial p_b^{DR*}/\partial\theta = (c_b - c_d - c_{vd})/2$

(2) $\partial\pi_r^{DR*}/\partial\theta = (c_b + c_r + c_{vr})[c - \alpha^{DR} + 2c_{ib} + c_d + c_d - c_r - c_{vr} + 2\theta(c_b + c_r + c_{vr})]/64\alpha^{DR} < 0$,
$\partial\pi_d^{DR*}/\partial\theta = (c_b + c_r + c_{vr})[c - \alpha^{DR} + 2c_{ib} + c_d + c_d - c_r - c_{vr} + 2\theta(c_b + c_r + c_{vr})]/32\alpha^{DR} < 0$,
$\partial\pi_b^{DR*}/\partial\theta = \beta(c_b + c_r + c_{vr})[c - \alpha^{DR} + 2c_{ib} + c_d + c_d - c_r - c_{vr} + 2\theta(c_b + c_r + c_{vr})]/16\alpha^{DR} < 0$.

According to (1) in Property 7, with the ascent of the cost improvement coefficient θ, the wholesale price will reduce and the retail price of book will add. Perhaps it is because, in the DR model, the retailer has used BDI to improve its costs and then can set a lower retailer price, and it will make the book publisher set a low wholesale price. However, with the ascent of the cost improvement coefficient θ, the change trends of the retail price of the Data Company are uncertain. When $c_b - c_d - c_{vd} > 0$, with the ascent of the cost improvement coefficient θ, the retail price of the Data Company will add; in contrast, it will reduce.

According to (2) in Property 7, with the ascent of the cost improvement coefficient θ, revenues of supply chain members will reduce. It demonstrates that when the optimization amplitude of the costs through using BDI (i.e., the cost improvement coefficient θ is small) is bigger, revenues of supply chain members are also higher. Thus, for decision

makers, if they want to gain more benefits through using BDI, they should try their best to excavate the value of BDI to reduce the value of θ. In addition, about the change of θ, the revenue of the Data Company will have a bigger fluctuation than benefits of the retailer and the book publisher.

6. Supply Chain Coordination

6.1. Benefit Model of the DS Model. In the DS model, to gain more benefits, the book publisher and the retailer will invest in BDI together. Assume that the BDI cost undertaken by the book publisher and the retailer is $(1-\delta)p_b^{DS}$ and δp_b^{DS}, respectively. Here, $\delta \in [0,1]$. Meanwhile, to encourage the retailer to bear the BDI cost, the book publisher will provide a low wholesale price to the retailer. The retailer will also share its benefits with the book publisher. Assume that the revenue sharing coefficient is ρ, and benefits of the Data Company, the retailer, and the book publisher are shown in functions (23), (24), (25), respectively.

$$\pi_b^{DS} = \left(p_b^{DS} - c_{ib} - \theta c_b\right)\beta^{DS} Q^{DS} \tag{23}$$

$$\pi_r^{DS} = \rho\left(p^{DS} - w^{DS} - \delta p_b^{DS} - \theta c_{vr} - \theta c_r\right) Q^{DS} \tag{24}$$

$$\begin{aligned}\pi_d^{DS} &= \left(w^{DS} - (1-\delta)\, p_b^{DS} - \theta c - \theta c_{vd} - \theta c_d\right) Q^{DS} \\ &\quad + (1-\rho)\left(p^{DS} - w^{DS} - \delta p_b^{DS} - \theta c_{vr} - \theta c_r\right) Q^{DS}\end{aligned} \tag{25}$$

$$\pi^C = \left[p^C - c_{ib} - \theta\left(c_b + c_r + c_{vr} + c_{vd} + c_d + c\right)\right] Q^C \tag{26}$$

Formula (26) stands for the benefit of the centralized supply chain. Based on formula (24), the optimal order quantity is $Q^{DS*} = (\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)/4\alpha^{DS}$. The optimal benefits of the Data Company, the retailer, and the book publisher are $(\pi_b^{DS*}, \pi_r^{DS*}, \pi_d^{DS*}) = (\beta^{DS}(\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)^2/8\delta\alpha^{DS}$, $\rho(\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)^2/16\alpha^{DS}$, $(\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)[2\delta\theta(c + c_d + c_{vd}) + (1-\delta)(\alpha^{DS} + \delta c_{ib} - \theta c_r - \theta c_{vr} + \delta\theta c_b) + (1-3\delta)w^{DS}]/8\delta\alpha^{DS} + (1-\rho)(\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)^2/16\alpha^{DS})$.

6.2. Decision Analyses and Coordination Policies

Proposition 8. *If the added cost of the Data Company because of using Big Data technology is $c_{ib} \in (0, \min\{\psi^1, \psi^2, \psi^3\})$, the three-stage book supply chain can be coordinated using revenue sharing contract.*

Proof. Based on formula (26), the optimal benefits and the optimal sale volume are shown as formulas (27) and (28).

$$\pi^{C*} = \frac{\left(\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vd} - \theta c_{vr}\right)^2}{4\alpha^C} \tag{27}$$

$$Q^{C*} = \frac{\left(\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vr} - \theta c_{vd}\right)}{2\alpha^C} \tag{28}$$

Assume that, before and after supply chain members using Big Data, the change values of supply chain benefits are Δ_1, Δ_2, and Δ_3. $\Delta_1 = \pi^{C*} - \pi_t^{ND*} = (\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vd} - \theta c_{vr})^2/4\alpha^C - (4\beta^{ND} + 3)(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})^2/64\alpha^{ND}$. When $c_{ib} < \alpha^C - \theta(c + c_b + c_d + c_r + c_{vd} + c_{vr}) - 4\sqrt{\alpha^C(4\beta^{ND} + 3)/\alpha^{ND}}(\alpha^{ND} - c - c_b - c_d - c_r - c_{vd} - c_{vr})$ can be met, $\Delta_1 > 0$. This condition is called ψ^1. $\Delta_2 = \pi^{C*} - \pi_t^{DR*} = (\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vd} - \theta c_{vr})^2/4\alpha^C - (4\beta^{DR} + 3)[\alpha^{DR} - c - c_d - c_{vd} - 2c_{ib} - (1+2\theta)c_b + (1-2\theta)(c_r + c_{vr})]^2/256\alpha^{DR}$. When $(8\sqrt{\alpha^C(4\beta^{DR} + 3)/14\alpha^{DR}} + 1)c_{ib} < \alpha^C - \theta(c + c_b + c_d + c_r + c_{vd} + c_{vr}) - 4\sqrt{\alpha^C(4\beta^{DR} + 3)/14\alpha^{DR}}(\alpha^{DR} - c - c_d - c_{vd} - (1 + 2\theta)c_b + (1 - 2\theta)(c_r + c_{vr}))$ can be met, $\Delta_2 > 0$. This condition is called ψ^2. $\Delta_3 = \pi^{C*} - \pi_t^{DM*} = 1/4\alpha^C \times (\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vd} - \theta c_{vr})^2 - (4\beta^{DM} + 3)[\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - c_{ib} - \theta c_b + c_r + c_{vr}]^2/64\alpha^{DM}$. When $(\sqrt{\alpha^C(4\beta^{DM} + 3)} + 4\sqrt{\alpha^M})c_{ib} < 4\sqrt{\alpha^M}(\alpha^C - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vd} - \theta c_{vr}) - \sqrt{\alpha^C(4\beta^{DM} + 3)}(\alpha^{DM} - \theta c - \theta c_d - \theta c_{vd} - \theta c_b + c_r + c_{vr})$ can be met, $\Delta_3 > 0$. This condition is called ψ^3.

Thus, if supply chain members invest in BDI together and apply revenue sharing contract to coordinate the supply chain, the added cost of the Data Company because of using Big Data technology should meet $c_{ib} \in (0, \min\{\psi^1, \psi^2, \psi^3\})$. In this condition, supply chain members investment together can gain more benefits. □

Proposition 9. *When the optimal wholesale price $w^{DS*} = (2-\delta)c_{ib} - \alpha^C + 2\theta(c + c_b + c_d + c_{vd}) + \theta c_r + \theta c_{vr} - \theta\delta c_b$ can be satisfied, meanwhile, $\delta(c_{ib} + \theta c_b) < 2c_{ib} - \alpha^C + 2\theta(c + c_b + c_d + c_{vd}) + \theta c_r + \theta c_{vr}$ can be satisfied, the revenue sharing contract can achieve the supply chain coordinate.*

Proof. Generally, the retail price is an exogenously given value; therefore, the order volume of the retailer will decide the profits of supply chain. To obtain the optimal profit, $Q^{C*} = Q^{DS*}$ should be satisfied. There is $(\alpha^C - c_{ib} - \theta c - \theta c_b - \theta c_d - \theta c_r - \theta c_{vr} - \theta c_{vd})/2\alpha^C = (\alpha^{DS} - w^{DS} - \delta c_{ib} - \theta c_r - \theta c_{vr} - \delta\theta c_b)/4\alpha^{DS}$. Due to $\alpha^{DS} = \alpha^C$, $w^{DS*} = (2-\delta)c_{ib} - \alpha^C + 2\theta(c + c_b + c_d + c_{vd}) + \theta c_r + \theta c_{vr} - \theta\delta c_b$. Let $w^{DS*} > 0$, so we get $\delta(c_{ib} + \theta c_b) < 2c_{ib} - \alpha^C + 2\theta(c + c_b + c_d + c_{vd}) + \theta c_r + \theta c_{vr}$.

Based on Proposition 9 and formulas (23) and (25), we get $(p_b^{DS*}, w^{DS*}, p^{DS*}) = (c_{ib} + \theta c_b - \rho(a - c_{ib} - \theta c - \theta c_d - \theta c_b - \theta c_r - \theta c_{vd} - \delta c_{vr}$, $(1-\delta)c_{ib} + \theta(c + c_b + c_d + c_{vd}) - \theta\delta c_b + \delta\rho(a - c_{ib} - \theta c - \theta c_d - \theta c_b - \theta c_r - \theta c_{vd} - \delta c_{vr})$, $(a + c_{ib} + \theta c + \theta c_d + \theta c_b + \theta c_r + \theta c_{vd} + \delta c_{vr})/2)$ and $\pi_r^{DS*} + \pi_b^{DS*} + \pi_d^{DS*} = \pi^{C*}$. Thus, we can get Property 10 and the analysis process is similar to Property 4, and we will not repeat here. □

Property 10. (1) $\partial p^{DS*}/\partial\theta = (c + c_b + c_d + c_{vd} + c_{vr} + c_r)/2 > 0$, $\partial w^{DS*}/\partial\theta = c + c_b + c_d + c_{vd} - \delta c_b - \delta\rho(c + c_b + c_d + c_{vd} + c_r + c_{vr})$, $\partial p_b^{DS*}/\partial\theta = c_b - \rho(c + c_d + c_{vd} + c_r + c_b)$;

(2) $\partial\pi_t^{DS*}/\partial\theta = (c_b + c + c_d + c_{vd} + c_r + c_{vr})[c_{ib} - \alpha^{DS} + \theta(c_b + c + c_d + c_{vd} + c_r + c_{vr})]/2\alpha^{DS} < 0$.

According to (1) in Property 10, with the ascent of the cost improvement coefficient θ, the retail price of book will add, and the change trend of the book wholesale price is determined by $c+c_b+c_d+c_{vd}-\delta c_b-\delta\rho(c+c_b+c_d+c_{vd}+c_r+c_{vr})$. When $c+c_b+c_d+c_{vd}-\delta c_b-\delta\rho(c+c_b+c_d+c_{vd}+c_r+c_{vr})>0$, with the growth of the cost improvement coefficient θ, the book wholesale price will increase; in contrast, it will reduce. However, with the ascent of the cost improvement coefficient θ, the change trends of the retail price of the Data Company are uncertain. When $c_b-\rho(c+c_d+c_{vd}+c_r+c_b)>0$, with the ascent of the cost improvement coefficient θ, the retail price of the Data Company will add; in contrast, it will reduce.

According to (2) in Property 10, with the ascent of the cost improvement coefficient θ, revenues of supply chain will reduce. It demonstrates that when the optimization amplitude of the costs through using BDI (i.e., the cost improvement coefficient θ is small) is bigger, revenues of supply chain are also bigger. Thus, for the decision makers, if they want to gain more benefits through using BDI, they should try their best to excavate the value of BDI to reduce the value of θ.

Proposition 11. *To achieve a win-win aim, benefits between supply chain members in different models,* $\max\{\zeta_1,\zeta_2,\zeta_3\}\le\rho\le\min\{\phi_1,\phi_2,\phi_3\}$, *should be satisfied.*

Proof. To achieve a win-win aim, benefits between supply chain members in different models should meet the following relationships: $\pi_r^{DS*}\ge\pi_r^{DR*}$, $\pi_r^{DS*}\ge\pi_r^{DM*}$, $\pi_r^{DS*}\ge\pi_r^{ND*}$, $\pi_d^{DS*}\ge\pi_d^{DR*}$, $\pi_d^{DS*}\ge\pi_d^{DM*}$, $\pi_d^{DS*}\ge\pi_d^{ND*}$, $\pi_b^{DS*}\ge\pi_b^{DR*}$, $\pi_b^{DS*}\ge\pi_b^{DM*}$, and $\pi_b^{DS*}\ge\pi_b^{ND*}$. Through calculating, we obtain $\rho\ge[\alpha^{DR}-c-c_d-c_{vd}-2c_{ib}-(1+2\theta)c_b+(1-2\theta)(c_r+c_{vr})]^2/64[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2=\zeta_1$; $\rho\ge[\alpha^{DM}-\theta c-\theta c_d-\theta c_{vd}-c_{ib}-\theta c_b+c_r+c_{vr}]^2/16[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2=\zeta_2$; $\rho\ge\alpha^{DS}(\alpha^{ND}-c-c_b-c_d-c_r-c_{vd}-c_{vr})^2/16\alpha^{ND}[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2=\zeta_3$; $\rho\le\{2/\delta-[\alpha^{DR}-c-c_d-c_{vd}-2c_{ib}-(1+2\theta)c_b+(1-2\theta)(c_r+c_{vr})]^2/32[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2\}+1=\phi_1$; $\rho\le\{2/\delta-[\alpha^{DM}-\theta c-\theta c_d-\theta c_{vd}-c_{ib}-\theta c_b+c_r+c_{vr}]^2/8[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2\}+1=\phi_2$; $\rho\le\{2/\delta-\alpha^{DS}(\alpha^{ND}-c-c_b-c_d-c_r-c_{vd}-c_{vr})^2/8\alpha^{ND}[\alpha^{DS}-c_{ib}-\theta(c+c_b+c_d+c_{vd}+c_r+c_{vr}]^2\}+1=\phi_3$. In addition, through calculating, $\pi_d^{DS*}\ge\pi_d^{ND*}$, $\pi_b^{DS*}\ge\pi_b^{DR*}$, and $\pi_b^{DS*}\ge\pi_b^{DM*}$ are established. Thus, Proposition 11 is proved. □

7. Numerical Simulation

To survey the validity of the proposed propositions, a numerical case was implemented. According to the research of Hernandez [48], we set $\theta=0.65$. According to our survey in a book publisher who has used BDI from Chongqing China, we choose a best seller as data sources; let $\beta^{ND}=1.5$, $\beta^{DR}=\beta^{DM}=\beta^{DS}=1.1$. $\alpha^{ND}=0.7$, $\alpha^{DR}=\alpha^{DM}=\alpha^{DS}=0.9$, $c_d=0.1$, $c_{vd}=0.1$, $c_r=0.15$, $c_{vr}=0.1$, $c=0.1$, $c_b=0.15$, $\delta=0.5$.

Based on formula (22) and Proposition 6, we get $c_{ib}\le0.089$. Without loss of generality, we set $c_{ib}=0.05$; therefore, $(\pi_b^{DR*},\pi_b^{ND*})=(1.2\times10^{-4},1.03\times10^{-34})$ and $(\pi_r^{DR*},\pi_r^{ND*})=(2.8\times10^{-5},1.7\times10^{-35})$. Obviously, $\pi_b^{DR*}>\pi_b^{ND*}$ and $\pi_r^{DR*}>\pi_r^{ND*}$. In addition, there is $(\pi_d^{DR*},\pi_d^{ND*})=(5.6\times10^{-5},3.4\times10^{-35})$; namely, $\pi_d^{DR*}>\pi_d^{ND*}$. These demonstrate that Big Data implementation of the retailer and the Data Company not only can help them gain more profits, but also can help the book publisher obtain more benefits. Proposition 6 was confirmed.

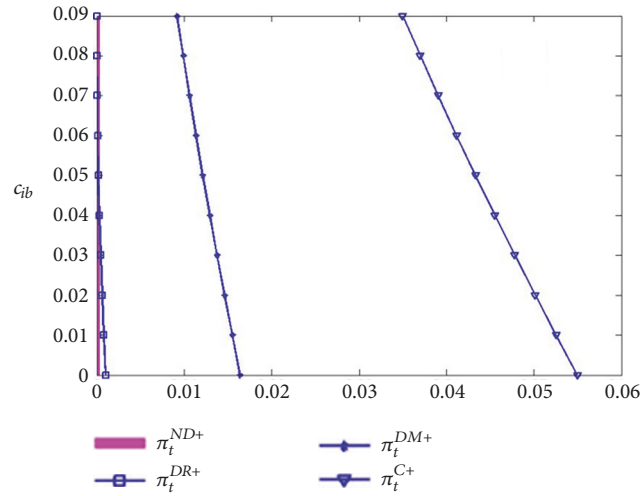

Figure 1: Impacts of c_{ib} on supply chain revenues.

Based on formula (15) and Proposition 3, we get $c_{ib}\le0.36$, Without loss of generality, we set $c_{ib}=0.05$; therefore, $(\pi_b^{DM*},\pi_b^{ND*})=(0.0072,1.03\times10^{-34})$ and $(\pi_d^{DM*},\pi_d^{ND*})=(0.0033,3.4\times10^{-35})$, Obviously, $\pi_b^{DM*}>\pi_b^{ND*}$ and $\pi_d^{DM*}>\pi_d^{ND*}$. Furthermore, there is $(\pi_r^{DM*},\pi_r^{ND*})=(0.0016,1.7\times10^{-35})$, namely, $\pi_r^{DM*}>\pi_r^{ND*}$. These demonstrate that Big Data implementation of the book publisher and the Data Company not only can help them gain more profits, but also can help the retailer obtain more benefits. Proposition 3 was confirmed.

According to Proposition 8, to study impacts of the benefit-sharing contract on the three-stage book supply chain coordination, benefits in models ND, DR, DM, and DS were compared, as shown in Figure 1. Based on Figure 1, we can get that when $c_{ib}\in(0,\{\psi^2\})$ can be met, implementing Big Data plan can help supply chain members obtain more benefits. Moreover, in the DS model, the benefit of supply chain is the highest; namely, benefit-sharing contract can achieve the three-stage book supply chain coordinate. Proposition 8 was confirmed.

To describe effects of BDI on pricing rules of supply chain members well, Figure 2 shows the change policies of decision variables with the cost improvement coefficient θ. From Figure 2, we get that, in the models of DM and DS, with the growth of θ, the retail price of Data Company, the wholesale price of the book publisher, and the retail price of the retailer will increase. It demonstrates that when the optimization amplitude of the costs through using BDI is lower, decision makers who have used BDI have to set a

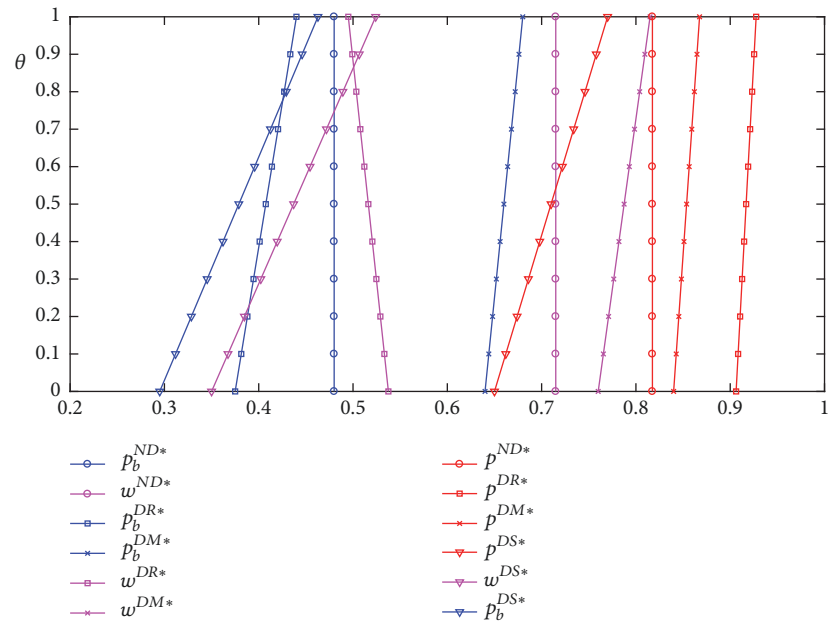

Figure 2: Change trends of decision variables with θ.

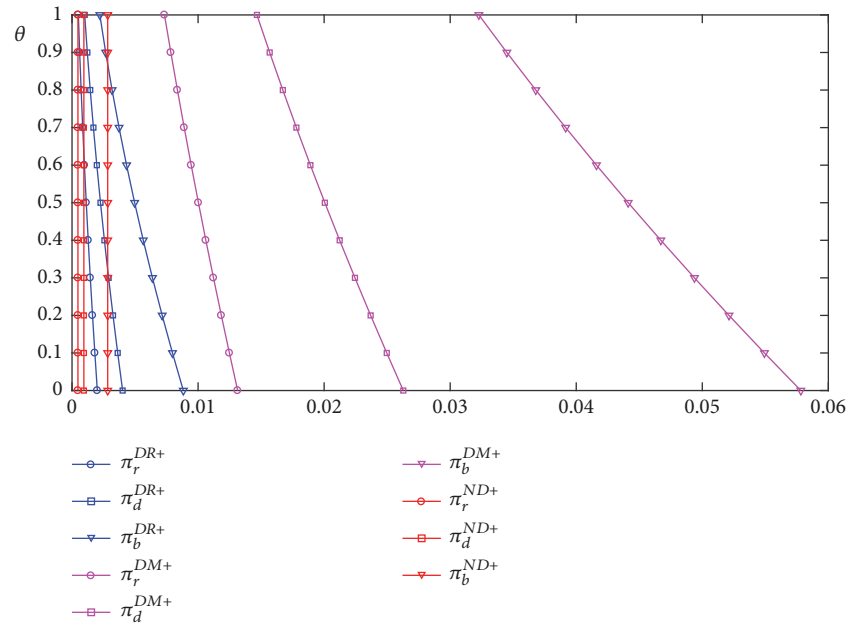

Figure 3: Change trends of benefits with θ in different models.

higher price to gain more benefits. In the DR model, with the ascent of θ, the wholesale price of book will decrease, and the retail prices of Data Company and the retailer will increase. Maybe it is because of the fact that, in the DR model, using BDI can help the retailer sell more books, and the increase of θ will lead to the decrease of the optimization amplitude of the costs through using BDI; meanwhile, the inputs of BDI will also add the additional expenditure of the Data Company and the retailer. Thus, they should set a higher price to gain more benefits. This will lead to the decrease of the market demand; to encourage the retailer to sell more books, the book publisher will set a lower wholesale price to gain more benefits.

To describe effects of BDI on revenues of supply chain members intuitively, Figures 3 and 4 indicate the change rules of benefit variables with the cost improvement coefficient θ. Based on Figure 3, we can understand that, in the models of DR, DM, and DS, with the ascent of θ, benefits of supply chain members will reduce. It demonstrates that when the optimization amplitude of the costs through using BDI is lower, benefits of decision makers will decrease. Thus, for decision makers, if they want to gain more benefits through

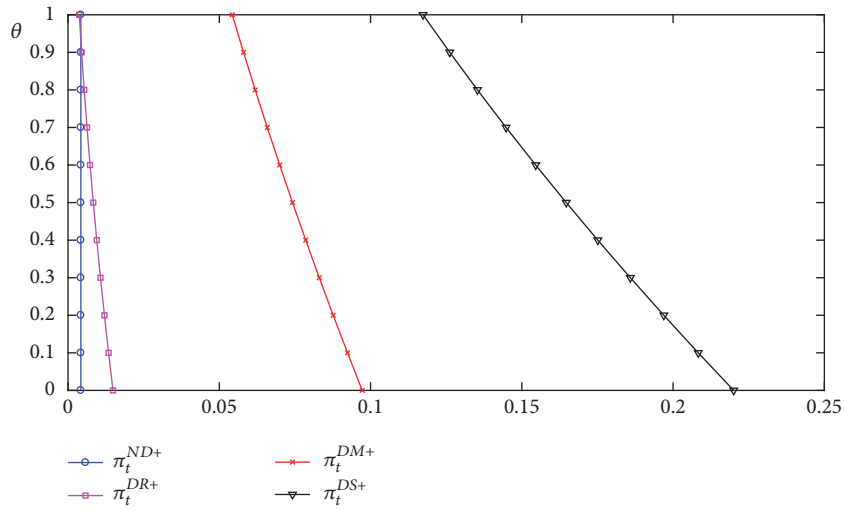

Figure 4: Influences of θ on supply chain total revenues.

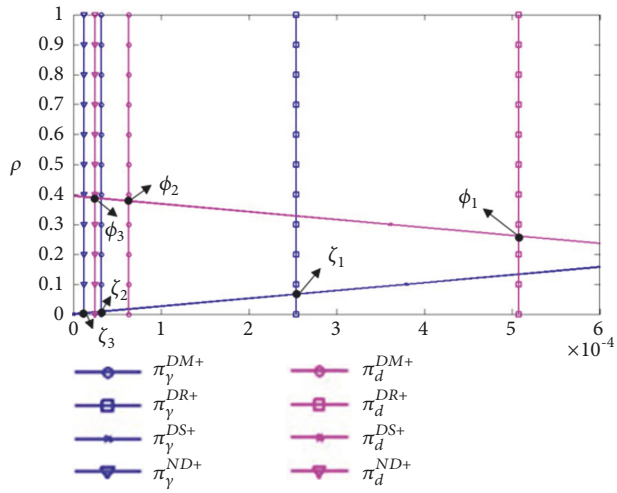

Figure 5: Coordination policy figure of the revenue sharing contract.

using BDI, they should try their best to excavate the value of BDI. In addition, we find that when θ can meet a certain range, for supply chain members, using BDI will gain more benefits compared with no using BDI.

From Figure 4, we can find that, in models DR, DM, and DS, with the ascent of θ, the overall benefits of supply chain will reduce. In addition, in the DR model, revenues of the total supply chain are lower than in the models DM and DS. It shows that, for the retailer and the book publisher, the investment of the book publisher in BDI will help the overall supply chain gain more benefits. Meanwhile, in the DS model, the entire benefits of supply chain are the biggest in the four models. It demonstrates that if supply chain members want to gain more revenues, a contrast should be used to coordinate the supply chain.

To provide an intuitional understanding about the coordination rules, Figure 5 was proposed. From Figure 5, we can get that when $\zeta_1 \leq \rho \leq \phi_1$, revenue sharing contract can achieve supply chain coordination, and all supply chain members can gain a win-win relationship. Thus, Proposition 11 was confirmed. Furthermore, we find some phenomenon through inspecting the benefit curves.

Benefits of the retailer and the book publisher in the models of DR, DM, and DS are higher than in the ND model. In addition, benefits of the book publisher are higher than revenues of the retailer in the models of DR, DM, and DS. Moreover, if supply chain members can invest in BDI, they will gain more benefits. Maybe it is because that, for the retailer, by using consumers BDI and its internal information, the retailers can make a good decision on their order volume and improve their sale cost and inventory cost, and it also helps them sell more books. Then benefits of the retailer and the book publisher will grow. For the book publisher, through using consumer preference information and its internal information, books needed by consumers can be designed and the sale cost and the inventory cost will be improved, which will help the book publisher and the retailer gain more benefits.

8. Conclusions, Significance, and Further Researches

8.1. Conclusions. In the era of Big Data, channels of book supply chain members obtaining the needed information are more than in the traditional circumstance. However, what kind of effects of BDI investment will bring to book supply chain members' benefits considering Data Company? How should supply chain members make an investment decision? How should the players balance profits and costs? The main problem is to study the investment decision-making and coordination rules of the three-stage book supply chain.

To explore the proposed problem, the importance of Data Company in a book supply chain has been discussed, and then researches on the investment decision-making and coordination problems of supply chain in the Big Data era have also been described. Then, four benefit models are developed and analyzed. We got some findings.

(1) In the models of DR, DM, and DS, with the ascent of the cost improvement coefficient θ, the retail price of the book will increase. However, the change trends of the book wholesale price and the retail price of the Data Company are different in different models.

(2) In the models of DR, DM, and DS, with the ascent of the cost improvement coefficient θ, benefits of supply chain members will reduce. Moreover, when the optimization amplitude of the costs through using BDI is lower, benefits of decision makers will decrease.

In other words, for decision makers, if they want to gain more benefits through using BDI, they should try their best to excavate the value of BDI.

(3) In models of DR and DM, when the added cost of the Data Company because of analyzing Big Data can meet a certain condition, implementing Big Data plan not only can make the investors gain more benefits, but also can help other book supply chain members obtain more profits. In addition, when θ can meet a certain range, for book supply chain members, using BDI will gain more benefits compared with no using BDI.

Namely, when one of the book supply chain members chooses to use and invest in BDI, not only their revenues can be improved, but also other members' in the supply chain can increase. "Spillover Effect" is existence. Moreover, the whole profits of the book supply chain will grow.

(4) If members of the three-stage book supply chain share the related costs and benefits, meanwhile, the related coefficients δ and ρ can meet a certain range, the revenue sharing contract can achieve the three-stage book supply chain coordination. Meanwhile, the whole benefit of the three-stage book supply chain is the highest after coordination.

8.2. Significance. This research has significance values in book supply chain management area. Theoretically, the important position of a Data Company in a book supply chain was analyzed under the era of Big Data. Then, combining with the actual situation, one investment model in the environment of information asymmetry and three models in the situation of information symmetry were proposed considering the Data Company, and then the investment decision-making conditions were analyzed. Finally, it was also proved that the revenue sharing contract could make the three-stage book supply chain coordinate. This research is a new development of investment decision-making theory of book supply chain. It offers a theoretical guidance for Data Company investing in Big Data technology and book publisher investing in consumer preference information. In practice, if Data Company wants to get more benefits, it should extract the value of data fully to improve the conversion value of data. For the book publisher, it should also use the consumer preference information fully to produce the books needed by consumers. In addition, the decision makers can use the revenue sharing contract to coordinate the book supply chain and then gain more benefits.

8.3. Future Research. This paper only studies a three-stage book supply chain system with one book publisher, one Data Company, and one retailer. In fact, a book supply chain system is very complex, and there are double channel and multichannel book supply chains. Moreover, in a book supply chain system, it contains author, book publisher, book retailer, or third party logistics; however, in this paper, only the relationships among book publisher, Data Company, and retailer are discussed. In addition, book supply chain members are assumed to be risk-neutral.

In the future, the investment decision-making and coordination policies of a book supply chain should be studied with a multichannel book supply chain or a multistage book supply chain in the Big Data environment. In addition, next, a three-stage book supply chain with members having risk appetite should be discussed. We can also explore the related questions in different competitive environments.

Appendix

Proof. Based on formula (13), we can get $\partial p^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})/8 > 0, \partial w^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})/4 > 0$, and $\partial p_b^{DM*}/\partial\theta = (c_b - c - c_d - c_{vd})/2$. The positive and negative of $\partial p_b^{DM*}/\partial\theta$. According to formula (14), we get that $\partial\pi_r^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})[c_{ib} - \alpha^{DM} + c_r + c_{vr} + \theta(c + c_b + c_d + c_{vd})]/32\alpha^{DM}$, $\partial\pi_d^{DM*}/\partial\theta = (c + c_b + c_d + c_{vd})[c_{ib} - \alpha^{DM} + c_r + c_{vr} + \theta(c + c_b + c_d + c_{vd})]/16\alpha^{DM}$, and $\partial\pi_b^{DM*}/\partial\theta = \beta(c+c_b+c_d+c_{vd})[c_{ib}-\alpha^{DM}+c_r+c_{vr}+\theta(c+c_b+c_d+c_{vd})]/8\alpha^{DM}$. Because Q^{DM*} should be bigger that zero, thus, $\partial\pi_r^{DM*}/\partial\theta < 0, \partial\pi_d^{DM*}/\partial\theta < 0$, and $\partial\pi_b^{DM*}/\partial\theta < 0$. Therefore, Property 4 was confirmed. □

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Authors' Contributions

Pan Liu conceived and designed the experiments and performed the experiments; Pan Liu analyzed the data and wrote the paper.

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