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A Study on the Collaborative Inventory Management of Big Data Supply Chain : Case of China's Beer Industry

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[Abstract]

The development history of China's big data is relatively short, and it has only been ten years so far. Although the application level of big data in real life is not high, some achievements have been made in the supply chain. Various kinds of data will be generated in the actual operation of the supply chain. If these data can be effectively classified and used, the "bullwhip effect" of the operation of the supply chain can be also effectively improved. Thus this paper proposes the development of a supply chain collaborative inventory management model and application framework using big data. In this study, we analyzed the supply chain of beer industry, which is the most prominent consumption industry with "bullwhip effect", and further established a big data collaborative inventory management model for the supply chain of beer industry based on system dynamics. We used the Vensim software for simulation and sensitivity test and after appling our model, we found that the inventory fluctuations of the participants in the beer industry supply chain became significantly smaller, which verified the effectiveness of the model. Our study can be also applied to the possible problems of the large data supply chain collaborative inventory management model, and gives certain countermeasures and suggestions.

▸ **Key words**: Big data, SCM, Inventory management, System dynamics, Bullwhip effect

[요 약]

중국에서의 빅데이터의 발전 과정은 비교적 짧아 10년 정도에 불과하다. 따라서 실제 생활에서의 구체적인 활용도는 높지 않으나, 공급망분야에서는 일부 성과를 보이고 있다.

공급망이 실제로 작동하는 과정에서 발생하는 각종 데이터를 효과적으로 분류·활용할 수 있다면, 공급망 운영 과정에서 발생하는 '채찍효과' 또한 개선될 수 있을 것이다. 본 연구의 목적은 빅데이터를 활용한 공급망 협업 재고 관리 모델과 응용 프레임워크의 개발이다. 본 연구에서는 "채찍효과"가 가장 뚜렷한 소비 업종인 중국의 맥주 업계 공급 체인을 분석하였으며, 시뮬레이션 및 민감도분석을 위해 Vensim을 사용하였다. 본 연구의 모델을 적용한 결과 맥주 업계 공급 체인의 각 참여 주체의 재고변화가 적어지는 의미 있는 결과를 발견하였다. 또한 이러한 연구가 더 큰 데이터를 갖는 공급망 협업 재고관리모델에도 적용될 수 있는 가능성을 제사하고, 공급망 협업 재고관리모델에서 발생할 수 있는 문제점 및 대응방안을 제시하였다.

▸ **주제어**: 빅데이터, 공급망관리, 재고관리, 채찍효과, 시스템역학

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I. Introduction

The development and research history of big data in China is relatively short, and it is mainly guided by policies and focuses on application. The ease and openness of data acquisition in different industries lead to different penetration rates of big data in different industries, resulting in different application degrees of big data in different industries. The application-oriented approach leads to the lack of a theoretical framework system for big data in academic research. In contrast, there are certain management theories and comprehensive applications for supply chain inventory management.In foreign research theories, Hau Lee was the earliest foundation of the research on supply chain inventory management in 1992, and pointed out that collaborative supply chain was the development trend of supply chain in 1999[1]. Based on Gurnani's study on the supply chain collaboration problem that minimizes the expected total cost under the random output of suppliers, Guer and Bilgic considered the supply chain bulk order collaboration problem under the maximized expected profit of the supply chain. Most foreign scholars study practical problems of supply chain inventory management, but they only explore the factors before and after the results when solving the problems. Chinese scholars are led by Maersk, who mainly studied multi-level inventory management, inventory management and logistics coordination theories on the basis of foreign inventory management research theories. There is also a type of scholars who think that the application of information technology is the main research on supply chain inventory management. Li Rong, Xie Liansheng and others use advanced management ideas such as MRP, JIT, OPT and the integrated ideas between them to assist in the development and production planning and control System etc.

There are few researches on the application of big data in supply chain inventory management. Although some of them involve information technology, they rarely go into the overall view of supply chain. Aiming at the "bullwhip effect[2]" in supply chain inventory management, this article uses big data to classify and share supply chain information based on the theory of supply chain collaborative inventory management, and proposes a supply chain collaborative inventory management model under the background of big data. We studied the industry with the most prominent "bullwhip effect" -- fast consumption industry (beer industry) for analysis, and used system dynamics to build a dynamics model for further analysis, to verify the feasibility of supply chain collaborative inventory management model under the background of big data.

II. Preliminaries

According to the Research Report of China Internet data center survey, by 2020, the global data storage capacity is expected to increase to 40ZB, and the data scale is about 44 times that of 2013, while China's data output is expected to increase from 13% to 25% of the global total data[3]. The inconsistency of the development of big data in various industries and the characteristics of the industry and corporate interests have led to the extremely low application rate of big data in various industries, especially in the supply chain[4]. Inventory is an important factor that affects the overall profit of the supply chain. If there is too much inventory in the supply chain, it will inevitably lead to waste of productivity and increase of management cost. Each entity in the supply chain needs to consume too much resources for management and control. It is worth noting that the Internet of Things represented by the use of RFID in the supply chain to sense inventory will grow from 12 million in 2021 to 209 billion[5]. If each subject can stand in the perspective of the system and cooperate with the inventory in the whole supply chain by combining different data, more profits can be obtained[6].

There is a short point in the analysis of

consumer demand in the supply chain of various industries in China -- the expansion of demand information transmission caused by the avoidance of consumer demand risk at each node of the supply chain[7]. China's existing supply chain still adopts point-to-point and face-to-face node information acquisition as a whole, which inevitably leads to mass production of top-level suppliers and massive accumulation of node inventory due to minor changes in low-level consumption and the "bullwhip effect" Getting worse. There are still many gaps in meeting the ever-expanding personalized needs of users[8-9]. Big data based on Internet data analysis and information sharing will provide management technical support for supply chain inventory and even supply chain operations to solve this problem[10].

The Chinese beer network organized by the China Food Industry Association Beer Professional Committee reported that the total output of beer in China reached 49.2185 million KL in 2014, down 6.01% year-on-year. According to the status of NBS, the total output of beer reached 50.6154 million KL, with a year-on-year growth of 3.25%, which is the second year under 5% and the first year of decline in the last decade. As it show in Figure 1. How to gain profits has become the first consideration of strategic transformation in beer enterprise. The industrial structure promoted to high-grade in succession, which needs the optimization and adjustment of industrial structure and integration planning from the inside purchase of raw material and outside production or even marketing in the beer industry[11].

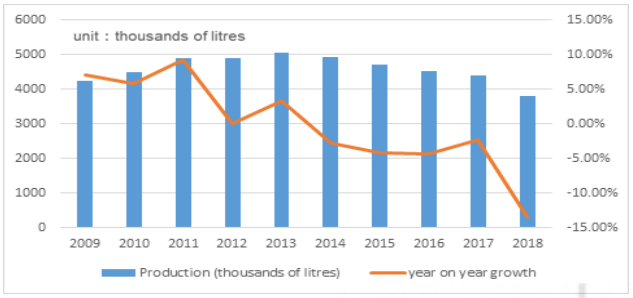

Fig. 1. Output and year-on-year growth in beer industry

III. The Proposed Scheme

3.1 Objectives of model construction

Since the first proposal of "big data", all circles have been continuously exploring it, but there is no unified definition at present. The most widely accepted viewpoint is the "4V" proposed by IBM, namely Volume, Velocity, Variety and Veracity. Based on this, the State Council of China defines big data and puts forward that big data is a data set dominated by these four characteristics. This paper holds that big data is a collection of management and service oriented to the whole life cycle of data from the generation of data to the collection, organization, storage, analysis, display and utilization of data, which is biased to the application of data.

Big data in the supply chain mainly comes from four aspects. One is the relevant data inevitably generated in the process of product value transfer of enterprises in the supply chain, such as production equipment quality data, planned procurement data, product data, etc; On the other hand, it is derived from the ERP data of various companies in the supply chain; The third is e-commerce data from the customer, and the last is data from external or manually entered data. A third-party data service center analysis and mining the data to predict and control the inventory in the process of supply chain operation. It brings innovation and change of management technology and way of thinking to the whole supply chain in many aspects, and finally achieves the goal of coordinated inventory and zero inventory of the whole supply chain[12-13]. The general process of the whole is shown in Figure 2.

3.2 Decision-making model of supply chain inventory management system

Set the overall supply chain demand at the highest node--- producers' greatest demand---by analyzing data based on big data and speculating the real information data, combined with the

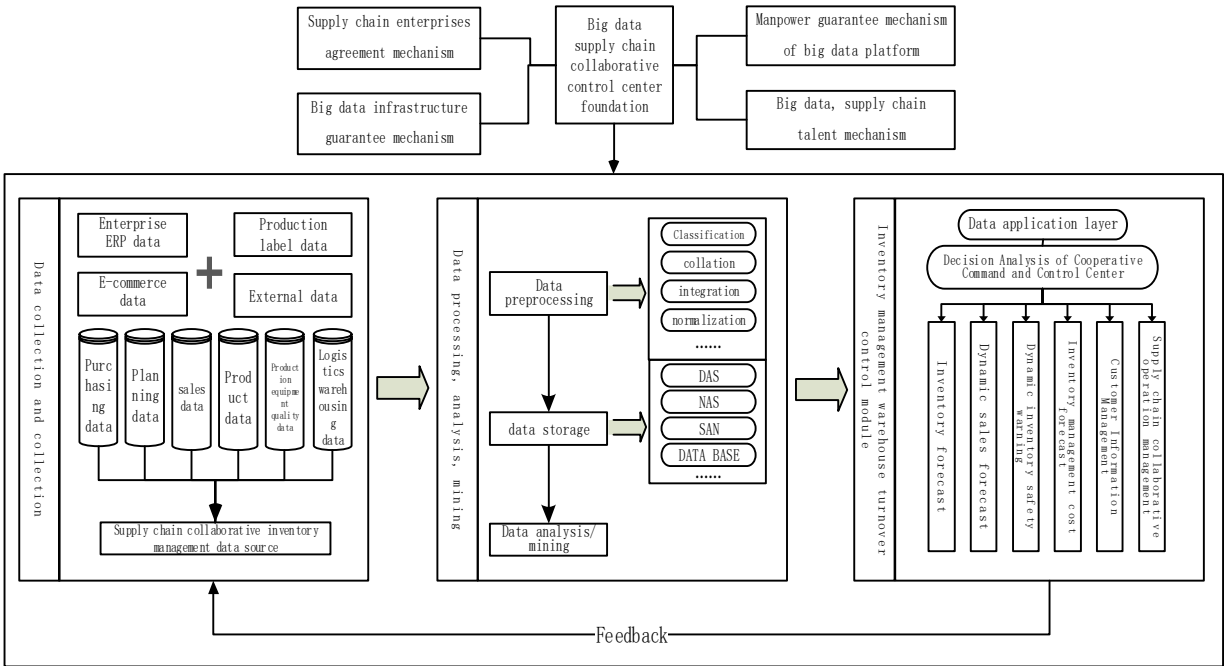

Fig. 2 .Construction of collaborative inventory management model of supply chain under the background of big data

industry market, and then to evaluate the demand of each node in surgical operations[14-15]. Given the range of changes, inventory decision is decided in the demand of oneself circumstance and the lower nodes in the available changes and collaborative platform information. From the above we note that

$$Q_{j1} = \frac{I_{ej} - I_j}{T_a} + N_k \qquad (1)$$

One function need to be explained:

SMOOTH() function is SMOOTH({in},{stime}). This function simulates the information delay effect and delays the input value. Its internal operating principle is equivalent to SMOTH=INTEG((input -smoth)/delay time, input).

Among them: Q_{j1} is order quantity for the j cycle; I_{ej} represents expectation inventory of logistics units for the j cycle, I_{ej} = smooth (N, t_e) as the smoothing function, N is the demand of downstream unit, t_e is smooth time; I_j is the current inventory of logistics units for the j cycle, 0 represents the shortage of inventory; T_a is inventory adjustment time of logistics units, namely, the cycle numbers that enterprise strives to adjust inventory for expected inventory; N_k stands for consumer demand of platform prediction.

3.3 Collaborative Inventory Management of Big Data Supply Chain in Beer Industry Based on System Dynamics

The supply chain collaborative inventory management model in the context of big data proposed in this article is mainly to solve the "bullwhip effect" caused by information asymmetry in China's supply chain inventory management mentioned in the previous article, which causes the inventory of each participant in the supply chain A large backlog and a waste of resources in the overall supply chain. The article chooses the most representative fast-moving consumer goods industry with the "bullwhip effect"—the beer industry as an example to construct and analyze the later model. The model conforms to the ordering characteristics of most Chinese consumer industries. In order to simplify the model, the author mainly sets three supply chain units: manufacturers, wholesalers and retailer[16]. A statistical prediction unit based on collaborative big data logistics and its direct relationship of each link is: in the whole supply chain, collaborative data platform units based on big data is directly

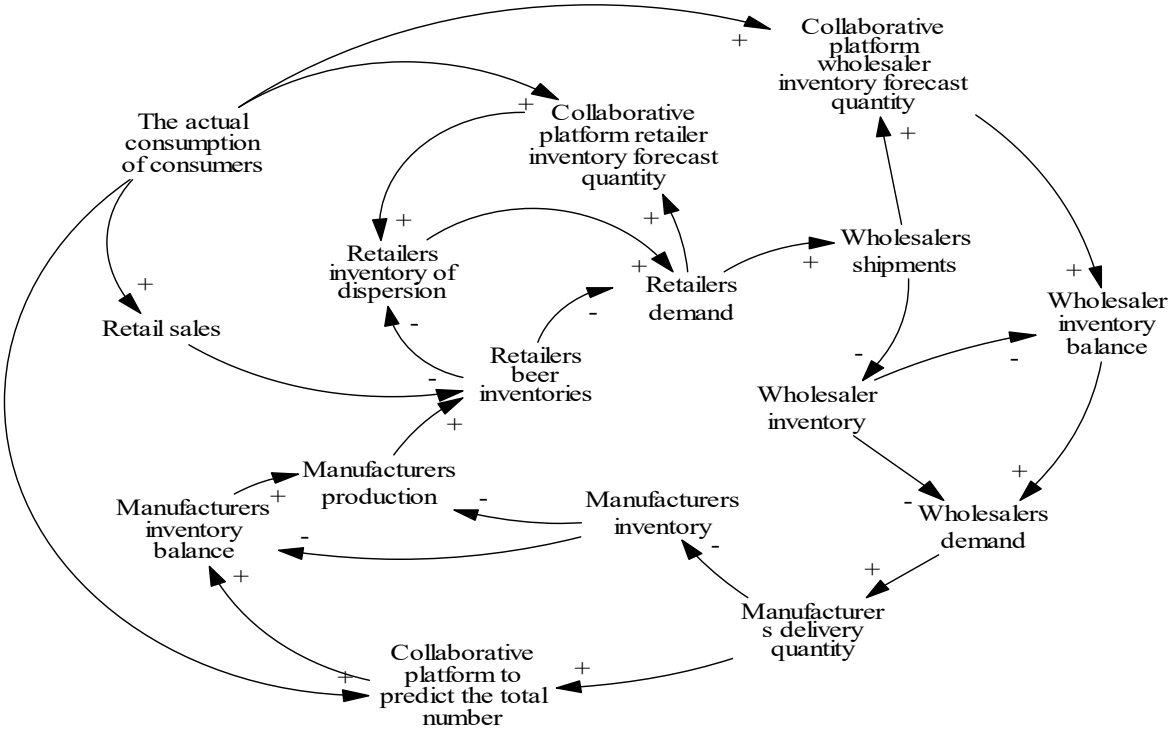

Fig. 3. the cause-and-effect graph of beer industry supply chain based on big data

influenced by past consumption data to predict product[17], manufacturers' production capacity and distribution transport capacity are affected by information flow provided by collaborative platform, and at the same time, actual information demand by beer wholesalers and retailers is the gist for producers to adjust and improve. By the same token, the wholesalers zero bound inventory is also affected by collaborative platform information flow. Retailer's inventory is also affected by the actual consumption. Each prediction unit on collaborative platform is affected by consumer information to different extent at the same time, according to the relationship of each link, drawing the cause-and-effect graph of beer industry supply chain based on big data as Figure 3 show:

According to the above cause-and-effect diagram, we can further get the system dynamics figure of beer industry collaborative supply chain based on big data, And simplify part of the simulation to make the model more compliant with specific operating conditions, we performed the following hypothesis:

(1) The basic conditions of management operation are to meet the maximum consumer demand of all nodes for the premise, at the same time, synthesize own situation to make a decision.

(2) In a certain stage of consumer demand, consumer demand will not have too much change, assuming that the consumer demand is a step function and can present a quarterly changes.

(3) Make use of the collaborative supply chain management of e-business for accurate judgment of the needs of the consumers to meet the needs of predictable demand. The amount of time is almost negligible. Each node in the supply chain in the actual production, outbound and distribution of existing gap time is zero. Production, outbound, ordering and delivery speed of all nodes are infinite.

(4) Uncontrollable risks exist in the operation of the system, which will lead to small variance between the actual consumption data and the predicted data, and cause the ordering behavior of members of the sales entity. Meanwhile, the inventory difference will be reported to the collaborative platform, which will inform the manufacturer of the specific difference for production and distribution.The collaborative platform did not make such a prediction in advance

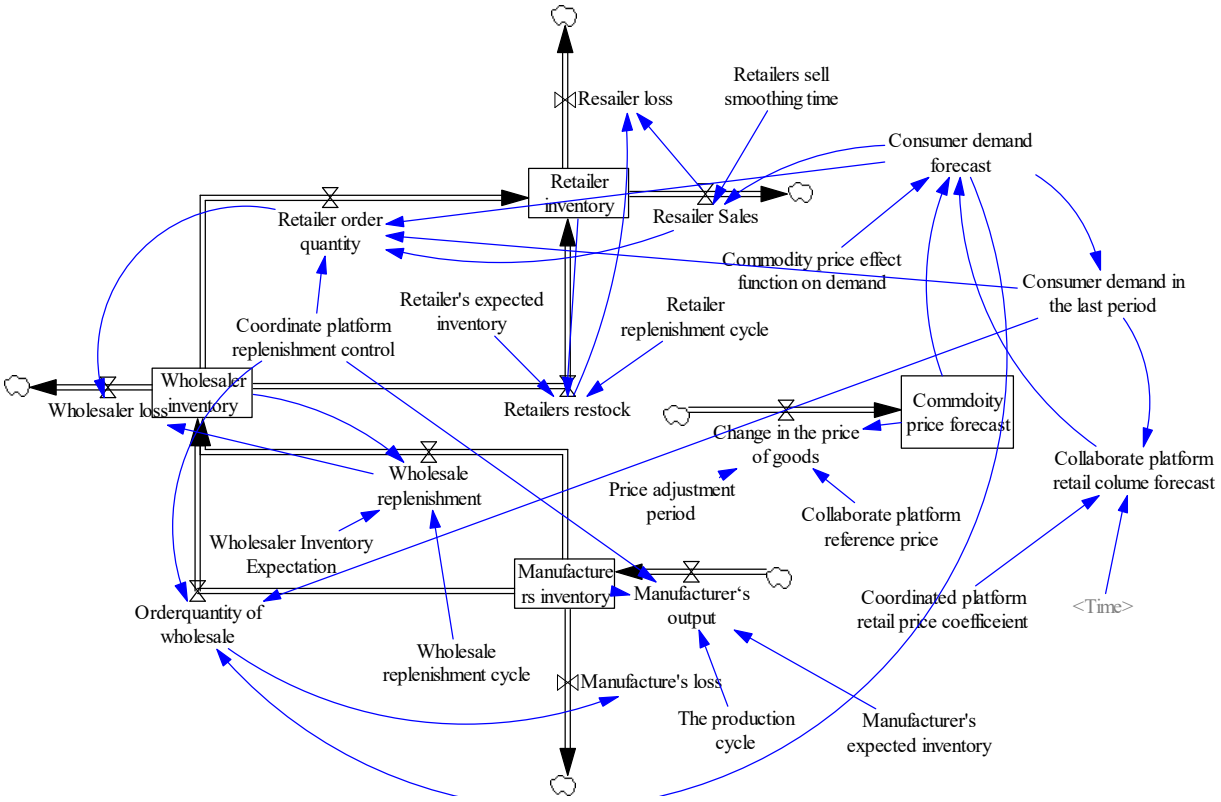

Fig. 4. Dynamic flowchart of collaborative inventory management system for beer industry supply chain based on big data

before, and the supply chain needs a certain amount of time for demand response, which is the time for inventory control of the logistics unit.

(5) sales activities generally consists of four types of entities in the supply chain members, manufacturers, suppliers, retailers and consumer groups, we assume that all members of the entity does not exist between uncontrolled factors produced by the mutual transfer the inventory, at the same time, all the members of the entity relationship rules are as follows: manufacturers, suppliers and retailers to the quantity of beer comes from two aspects, on the one hand for the unpredictable situation appeared in the process of actual operation of supply chain, which occurred from prediction of expected stock inventory difference when taking orders, on the other hand from the collaborative platform to provide prediction of consumer spending data.

(6) in this paper, the process of collaborative inventory management system is studied for highlight the data analysis and forecasting ability of the collaborative platform, the platform system based on previous sales/production data to forecast monk and guide consumers, retailers, suppliers/wholesale manufacturers demand/production each member entities such as production orders, but in the process of system simulation, can't fully reflect the forecast analysis of complex data mining process. In this paper, through the research on the data of beer production and consumers in the beer industry, it was found that they have certain linear characteristics, so the linear function was adopted for the prediction value.

In order to distinguish the effects of collaborative management and non-cooperative management on the supply chain inventory management control, the dynamics flowchart of the collaborative supply chain inventory management system[18-19] (Figure 4), The main function used in this paper are:

If THE ELSE() function is generally expressed as IF THE ELSE(a,b.c), meaning that THE value of this function is b IF THE variable conforms to a, otherwise it is c. In this paper, to distinguish whether

to adopt collaborative management mechanism, this function is used for the order quantity of the retailer, the order quantity of the wholesaler and the production quantity of the manufacturer.

The basic setup of the model and its equations in table 1:

Table 1. Equations

name	Equations
Retailer order quantity (Rq)	=IF THEN ELSE (collaborative platform replenishment control =1,IF THEN ELSE(consumer demand forecast >Consumer Demand of Last Period, Consumer demand forecast *1.1,0), retailer Sales *1.2)
Wholesaler order quantity (Wq)	=IF THEN ELSE (collaborative platform replenishment control =1,IF THEN ELSE(consumer demand forecast >Consumer demand of last period, forecast of consumer demand *1.1,0), order quantity of retailers *1.2)
Manufacturer production(Mp)	=IF THEN ELSE(collaborative platform replenishment control =1,IF THEN ELSE(manufacturer expected inventory >Manufacturer's inventory,(manufacturer's expected inventory - manufacturer's inventory)/ production cycle,0), wholesaler's order quantity *1.2)

In the variable name Rq, Wq and Mp are short for Retailer order quantity、Wholesaler order quantity and Manufacturer production, the replenishment control under collaborative management adopts 1, otherwise it is 0, which is the traditional management method. The values 1.1 and 1.2 in the equation are from the approximate values used in the production operation of GZ Yanjing(China) Brewery to simplify the analysis.

The decision function of traditional management is as follows:

$$Q_{j2} = \frac{I_{ej} - I_j}{T_a} + N_a \qquad (2)$$

What's different from Formula (1) is that the N_a is the quantity demanded for downstream units in Formula (2). But N_k stands for consumer demand of platform prediction in Formula (1).

IV. Simulation

Combined with the dynamics model of supply chain inventory management system based on big data, we use Formula (1) and Formula (2) adopted for the three functions Rq, Wq and Mp respectively and use Vensim to simulate and analyze them. Examples of specific formula application (taking wholesaler order zero as an example in table 2):

Table 2. How to use Formula(1) and (2)

name	platform control	Equations
Wholesaler order quantity	=1	=IF THEN ELSE (collaborative platform replenishment control =1,IF THEN ELSE(consumer demand forecast >Consumer demand of last period, forecast of consumer demand *1.1,0), order quantity of retailers *1.2) Forecast of consumer demand =Q_{j1}*Commodity price effect function on demand
	=0	=IF THEN ELSE (collaborative platform replenishment control =1,IF THEN ELSE(consumer demand forecast >Consumer demand of last period, forecast of consumer demand *1.1,0), order quantity of retailers *1.2) Order quantity of retailers=Q_{j2}

It should be noted that, for the order quantity of different subjects, although formulas (1) and (2) are used, the internal objects used by I_{ej} and I_j are different, which ensures that the final equations of different objects are also different. We use the 0 and 1 of the platform control to control whether the model needs to be controlled by the platform. For comparison and analysis, it should be noted that if the parameters of the platform control are set to 0, additional adjustments to the original dynamic flow diagram are required For example, it is necessary to reconsider the retailer's zero order into the wholesaler's order quantity and reflect it in the formula of Q_{j2}.

We used the production and operation data of GZ Yanjing Beer Company (China) and used vensim 8.1.0 software for model analysis. And then we have the inventory of each logistics unit in the

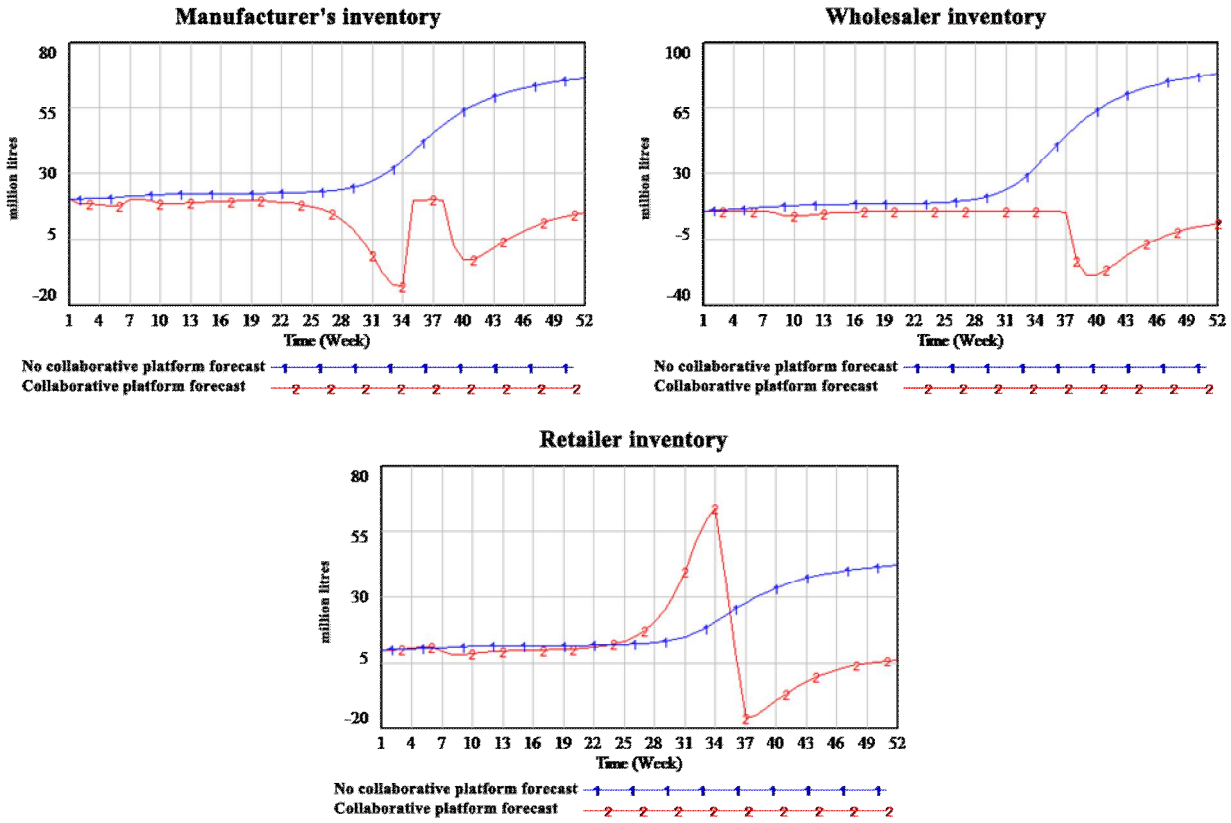

Fig. 5. Inventory

supply chain is simulated as it shown in Figure 5:

From the simulation of using collaborative management (Figure 5), the system-related variables such as replenishment quantity, order quantity, replenishment quantity and wastage of retailers all experienced a sudden increase, while wholesalers and manufacturers increased almost at the same time, and the increase range was nearly the same. The simultaneous occurrence is due to the adoption of collaborative management control and the accurate transmission of demand information to each node of the supply chain through the collaborative platform without any information delay. The reason for the consistent increase is that the collaborative platform accurately transmits the demand information to each segment of the supply chain, ensuring that the information is not expanded or distorted during the transmission process within the supply chain.

It can be found that the overall predictive management control with collaborative platform is lower than that without collaborative platform from the simulation results. The inventory of each node has an increasing trend in the absence of the traditional management strategy of collaborative management, which indicates that the use of collaborative inventory management control of supply chain is effective for the beer industry and can effectively inhibit the generation of bullwhip benefit.

The simulated fluctuations of retailers, wholesalers, and manufacturers adopting the supply chain collaborative inventory control system are relatively large because the collaborative platform predicts the inventory at each node of the supply chain. The collaborative platform provides the expected inventory. When the expected inventory is lower than the expected inventory, an ordering activity will take place, and when the expected inventory is higher, the ordering activity will not be taken. At the same time, we found that the expectation of inventory fluctuation is zero. In

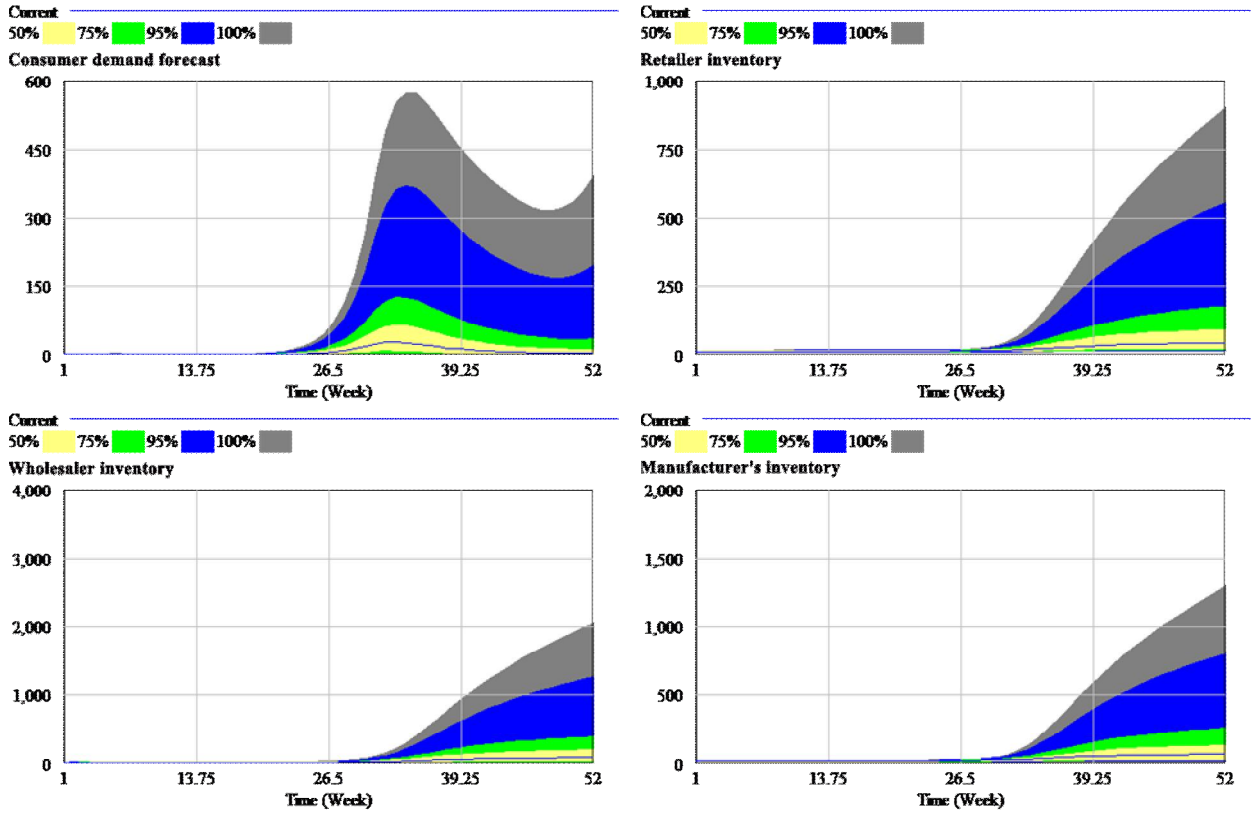

Fig. 6. Sensitivity analysis

the long-term simulation, the inventory fluctuates above and below the expected inventory, but the fluctuation range tends to be stable.

We analyzed the rationality of the model : It is assumed that the reference price of the collaborative platform obeys the uniform distribution of U(5,7), the wholesaler's inventory obeys the uniform distribution of U(5,20), the retailer's expected inventory obeys the uniform distribution of U(5,20), and the manufacturer's expected inventory obeys the uniform distribution of U(10,30)[20].

The demand forecast and the sensitivity analysis of each inventory are done, and the analysis results are in Figure 6

It can be found from Fig. 6 that the demand forecast and each inventory are significantly affected by the parameters which indicating that the model is reasonable and conforms to the actual operation of the system.

V. Conclusions and Suggestions

From the simulation results, under the collaborative platform of big data based on coordination of the beer industry to mobilize the supply chain operation condition, supply chain direct logistics inventory are in a relatively stable value, and there is no zero inventory or even a serious lack of beer in the stock situations like traditional beer supply chain operation, which avoid the situation of demand information expansion caused by chain inventory levels report because of the serious lack of supply. In the whole supply chain, it avoid small changes of consumers demands causing the change of the logistics inventory from the bottom to top, which directly affect the overall operation of supply chain. Accurate production and management and improving the operation efficiency of the supply chain of beer, avoid the bullwhip effects due to the expansion in demand information transfer process.

There are some Possible problems in model

implementation

First、it is difficult to build a large data collaborative control inventory management center

The establishment of the platform requires investment in several aspects, including the collection, processing and analysis of supply chain operation data, and the application of specific collaborative inventory management[21]. Although it can increase profits, it is difficult to deal with the cost allocation problems resulting from this, which makes it difficult to determine the ownership of the construction

Second、 the awareness of big data collaboration is relatively shallow, and the depth of big data application is not enough

Each node in the supply chain is required to have a sense of collaboration, and also realize the symmetry of supply chain data information[22-23]. The management concept needs to stand in the perspective of overall system collaboration and effectively application of big data. At present, each node enterprise in the supply chain still communicates through methods outside the system. According to the China Internet development statistics report 43 times data and large data of peak BBS in China in 2018, China's big data market is expected annual compound growth rate will reach 17.3%, but the application field are mainly concentrated in the financial and government affairs two areas, most of the industries exist only data collection and standardized, big data in the application of supply chain is almost zero, the basic data acquisition is difficult.

Third、it is difficult to implement the collaborative inventory management feedback mechanism in the model

In the context of big data, although the modern supply chain management mechanism has matching supporting services, it is still in the initial stage of exploration, and the source points of feedback mostly belong to the policy guide[24]. Reverse supply chain system is far from meeting the requirements of collaborative inventory management of big data supply chain. Moreover, most enterprises in China do not have the corresponding enterprise resource planning system (ERP) and customer relationship management system (CRM), so the construction of feedback mechanism is more difficult.

Fourth、there is a serious shortage of supply chain management and big data compound talents

It has only been less than ten years since the establishment of China's big data platform. In the past two years, Chinese universities have started to train big data-related talents, and it takes time for compound talents to be cultivated[25]. In addition, the global big data-related job entry rate Less than 30% makes the talent problem more prominent.

There are some Suggestions for supply chain collaborative inventory management countermeasures under the background of applying big data

First、Strengthen government guidance and deepen the application of big data supply chain inventory management

It can be seen that the application penetration of big data in China's industry is extremely uneven, and the application of big data to supply chain collaborative inventory management needs to be strengthened. However, due to the cost reverse supply chain cost in the feedback mechanism, the government needs to conduct policy guidance and regulation, so as to provide a good development of supply chain operation inventory management[26].

Second、Actively promote first-party data services to improve the synergy effect of supply chain inventory management

In order to coordinate the development of supply chain operation inventory big data system transformation and data service, the strategic objectives should be consistent at first[27]. Only through the cooperation of both sides can the benefits of big data in supply chain inventory management be maximized to the greatest extent. Second, for data service providers, whether to have data sources can be divided into the first and third data service, should actively promote comfortable

business into a professional industry general technology application in the field of the first or the third data service, into industry applications, specialized in providing data services to become the first data service platform, realize information docking collaborative supply chain inventory management system[28-29].

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