Theoretical framework of agricultural precision management based on the smart supply chain: Evidence from China

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Abstract: Agricultural precision management (APM) is based on the smart supply chain (SSC) and uses relevant smart technologies to realize the smart operation of the entire life cycle of agricultural products. However, theoretical frameworks for APM to guide its practice are lacking. This study adopts the inductive multi-case study method, taking four agricultural companies from China as the research object to investigate the current situation of APM based on SSC. Through interviews and critical analysis, this study proposes a theoretical framework for APM. First, we obtain the factors influencing APM capabilities based on SSC. Second, the relationship between APM capabilities and performance is expounded. Finally, we analyze the role of agricultural policies and the rapid response of agricultural supply chains as moderators. This study provides a new theoretical reference for APM research and an important management perspective for related companies to implement APM.

Keywords: Smart supply chain; Agricultural precision management; Precision management capability; Performance; Inductive multi-case study

1. Introduction

With the rapid development of smart technology and e-commerce, the consensus in the industry has been to accelerate the adjustment of the agricultural industrial structure and realize the transformation of the industry to a precision mode. In the actual operation process of agricultural companies, an increasing number of managers have begun to emphasize agricultural precision management (APM) at the tactical level. APM refers to the management and operation modes that use information technology as support. The timing, positioning, and quantification of agricultural production links and the predictability, visualization, and traceability of circulation links are used to realize the precision management of each link in the agricultural supply chain and the efficient utilization of various agricultural resources (Lindblom et al., 2017; Li et al., 2019). Studies have shown that the implementation of APM not only improves agricultural productivity but is also an effective way to achieve sustainable development of agriculture with high-quality, high-yield, low-consumption, and environmental protection (Kendall et al., 2017). Moreover, APM plays an active role in addressing food quality and safety issues (Brown et al., 2016).

With the rapid development of the smart supply chain (SSC), APM pays more attention to the use of new smart technology to realize the precise operation of agricultural products

throughout the life cycle. Smart supply chain refers to the theory and method of combining the Internet of Things (IoT) technology and modern supply chain management. It is an integrated system of technology and management that realizes the intelligence, networking, and automation of the supply chain (Kamble et al., 2020), which implies higher requirements for the development of APM. On the one hand, it is necessary to focus on the optimal ratio of input and output in the "upstream" production link and to obtain the maximum economic benefits while minimizing the impact on the ecological environment. On the other hand, enterprises should also pay attention to the accurate positioning and personalized service of "downstream" sales links (Grimm et al., 2014; Miranda and Azzaro, 2017). As a condition to achieve APM, APM capability can directly affect the efficiency of agricultural activities as it is linked to practice and measures the degree of management (Saguy et al., 2013; Mohsin et al., 2018). Therefore, on the basis of SSC, improving APM capability from the four aspects of procurement, production, sales, and supply chain coordination is necessary to improve the APM performance of enterprises. In other words, it is necessary to build an APM capability system based on four aspects: agricultural material precision purchasing, agricultural precision production, agricultural product precision sales, and agricultural supply chain coordination.

In addition, compared with other industries, on the one hand, agriculture is greatly affected by policies in many countries; therefore, the support of incentive agricultural policies will stimulate agricultural development, which will have a profound impact on the speed of APM development. However, the characteristics of agricultural products, such as regionality and perishability, also differ from those of ordinary manufacturing enterprises. This indicates that a rapid response must be adopted during the operation of the entire agricultural supply chain. Therefore, APM based on SSC has become the direction of transformation and upgrading of the agricultural industry.

In the existing theoretical research, the previous literature has focused on improving APM capability only from the development of agricultural precision production or precision sales. In terms of agricultural precision production, some scholars have explored the impact of the application of smart technology (Kamble et al., 2018) and the implementation of national policies (Huang and Yang, 2017) on increasing the output of agricultural products, reducing production costs, and mitigating environmental pollution. In terms of precision sales of agricultural products, most scholars have focused on the prediction and sales of agricultural products with the help of smart technology and e-commerce platforms (Wang and Yue, 2017), as well as the application of technologies such as the IoT and blockchain in cold chain logistics and agricultural product traceability (Jill and Hobbs, 2016; Liu et al., 2020). However, the

realization of APM is inseparable from the coordination of the upstream and downstream channels of the agricultural supply chain and the breakthrough of smart technology. It is obviously inadequate to consider APM only from the production or sales nodes of the supply chain. At present, limited literature exists on precision management of the entire agricultural chain based on SSC. The previous literature has indicated that relevant research on APM performance is an important factor in measuring APM. First, most studies have shown that smart technologies, such as the IoT, big data, and blockchain, can improve agricultural precision production and precision sales capabilities, thereby affecting APM performance (Li and Chung, 2015; Yan et al., 2015). Second, the seasonality, periodicity, and volatility of agricultural production also has a certain impact on APM capability (Huang et al., 2019), which in turn affects APM performance. However, the research that explores the factors influencing APM and the relationship between APM capability and APM performance through empirical research methods is inadequate. Further, little research has been conducted on building a systematic and complete theoretical framework to guide business practices, which has caused certain obstacles to the APM of enterprises. Therefore, it is necessary to construct a theoretical framework for APM based on SSC to guide practice.

Exploratory research is critical for filling this research gap. This study focuses on two important issues:

RQ1: What are the influencing factors of APM capability based on SSC?

RQ2: What is the relationship between APM capability and APM performance? What factors can be effectively adjusted between APM capability and APM performance?

Based on first-hand interview data from four Chinese agricultural companies, this research conducted an inductive multi-case study. By comparing and analyzing multiple cases, we determine the influencing mechanisms of relevant factors and propose a theoretical framework of APM based on SSC.

Our study draws some interesting conclusions. First, for RQ1, we determine the factors influencing APM capability: the characteristics of agricultural products have a negative impact on the improvement of APM capability, and the agricultural sales service platform and the application level of smart technology have a positive impact on APM capability. Second, for RQ2, we clarify the relationship between APM capability and APM performance: agricultural materials precision purchasing capability, agricultural precision production capability, agricultural products precision sales capability, and agricultural supply chain coordination

capability are all conducive to improving companies' APM performance, and APM capability has a positive impact on the economic, environmental, and social performance of APM. Finally, our study finds that both incentive agricultural policies and the supply chain's rapid response have positive moderating effects.

The main contributions of this study are twofold. From a theoretical perspective, unlike most previous studies, which conducted research starting from agricultural precision production (Kamble et al., 2018; Wang and Yue, 2017), this study builds an APM capability system including agricultural materials precision purchasing, agricultural precision production, agricultural products precision sales, and agricultural supply chain coordination from the perspective of SSC. It can provide a new theoretical reference for research on APM. Unlike previous studies, only the economic performance of APM is used to study the impact of implementing APM (Huang et al., 2019). From a sustainability perspective, this study proposes that the improvement of APM capability has a positive impact on economic, environmental, and social performance. Finally, based on first-hand interview data of four agricultural companies in China, this study proposes a theoretical framework for APM based on SSC through a comparative analysis of multiple cases, which compensates for this defect. From a practical viewpoint, this study provides an important management perspective for related companies to implement APM. The research shows that in the process of implementing APM, managers should fully consider the influence of seasonal, regional, and price fluctuations on agricultural products. Simultaneously, the active application of smart technology and agricultural sales service platforms can improve agricultural materials precision purchasing, agricultural precision production, agricultural products precision sales, and agricultural supply chain coordination capabilities. Actively understanding the relevant agricultural policies and improving the response speed of the agricultural supply chain have important regulatory effects on the improvement of APM capability and APM performance.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 describes the selection of research methods and cases. Section 4 presents the inductive, multi-case analysis process, including collating interview results and proposing and verifying the study hypotheses. Section 5 proposes and discusses the theoretical framework of APM based on SSC. The conclusions and management implications, limitations, and future research directions are presented in Section 6.

2. Literature review

To prove that the research findings and research framework of this research have not been systematically studied in recent literature, this study referred to Jia et al. (2018) and conducted a keyword search in the Web of Science (WoS) database, which has many publications and is

known for its comprehensive coverage of high-impact journals (Chadegani et al., 2013). We searched for papers published between 2010 and 2021 using the following keywords: 'APM,' 'APM capability,' 'APM performance,' 'precision agriculture,' and 'precision farming.'

First, we ensured that all chosen papers were related to the APM research field, and we selected 317 papers by searching. Second, we read the abstracts, keywords, and research scope of the selected papers and filtered out those that were not related to the content of this research, such as the construction of APM information systems, the application of smart technology in APM, and the future development trend of precision agriculture. Finally, by reading the articles' contents, a summary review of 65 articles that were closely related to APM and the influencing factors of APM performance was conducted. Table 1 lists the detailed classification of the 65 selected articles. The papers presented in each category are not necessarily mutually exclusive.

The research questions were based on SSC, including the factors influencing APM capability, the relationship between APM capability and APM performance, and the influence of the adjustment factors. Related research has been reviewed along two lines: APM capability and APM performance.

2.1 APM capability

In recent years, most research on APM capability has started from two aspects: agricultural precision production capabilities and agricultural precision sales capabilities. With regard to agricultural precision production capabilities, most studies have shown that smart technologies, such as the IoT, GPS, GIS, and remote sensing can remotely produce data, achieve standardized planting and precise fertilization (Shepherd et al., 2018; Li and Chung, 2015) and improve agricultural precision production capabilities. In addition, studies have shown that the characteristics of the agricultural industry, such as the seasonality and periodicity of agricultural production, have a certain impact on agricultural precision production capabilities (Huang et al., 2019).

Second, in terms of agricultural precision sales capability, the existing research has proven that smart technologies such as RFID, big data, and blockchain can achieve precise positioning in the sales, circulation, and traceability of agricultural products (Yan et al., 2015; Bjornberg et al., 2015), thereby enhancing agricultural precision sales capabilities.

Currently, an increasing number of companies are selling agricultural products through agricultural sales service platforms. On one hand, this reduces the negative impact of agricultural products' perishability and regional characteristics on APM (Wedel and Kannan, 2016); on the other hand, consumers' purchasing habits and behaviors are analyzed through platform pre-sales and other forms (O'Hara and Low, 2020), thereby effectively improving agricultural precision sales capabilities.

2.2 APM performance

APM performance refers to the degree of precision management of each link in the agricultural supply chain under certain resources, conditions, and environments. This is the measurement and feedback of the efficiency of precision management goals (Liu et al., 2018; Yazdinejad et al., 2021). At present, the relevant research on APM performance is mainly being conducted from the following aspects. First, some scholars have found that the improvement in agricultural precision production capability has a positive effect on improving enterprise production efficiency, controlling food security, reducing labor input, and reducing environmental pollution (Talebpour et al., 2015; Brown et al., 2016). That is, agricultural precision production capability has a positive impact on promoting economic, environmental, and social performance under APM. Second, some studies have shown that the improvement of agricultural precision sales capabilities can help agricultural enterprises achieve product and service positioning and formulate marketing strategies, thereby improving economic performance (Jill and Hobbs, 2016; Wang and Yue, 2017). Finally, some scholars are concerned about the impact of agricultural supply chain coordination capability on APM performance. They believe that only by realizing a seamless connection between the upstream and downstream of the agricultural industry and the full cycle of product production can the visibility and traceability of the agricultural supply chain be improved, thereby improving APM performance (Despoudi et al., 2020).

2.3 Literature summary

The review of the existing research in the above two aspects suggests that current research results exist on APM capability and its influencing factors and on APM performance in different aspects.

Considering the results of previous studies on APM capability and its influencing factors, it can be found that most of the research has been conducted from the two aspects of agricultural precision production capability and agricultural precision sales capability, and few studies have focused on the precision management of the entire agricultural supply chain. In addition, no studies have focused on the impact of agricultural material precision purchasing capability and the improvement of agricultural supply chain capability on the entire chain of APM, and no articles exist on the construction of a complete APM capability system from the perspective of SSC. In addition, although the current research focuses more on the factors influencing APM capability, no systematic study has been conducted on how different influencing factors affect APM capability in different types of companies.

Current research on APM performance still focuses on the impact of improving precision capabilities in a certain link of the agricultural supply chain on performance, but no study has

discussed the relationship between APM capability and APM performance from the perspective of the entire SSC. In addition, no studies have explored the influence of moderating factors on APM performance, and no research has developed a systematic and complete theoretical framework to explore the influencing factors of APM capability and the relationship between APM capability and APM performance.

Table 1 summarizes the comparison of this study with the relevant literature. To fill this research gap, this paper conducted a relevant study on APM based on SSC to construct a theoretical framework that covers the influencing factors of APM capacity and APM performance as well as the influence of incentive agricultural policy and supply chain rapid response as moderating factors on APM capacity and performance.

[Table 1 near here]

3. Research method and case description

3.1 Research methods

An inductive multi-case study can be used to achieve different goals, including providing descriptions, testing theories, and constructing theories (Eisenhardt, 1989; Yin, 1994). Constructing theories from inductive multi-case studies can generate novel theoretical frameworks, and because theories are derived from actual data and are closely linked to evidence, they also have empirical validity. Based on these advantages, inductive multi-case studies have become an important research method in empirical research, and many scholars have conducted interesting studies using this method (Zhu et al., 2020). For example, Eisenhardt and Graebner (2007) and Graebner et al. (2010) use inductive multi-case studies to construct theoretical frameworks.

With reference to the abovementioned literature, this study aims to use inductive multi-case study methods to explore the influencing factors of APM capability, the relationship between APM capability and APM performance, and the influence of moderating factors. Based on this, a corresponding theoretical framework is established.

3.2 Case selection and description

This study selected Chinese agricultural enterprises for research for two main reasons. On the one hand, with the continuous progress and development of information technology, as a major agricultural country, China has made rapid progress in promoting agricultural structural reform in recent years and has had a steady development momentum. Scholars have begun to increasingly focus on the practice of APM in China (Wang et al., 2013). However, innovation has brought enormous changes to various industries, and the agricultural industry is no

exception. Many agricultural companies and e-commerce platforms in China are actively exploring agricultural precision production and agricultural products precision sales, which makes China's agricultural boom unprecedented and significant (Huang and Yang, 2017). Furthermore, many typical cases of APM have emerged. Therefore, selecting corresponding case companies from China was suitable for conducting a case study in this research.

The members of the research team consulted the website information of several companies and selected 51 companies with APM practices in different fields from the top 500 leading companies in the agricultural industry in 2020. They contacted the leaders of these companies by telephone and email and learned about their willingness to be interviewed; ultimately, 37 companies were identified. The selection standards for our case study enterprises were as follows:

(1) The selected case companies should have at least 5 years of agricultural development experience and clear APM-related construction in the past 3 years.

(2) The selected case companies should have certain differences in the characteristics of enterprise scale, enterprise positioning, business field, and service scope so that the conclusions obtained by comparison are more valuable and universal.

(3) Considering the core definition of APM, relevant information, such as the smart technology adopted by the companies and the organizational environment it faces, is available and true.

According to the above standards, this study selected 11 companies that have developed well in APM. On this basis, the team considered that it needed to start from the perspective of SSC and selects companies in different agricultural chain links as case companies to establish a complete theoretical framework for APM based on SSC. Therefore, this study selected the most representative four companies for interviews and investigations. For confidentiality, we named them A, B, C, and D. Companies were divided into two categories: A and D mainly focus on the cultivation of agricultural products at the front end of the agricultural supply chain (divided by primary agricultural products; A is a grain planting company, and D is a vegetable planting company). B and C are mainly based on the processing and manufacturing of agricultural products in the agricultural supply chain (divided by storage age; B is a dairy product processing enterprise, and C is a food crop processing enterprise).

3.3 Data sources

This study conducted interviews with senior managers (including CEOs and their direct subordinates) of four companies that implemented APM. Similar to a typical inductive study, it initially constructed each case through interview transcripts, telephone tracking, and file data. Telephone tracking is a form of re-interviewing for unclear answers or additional questions. As

shown in Table 3, file data refers to the basic information collected about the company, which includes the founding, size, position, business field, and service scope of the company. The data collection process included the following stages:

(1) Design research drafts, outlines, and initial interviews with company managers. Prior to the initial interview, the research team members retrieved previous research results related to this study and designed a case study draft. By understanding the actual situation of the investigated companies, a corresponding research outline was drawn. Initial interviews with company managers were conducted to help them understand the purpose of this study, so that they could more accurately combine the actual situation of the company, feedback, and the necessary information for this study.

(2) Conduct in-depth, semi-structured interviews with senior managers. The purpose of the interview was to understand the service scope and APM capability of the interviewed companies, the influencing factors and moderating factors of APM performance, and the impact of APM capability on APM performance. According to the initial interview, the theoretical framework of APM was constructed, the hypotheses proposed, and a detailed interview questionnaire comprising nine questions with no definite answers was developed. In addition, according to the inductive research method, some questions were added to the interviews to improve the effect. In the research process, we conducted a total of 20 interviews, including four formal interviews and 16 informal interviews (see Table 2). The interviews lasted for 30–60 minutes, and the interview questions were concerned with the actual situation of the company rather than the interviewees' personal views and interpretations. It was necessary to record the interview content to ensure the accuracy of the information. Semi-structured interviews provide in-depth analysis and supplement the content of the initial interviews (Moazzam et al., 2018).

(3) Late interview data. After the interview, the information was organized, including the questions in the research outline and questions added to the spot. By organizing the interview data, we identified other questions that had not been clearly answered and that needed to be added, and we conducted additional interviews.

(4) Organize other related second-hand information. This study organized second-hand information related to topics published by research companies. Available industry reports, internal documents, and basic information of companies were collected to fully grasp the development process and latest trends in the APM of research companies.

[Table 2 near here]

3.4 Data analysis

According to the classic inductive multi-case study, this study had to conduct an internal case analysis and cross-case analysis. Internal case analysis usually includes detailed descriptions of each case and has no standard form; its main purpose is to help researchers process large amounts of data and become familiar with patterns unique to each case (Eisenhardt, 1989). Table 3 provides detailed information on the four companies.

[Table 3 near here]

After the internal case analysis, a cross-case analysis was used to arrive at the final theoretical framework. Tables 4–7 show the analysis of the interview content of the four companies compared to the secondary information, which can assist the researcher in triangulating the evidence for the cross-case analysis, thus providing better support and interpretation of the research hypotheses.

[Tables 4 to 7 near here]

Cross-case analysis is mainly used to determine the influencing factors of each enterprise's APM capability and the relationship between different influencing factors. In the process of cross-case analysis, we must continuously cycle between the generated theories, case data, and literature and further refine the generated concept definitions and theoretical relationships. The existing research is particularly helpful for the refinement of the theoretical framework and creation of propositions; therefore, the theoretical logic of each proposition is a typical mixture of viewpoints based on case evidence, existing research, and independent logic. We continue to circulate the argumentation until the case and the generated theory reach a firm match, and this result is the final theoretical framework.

4. Theoretical framework of APM based on SSC

This section presents a cross-case analysis based on the interviews with four companies and starts by addressing the following three questions to conduct corresponding research: (1) the relationship between APM capability (such as agricultural materials precision purchasing capability, agricultural precision production capability, agricultural products precision sales capability, and agricultural supply chain coordination capability) and APM performance based on SSC; (2) factors influencing APM capability and their influence on APM capability; and (3) the impact mechanism of moderating factors (such as incentive agricultural policy and supply chain rapid response) on APM capability and performance based on SSC.

4.1 Influencing factors of APM capability

4.1.1 The relationship between characteristics of agricultural product and APM capability

The most important characteristics of the agricultural industry are its distinct regional, seasonal, volatile, and perishable natures; therefore, agricultural supply chain processes are complex ones, where natural products are partly based on biological processes and have many specific characteristics that make them perishable if not handled properly (Akkerman et al., 2010). Specifically, due to differences in regions and seasons, changes in the natural environment, climate, moisture, and light directly impact the quantity and quality of agricultural products (Huang et al., 2019). The volatility and perishability of agricultural products make them difficult to market, store, and transport (Chapin et al., 2011), and the corresponding storage and logistics costs are relatively high. In addition, agricultural procurement, production, sales, transportation, processing, and other activities based on SSC are closely related to the characteristics of agricultural products; therefore, these characteristics have an impact on APM capability (Wang et al., 2017). From this point of view, the characteristics of agricultural products themselves seem to invariably increase the difficulty of agricultural materials precision purchasing, agricultural precision production, and agricultural product precision sales, which also implies higher requirements for the collaborative ability of the entire agricultural supply chain of enterprises.

Table 8 shows that, as front-end enterprises in the supply chain, managers A and D made similar statements. The manager of company D, a vegetable planting company, said, “The characteristics of agricultural products have a great negative impact on the agricultural materials precision purchasing and agricultural precision production, especially in the production process, we should pay special attention to the characteristics of agricultural products.” That of company A, a grain planting company, said:

> *Due to the seasonal characteristics of agricultural products, changes in the natural environment will have a great impact on the quantity and quality of agricultural products in the agricultural production process, which will have a greater negative impact on the production and sales of agricultural products.*

Companies in the processing and manufacturing segments of the supply chain B and C exhibit similar statements. The manager of company B, a dairy product processing enterprise, said, “Some products have more obvious regional characteristics and cannot be circulated nationwide like normal temperature products. This is related to various links in the supply chain. Therefore, it will increase the difficulty of APM.” That of company C, a food crop processing

enterprise, emphasized that "because the company uses agricultural products as raw materials, it needs more advanced equipment and technology to solve the impact of agricultural product characteristics on APM capability."

In summary, despite the different links of the agricultural supply chain, corporate positioning, and business field, the managers of the four companies have shown that the characteristics of agricultural products, such as seasonality, volatility, and regionality, can negatively impact APM capability and make APM more difficult to achieve. This negative impact manifests differently; thus, Hypothesis 1a is proposed:

Hypothesis 1a: The characteristics of agricultural products have a negative impact on APM capability.

4.1.2 The relationship between agricultural sales service platform and APM capability

As China enters the era of e-commerce, the marketing of agricultural products has progressed, and agricultural sales service platforms have gradually become the basis for achieving accurate predictions of sales of agricultural products. The development of internet-based transaction platforms and transaction payment applications has greatly promoted the online marketing of agricultural products (Hounkonnou et al., 2018). Agricultural sales service platforms can improve the transparency and timeliness of purchases by realizing online matchmaking among companies and by guiding agricultural materials precision purchasing capability. By accurately predicting the sales volume of agricultural products, agricultural sales service platforms can help guide precision production in agriculture to improve this capability. Agricultural products precision sales can be realized by expanding the circulation scope and enhancing the brand image of agricultural products to improve precision sales capability. Thus, through the realization of the interconnection of all links in the agricultural product supply chain, agricultural sales service platforms can help improve the agricultural supply chain's coordination capability, and APM based on SSC can then be effectively realized (Totin et al., 2020). In addition, the development of agricultural sales service platforms has changed the purchasing method of agricultural materials and the production and sales of agricultural products. At present, an increasing number of companies are pre-selling their products through e-commerce platforms, which greatly shortens the circulation links of agricultural products and improves the efficiency of agricultural product sales (Schut et al., 2016).

As can be seen from Table 8, as agricultural product planting enterprises, both A and D have established their own sales service platforms. The manager of company A said, "Actively developing e-commerce will help improve the agricultural products precision sales capability, and e-commerce will definitely become a sales trend in the future," and that of company D said, "Our company has opened a WeChat public platform for vegetable sales, which makes it easier

and more convenient for customers to place orders, and it also helps the company to strengthen its APM capability."

For agricultural product processing enterprises, the establishment of agricultural product service platforms is even more important. The manager of company B said, "Having our own sales service platform is more helpful for customers to place orders independently, which will increase revenue and reduce many other promotion expenses," and that of company C added that "having our own e-commerce platform, which can innovate and customize products by analyzing consumer buying habits and behaviors."

In summary, although the four companies have different business scales and service scopes, they all have established their own sales service platforms. In addition, the managers of the four companies stated that compared with before, when a sales service platform was absent, the companies currently see obvious effects in terms of personalization management and prediction of consumer preferences, which are beneficial for improving agricultural precision production capability and agricultural products precision sales capability. Therefore, Hypothesis 1b is proposed:

Hypothesis 1b: The construction of an agricultural sales service platform will improve APM capability.

4.1.3 The relationship between application level of smart technology and APM capability

Emerging technologies are increasingly used in the smart agricultural supply chain (Kamble et al., 2018). On the one hand, through technologies such as the IoT and Sensor Technology, producers can more accurately determine the types and quantities of plants, use fertilizers and pesticides more effectively and achieve the accurate and timely procurement of production materials according to the production scheduling plan, thus maximizing crop yields, reducing operating costs, increasing production profits, and achieving agricultural material precision purchasing and agricultural precision production (Brown et al., 2016).

On the other hand, in the sales link of agricultural products, the use of big data, cloud computing, and other technologies to analyze a large amount of data generated by the IoT platform can help predict and analyze the purchasing behavior of consumers and meet their personalized needs, thus realizing agricultural products precision sales (Verdouw et al., 2016).

In addition, in terms of agricultural supply chain coordination, the rise of blockchain technology is expected to play an important role in improving the visibility of the delivery process and the traceability of agricultural products (Sharma et al., 2018). Technologies such as RFID are used to deploy the entire cold chain transportation and storage of fresh products (Yang et al., 2017). The maturation and development of these emerging technologies have a positive impact on agricultural production, agricultural product sales, and agricultural supply

chain coordination (Zaks and Kucharik, 2011).

As can be seen from Table 8, for companies A and D, which focus on the front-end procurement and production links of the supply chain, the manager of food crop planting company A said, “Although smart technology is still unable to fully cover the production process, the application of smart technology will have a positive effect on agricultural precision production and sales.” In addition, the manager of vegetable planting company D stated,

> *The business model of internet technology + agriculture can achieve sales-based fixed production, which provides a basis for the second year's production scheduling plan. In addition, the application of smart technology not only shortens the circulation of agricultural products, but also ensures that customers can eat cheap and high-quality agricultural products.*

For companies B and C, which focus on the processing and circulation links at the back end of the agricultural supply chain, the manager of dairy product processing company B stated that “the application of smart technology has further improved the APM capability. A series of information including sales, orders, and customer needs can be analyzed through big data, which can help managers make decisions more accurately and objectively.” Further, the manager of food crop processing company C said, “In terms of APM, some advanced smart technologies will be used to accurately control the quality of agricultural products during the processing and manufacturing process, as well as accurately predict consumer preferences during the sales process.”

In summary, the four companies focused on different aspects of the agricultural supply chain, such as the smart technologies they adopted, and the level of technology application varied. However, all managers reported that an improvement in the application level of smart technology has a positive effect on the agricultural materials precision purchasing, agricultural precision production, agricultural products precision sales, and agricultural supply chain coordination. Therefore, Hypothesis 1c is proposed:

Hypothesis 1c: The improvement of application level of smart technology will promote APM capability.

[Table 8 near here]

4.2 Relationship between APM capability and APM performance

The precision management of the agricultural supply chain is supported by information technology, aiming to achieve close connection and precision control of the upstream and

downstream flows in the agricultural industry (Allaoui et al., 2017) to enhance the overall competitive advantage of the agricultural supply chain.

This study investigates APM from the perspective of SSC, aiming to achieve precision management of all links from procurement and production to sales and the entire supply process, mainly including agricultural materials precision purchasing, agricultural precision production, agricultural product precision sales, and agricultural supply chain coordination. Therefore, this section discusses the relationship between APM capability and APM performance based on SSC from three aspects: agricultural materials precision purchasing capability and agricultural precision production capability in the upstream agricultural supply chain, agricultural products precision sales capability in the downstream agricultural supply chain, and agricultural supply chain coordination capability in the entire agricultural supply chain cycle. We use the triple bottom line method proposed by Elkington (1998) to measure APM performance. This method refers to the economic, environmental, and social bottom lines. Companies must fulfill their basic economic, environmental, and social responsibilities, and those that implement APM must maintain a balance in these three dimensions. If the organization is unable to fulfill its responsibilities on any of the three pillars of APM, it will not be able to improve its performance (Govindan, 2018). Therefore, this study measures the impact of APM capability on APM performance in terms of economic, environmental, and social performance.

First, agricultural materials precision purchasing is the starting point of APM based on SSC, and it is also the most important link in APM. Owing to the variety of materials required by agricultural companies and the long supply chain process, the timeliness and accuracy of demand information in the procurement process are crucial factors for agricultural precision purchasing (Liu et al., 2018). In recent years, an increasing number of agricultural companies have noticed that the improvement in agricultural material precision purchasing capability plays a positive role in saving manpower and time and reducing inventory management costs, thus improving APM performance (Kamble et al., 2020; Liu et al., 2022).

With the widespread popularity of computers and internet technology and the continuous improvement of management methods and purchasing modes, agricultural companies have gradually shifted away from the traditional purchasing model of precision purchasing (Yang et al., 2017). In other words, according to the market demand and production plan, companies reasonably control the purchase quantity of agricultural materials, combine the purchasing link with e-commerce and use online material purchasing platforms to realize the “sunshine purchase” with controlled process, guaranteed timeliness, and permanent traceability (Fecke et al., 2018).

As shown in Table 9, the managers of companies A and D indicated that implementing

precision procurement would improve the precision management performance of their enterprises. Company A purchases grain crop seeds and planting equipment, and its manager said, "The agricultural materials required for production are purchased by the company through online bidding according to the production plan, which can achieve timely and precise." Company D purchases vegetable seeds and production equipment, and its manager said, "Achieving agricultural materials precision purchasing can save costs, reduce inventories, and increase corporate profits."

Companies B and C are agricultural products processing enterprises that mainly purchase agricultural products and processing equipment, and their managers stated that the stronger the agricultural materials precision purchasing, the better the corresponding business performance. Company B purchases raw milk and processing equipment, and its manager said, "Achieving agricultural materials precision purchasing plays an important role in controlling enterprise costs, reducing production inventory, and improving enterprise performance." Company C purchases food crops and processing equipment, and its manager stated that "the precision of the procurement process can effectively reduce the waste of resources, thereby improving the efficiency of the enterprise."

From this point of view, the improvement in the agricultural materials precision purchasing can not only effectively improve the APM performance of enterprises but also have a positive role in optimizing the allocation of resources and improving social and environmental performance. This is unanimously recognized among companies with different business fields, business scopes, and different links in the agricultural supply chain.

Second, agricultural precision production refers to the use of GPS, GIS, IoT, and other information technology to obtain agricultural production data from multiple sources to make management decisions related to crop production (Li and Chung, 2015). Many studies have shown that the benefits of improving agricultural precision production capability include improving the efficiency, productivity, and profitability of agricultural operations; effective control of food security (Talebpour et al., 2015); and minimization of the impact of chemical inputs (such as pesticides and fertilizers) on the agricultural production system and environment (Brown et al., 2016). Therefore, the improvement of agricultural precision production capability can effectively improve economic, environmental, and social performance under APM. In addition, the proportion of China's agriculture in the GDP is declining, but the total agricultural output value is rising. This shows that the improvement of agricultural precision production capability can effectively contribute to the improvement of economic, environmental, and social performance under APM.

As shown in Table 9, companies A and D are both planting agricultural products in the

front-end production link of the supply chain. The manager of company A said, “At present, the company has achieved precise fertilization by taking comprehensive samples of soil, which not only saves production costs, but also improves the quality of product, thereby improving corporate performance.” In addition, the manager of company D stated that “the company mainly planted based on customer orders. At present, it can achieve precise fertilization and standardized planting, which can effectively improve the profitability of the company.”

Even though companies B and C are in the processing and circulation link at the back end of the agricultural supply chain, their business scope is different from that of other enterprises, but the improvement of agricultural precision production capability to effectively promote APM performance has been unanimously recognized. The manager of company B, a dairy product processing enterprise, said, “After the implementation of agricultural precision production, certain products can be set production based on sales, and the production will not be interfered by human factors as before.” In addition, the manager of company C, a food crop processing company, stated that “the company has always emphasized precision in the production process, and it has basically realized the adjustment of production capacity and production structure according to market demand.”

Third, agricultural product precision sales capability refers to the ability to provide personalized products and services to meet different consumer needs based on precision positioning and modern information technology (Wedel and Kannan, 2016). With the rapid development of China’s economy and the widespread use of internet technology, Chinese farmers have started to use internet sales platforms and smart technology to shorten the circulation time of agricultural products and improve their precision sales capability (Wang and Yue, 2017). In addition, studies have shown that the marketing channels of companies that use sales platforms for precision sales are more stable, which has a positive impact on improving the brand image of agricultural products, predicting and analyzing consumer purchase behavior, and helping farmers solve the problem of supply and marketing mismatch (Jill and Hobbs, 2016). Therefore, improving the precision sales capability of agricultural products can effectively improve the economic and social performance of APM.

As shown in Table 9, companies A and D are agricultural products planting enterprises that mainly sell food crops and fresh vegetables. The manager of company A said, “We have now achieved the private customization of some products and the accurate positioning of the sales market, and the corresponding product prices can be slightly higher than the existing market prices.” The manager of company D added that “by using the agricultural sales model of the internet, the company has accumulated fixed customers, and the benefits have improved a lot.”

B and C are agricultural products processing companies that mainly sell traded and stored food ingredients and packaged food. The manager of company B said, “At present, enterprises are already carrying out agricultural products precision sales, and this is quite effective in improving the APM performance.” The manager of company C said, “The company will produce personalized products to meet different consumer needs to be able to achieve precise sales.”

From this point of view, the improvement of agricultural product precision sales has a positive impact on the economic and social performance of enterprises in APM performance. This has been unanimously recognized among the four companies A, B, C, and D with different positioning, business scopes, and agricultural supply chain links.

Finally, from the perspective of agricultural supply chain coordination, the escalating consumption patterns and increasingly fierce competition necessitate higher requirements for the agricultural supply chain (Network, 2012). To cope with the complexity and variability of the market environment and realize APM based on SSC, companies must fully integrate the upstream and downstream resources of the supply chain and improve the coordination capability of the agricultural supply chain to rapidly respond to market demand (Allaoui et al., 2017). Research shows that the improvement in agricultural supply chain coordination capability can help realize information sharing and risk sharing among members of each node in the supply chain as well as real-time monitoring, control, planning, and optimization throughout the supply chain (Verdouw et al., 2015).

In addition, the enhancement of supply chain coordination capability can effectively improve the visualization of the agricultural supply chain and the traceability of agricultural products (Saguy et al., 2013), thus improving APM performance based on SSC. During the interviews, although the four interviewed companies were located in different links of the agricultural supply chain, their managers all indicated that the improvement of agricultural supply chain coordination capability is critical to improving the company’s APM performance.

As shown in Table 9, A and D are agricultural products planting enterprises in the front-end production link of the supply chain. The manager of company A said, “The better the agricultural supply chain coordination, the more it helps to accurately mine customer information and achieve more precise sales, thereby improving corporate performance.” Further, the manager of company D stated that “the operation model integrating product planting, sales, and distribution puts forward higher coordination requirements for the agricultural supply chain. Only by ensuring the precise cooperation of each link can the growth of benefits be achieved.”

Companies B and C focus on the processing and circulation links at the back end of the

agricultural supply chain. The manager of company B said, “New products need to be adjusted quickly according to market feedback, and the improvement of the agricultural supply chain coordination can realize the rapid response, so as to set production based on sales.” In addition, the manager of C said, “The agricultural supply chain coordination can achieve the precise operation of the company. The better the coordination effect, the higher the company’s performance.”

In summary, although the scale, positioning, business scope, and links of the agricultural supply chain of the four interviewed companies are different, their managers all indicated that APM capabilities have a positive impact on the improvement of APM performance in terms of corporate economic performance, environmental performance, and social performance.

As shown in Table 10, companies A and D are agricultural products planting enterprises, and the manager of company A said, “The improvement of the APM capability has a positive effect on the improvement of the company's economic profits and the employee benefits,” while the manager of company D stated that “the improvement of the APM capability can increase the income of growers by achieving precise sales, and it can also achieve the purpose of protecting environment by precise fertilization through precise production.”

Further, the manager of company B said,

> *The improvement of APM capability is beneficial to the economy, environment, and society. The active implementation of APM from the four aspects of agricultural materials precision purchasing, agricultural precision production, agricultural products precision sales, and agricultural supply chain coordination just illustrates that APM capability can improve the economic performance of the enterprise*.

In addition, the manager of company C stated,

> *Implementing APM makes a certain social contribution to social stability and promotes people’s livelihood. As all links in the supply chain under APM have passed the green pollution-free certification, it has also made a certain contribution to environmental performance.*

Based on this, hypotheses 2a, 2b, 2c, and 2d are proposed:

Hypothesis 2a: Agricultural materials precision purchasing capability is conducive to improving APM performance based on SSC.

Hypothesis 2b: Agricultural precision production capability can help improve APM

performance based on SSC.

Hypothesis 2c: Agricultural products precision sales capability is conducive to improving APM performance based on SSC.

Hypothesis 2d: Agricultural supply chain coordination capability can help improve APM performance based on SSC.

[Table 9 near here]

[Table 10 near here]

4.3 Moderating factor 1: Incentive agricultural policy

The development of modern agriculture requires not only the innovation of smart technology and the construction of agricultural sales service platforms but also the guarantee of incentive agricultural policies. Agricultural policy propels agricultural industry development (Huang and Yang, 2017). Especially in China, where agriculture is the primary industry, the support of incentive agricultural policies will have a profound impact on the development direction and trends of agriculture.

In terms of promoting the improvement of agricultural materials precision purchasing capability, agricultural policy has provided strong support to the construction of online bidding and procurement platforms, helping production entities and buyers release information on the supply and demand of agricultural products; ensure the authenticity, reliability, and validity of supply and demand information; realizing effective connection between supply and demand; and promote agricultural enterprises to realize transparent procurement with positive effects. In promoting the improvement of agricultural products precision production capacity, the government promotes the innovative application of agricultural information technology by issuing relevant policies and accelerating the online monitoring, precision operation, and digital management of agricultural production (Alizamir et al., 2019). Simultaneously, the government promotes the innovative application of smart technologies through activities such as decision-making consultation, technical guidance, and training exchanges, which in turn can improve the precise production capacity of agricultural products. To boost agricultural products precision sales capability, the encouragement and support of agricultural policies have promoted agricultural sales platforms. Through the platforms' network advantages, guidance has helped enterprises and farmers expand their e-commerce sales, promoting the integration of the agricultural industry with the electronic sales platform (Lele and Goswami, 2020). Finally, the direction of agricultural-related policies will effectively strengthen the docking of upstream and downstream systems in the agricultural supply chain and the sharing of information. It will also enable the full traceability of agricultural products "from farmland to table" to improve the

coordination capability of the agricultural supply chain (Akkaya et al., 2020).

Table 11 shows that, as agricultural product planting enterprises, companies A and D both indicated that they were supported by incentive agricultural policies in terms of development direction and equipment investment. The manager of company A emphasized that "the development model of the company actively responds to relevant agricultural policies, which promotes the positive relationship between influencing factors and the APM capability." The manager of company D, a vegetable planting company, said, "In terms of investment in smart facilities and equipment, the state will provide certain subsidies in accordance with agricultural policies, which promotes the company's enthusiasm for improving the APM capability."

As a dairy processing enterprise, the managers of company B indicated that

> *Incentive agricultural policy has a positive effect on promoting the positive relationship between influencing factors and the APM capability. This can enable enterprises to make great improvements in smart technology innovation and improve the quality of agricultural products, which in turn will help improve APM capability*.

The manager of company A added: "The company has been supported by incentive agricultural policy in equipment investment and product innovation. Actively responding to agricultural policies has enabled the company to achieve significant results in smart technology equipment and development direction."

From this point of view, although the four companies are currently supported by incentive agricultural policy, the incentive policies and subsidies received by each enterprise in implementing APM are not the same. The managers of the four companies all stated that compared to before paying attention to the policy, they have achieved remarkable results in the application of smart technology and the transformation of agricultural development directions. Obtaining agricultural policy subsidies has further promoted the enthusiasm of enterprises to improve their APM capability. Hence, we propose Hypothesis 3:

Hypothesis 3: The support of incentive agricultural policy can promote the positive relationship between influencing factors and APM capability.

[Table 11 near here]

4.4 Moderating factor 2: Supply chain rapid response

The current agricultural industry is no longer a single production activity as in the past, but it is an agricultural form that makes natural production factors, modern smart technology, and scientific management methods for socialized production based on market demand (Luthra

et al., 2018). With increasing uncertainty in market demand, the rapid response of the supply chain is particularly important. On the one hand, it can recognize changes in the market environment and consumer demand and organize supply chain members to learn, which lays the foundation for the improvement of agricultural materials precision purchasing capability, agricultural precision production capability, agricultural product precision sales capability, and agricultural supply chain coordination capability. It is necessary to shorten the time for agricultural products to respond to the market to achieve the goal of targeted production, reduce the waste of resources in the agricultural supply chain and achieve precision production and precision marketing (Tsuchiya et al., 2015). On the other hand, studies have shown that a supply chain rapid response can play a key role in driving supply chain performance (Allaoui et al., 2017), especially for agricultural supply chains, which, to some extent, affects the visibility and traceability of agricultural supply chains (Grimm et al., 2014). A higher degree of rapid response in the agricultural supply chain can reduce the supply chain consumption of market research costs that must be invested in the production process of supply chain products or services and improve the quality and efficiency of product or service production and operation as well as the benefits of enterprises. In addition, a rapid supply chain response can also help stakeholders more accurately predict and identify hidden opportunities and threats in the market economy, improve the ability of stakeholders to perceive and predict risks and reduce the hazards caused by risks.

As can be seen from Table 12, the manager of company A stated that "opening up the logistics, capital, and information flow along the entire agricultural supply chain and improving the response speed can effectively promote the positive relationship between APM capability and performance." Further, the manager of company D said, "In today's diversified demand, the agricultural industry is also gradually developing in the direction of platform. Therefore, the responsiveness of the supply chain is very important in the actual operation process."

B and C focus on the back-end processing and circulation links in the agricultural supply chain. The manager of company B said, "Whether it is daily production operations or in response to emergencies, the supply chain rapid response plays a very critical role in promoting the APM performance." In addition, the manager of company C stated that

> *From placing orders based on sales forecasts to developing customized products by the R&D department, to factory production and sales, each link puts forward higher requirements for the response speed of the agricultural supply chain, which has a positive relationship between APM capability and APM performance.*

In summary, although the links in the agricultural supply chain and business scopes are different for the four companies, their managers all indicate that the supply chain's rapid response can greatly improve its efficiency and the positive relationship between APM capability and APM performance. Based on this, Hypothesis 4 is proposed:

Hypothesis 4: The supply chain's rapid response can promote the positive relationship between APM capability and APM performance.

[Table 12 near here]

5. Theoretical framework of APM based on SSC

This study explores APM based on SSC and examines the factors influencing APM capability, the relationship between APM capability and APM performance, and the influence of incentive agricultural policy and supply chain rapid response as moderating factors of APM capability and performance, respectively. Based on this, we proposed four hypotheses. According to the research results, this study constructs a theoretical framework for APM based on SSC, as shown in Figure 1.

[Figure 1 near here]

Our hypotheses describe how various factors affect APM capability and performance based on SSC. Through the inductive multi-case study method, we found that the perishability, regionality, volatility, and other characteristics of agricultural products increase the difficulty in implementing APM (Huang et al., 2019), which has a negative impact on the improvement of APM capability. In addition, the construction of an agricultural sales service platform and the improvement in the level of application of smart technology can reduce the negative effects of the characteristics of agricultural products, while having significant effects on the full traceability of agricultural products, personalized and branded management, and the prediction of consumer preferences (Brown et al., 2016; Sharma et al., 2018; Totin et al., 2020), to realize the precise management of the whole process of purchasing, production, and sales and then improve APM capability (Hypothesis 1). In terms of APM capability, the improvement of the agricultural materials precision purchasing capability, agricultural precision production capability, agricultural products precision sales capability, and agricultural supply chain coordination capability has a positive impact on both the improvement of environmental performance and social performance (Hypothesis 2). Figure 1 clearly suggests that APM capability is built with the effect of the influencing factors, which then promotes APM performance; therefore, H1 and H2 are related sequentially.

In addition to the direct influencing factors, incentive agricultural policy, as a moderating

factor, has a positive guiding effect on the change in the business model and development direction of a company (Huang and Yang, 2017). Therefore, the support of incentive agricultural policy can promote a positive relationship between the influencing factors and APM capability (Hypothesis 3). The rapid response to business, logistics, capital, and information flows in the agricultural supply chain can effectively respond to emergencies and greatly enhance the stability of the supply chain (Allaoui et al., 2017), and a rapid supply chain response can promote a positive relationship between APM capability and APM performance (Hypothesis 4).

The framework in Figure 1 clearly illustrates the relationship among the related influencing factors, APM capability, APM performance, and moderating factors. On this basis, this study constructs the theoretical framework of APM based on SSC for the first time, which enriches previous research and fills the research gap in APM. In addition, the proposed framework provides a rich theoretical reference for relevant companies to carry out APM. In the process of implementing APM, managers should improve the APM capability from the four aspects of purchasing, production, sales, and supply chain coordination, grasp the role of moderating factors accurately, actively respond to incentive agricultural policies, and establish a perfect supply chain rapid response mechanism. The construction of this framework points to ways to improve companies' APM performance.

6. Conclusions and management implications

Based on the inductive multi-case study method, this study selected four Chinese companies that implemented APM for internal and cross-case analyses. On this basis, the APM capability system was constructed from four aspects: agricultural materials precision purchasing, agricultural precision production, agricultural product precision sales, and agricultural supply chain coordination. The factors influencing APM capability and the relationship between APM capability and APM performance were analyzed. Finally, a theoretical framework for APM based on SSC was obtained.

6.1 Conclusions

First, this paper proposes the concept of APM capability system for the first time, emphasizing the improvement of APM capability from four aspects—agricultural materials precision purchasing, agricultural precision production, agricultural products precision sales, and agricultural supply chain coordination—on the basis of SSC. This further expands the research on APM and fills the research gaps in related fields.

Second, this study innovatively proposes a theoretical framework of APM based on SSC from three dimensions: the influencing factors of APM capability, the relationship between APM capability and APM performance, and the impact of adjustment factors. The results show

that APM capability is negatively influenced by the characteristics of agricultural products, while the agricultural sales service platform and application level of smart technology are positively affected by APM capability, which in turn has a positive impact on APM performance.

Finally, this study draws some interesting conclusions: as a moderating factor, incentive agricultural policy can effectively promote the positive relationship between influencing factors and APM capability. Further, the supply chain's rapid response has a positive moderating effect on the positive relationship between APM capability and APM performance. Improving the agricultural materials precision purchasing capability, agricultural precision production capability, agricultural products precision sales capability, and agricultural supply chain coordination capability can effectively improve companies' APM performance, economic performance, environmental performance, and social performance.

6.2 Theoretical contribution and management implications

Based on the above conclusions, we provide the following theoretical contributions and management implications for APM.

From a theoretical perspective, previous studies only focused on the precision of a certain link in the supply chain, such as agricultural precision production (Brown et al., 2016; Kamble et al., 2018), and no research has discussed the relationship between relevant influencing factors, APM capability, and APM performance from the perspective of SSC. This study innovatively considers APM based on SSC and explores the influencing factors of APM capability, the relationship between APM capability and APM performance, and the mechanism of adjustment factors.

Second, although the previous literature has explored the factors influencing APM (Shepherd et al., 2018; Huang et al., 2019), no studies have analyzed how relevant influencing factors affect APM capability in different types of companies, and even fewer have explored the impact of moderating factors on APM capability and APM performance. This study uses an inductive multi-case method to illustrate the impact of relevant influencing factors in companies with different corporate positions and operating fields, which further expands the research on APM. Finally, no research currently exists on constructing an APM capability system based on the procurement, production, sales, and coordination of the supply chain. This study builds an APM capability system from four aspects—agricultural material precision purchasing capability, agricultural precision production capability, agricultural product precision sales capability, and agricultural supply chain coordination capability—which fill the relevant research gap.

From a practical perspective, this study innovatively constructs a theoretical framework of APM based on SSC, which can help managers understand the relationship between various

factors in the process of implementing APM more clearly. At the same time, it points out the direction for improvement in APM performance.

First, managers should improve their precision management capabilities in four areas—precision purchasing, precision production, precision sales, and supply chain collaboration—in the process of implementing APM. The improvement in APM capability is inseparable from the correct understanding of the characteristics of agricultural products, the support of agricultural sales service platforms, and the application of smart technology.

Second, managers must understand the relationship between APM capability and APM performance. According to the companies' development strategy, there is a need to reasonably improve precision management capability; this can be achieved by fully considering the impact of the improvement in precision purchasing capability, precision production capability, precision sales capability, and supply chain coordination capability on economic, environmental, and social performance. This facilitates an overall improvement in the APM performance of companies.

Finally, while conducting APM, managers should accurately grasp and actively respond to relevant agricultural policies that can play a positive regulatory role in improving APM capability. Simultaneously, the establishment of a supply chain rapid response mechanism can help companies adjust the positive relationship between APM capability and APM performance, thus promoting the improvement of the latter.

6.3 Future works

The proposed theoretical framework of APM based on SSC can not only be applied to agricultural companies, but it can also be extended to precision management by other industries to provide a reference for the managers of those companies.

In general, we compared the four companies that implemented APM directly using semi-structured interviews to collect information but did not verify the relevant hypotheses. In subsequent research, the hypotheses of this study can be verified based on statistical data. Through the data indicators, the degree of influence of various factors can be seen more intuitively to further improve the article's structure.

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