

Strategies for Investing in Big Data Information Services in Community Group Buying Supply Chains and Their Comparative Study

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Abstract: This study investigates the investment strategy of big data information service in community group-buying supply chain. Combined with the background of big data information service, it constructs three investment decision models, compares the optimal profits of all parties of the game under different modes, and analyzes the problem of choosing the optimal investment strategy for suppliers, community group-buying platforms and group leaders. It is found that: 1) The community group-buying supply chain invests in big data information service, which has a promotion effect on the supply chain profit, and when the supplier's marginal profit and the head's marginal profit satisfy certain conditions, the investment model is the O-mode, which can make the supply chain realize a long-term win-win situation. The profit of the supply chain is related to the consumer conversion rate, discount rate, cost coefficient of supplier's quality management efforts, cost coefficient of platform's big data marketing, and cost coefficient of group leader's marketing.

Keywords: Community Group-Buying Supply Chain; Big Data Information Service; Investment Strategy.

1. Introduction

Community group purchase is a product of the combination of online group purchase and e-commerce, referring to a model in which residents near the community directly place a pre-order through the WeChat group of the head, small programs, etc., and the platform is delivered to the head of the self-pickup point the next day, and the consumer picks up the goods^[1]. The more typical community group purchase platforms are Xing Sheng Youchuan, Duo Duo Buying food, Tao Cai Cai and so on. At present, there are two main modes of community group purchasing, namely, the mode in which enterprises carry out community group purchasing business on established platforms (hereinafter collectively referred to as the self-operated mode) and the mode in which community group purchasing platforms are built with the help of third-party mini-program developers (hereinafter collectively referred to as the third-party mode). In this paper, we study the community group-buying supply chain in the self-operated mode.

With the advancement of technology and the updating and iteration of WeChat applets in recent years, community group purchases are easy to operate and easily accepted, while large companies with good management capabilities have entered the market, integrating the supply chain, reducing channels, minimizing waste and providing inexpensive products. In addition, community group purchasing has attracted major companies to enter the market by virtue of its ability to withstand risks in an epidemic, and has gained a large amount of capital support. According to public information, China's community group-buying market size in 2022 will be about 210 billion yuan, and in 2023 it will reach 320 billion yuan. At the same time, with the increase in consumer awareness of community group purchasing, the user scale of the community group purchasing market increased from 0.95 billion people in 2016 to 626 million people in 2022. Foresight Industry Research Institute expects the user size

increase to slow down from 2024 to 2029, but the overall value shows a continuous rise.

The main aspects of the literature related to this study are as follows. The first is the research on the operational problems of community group purchasing. The second is the research on the application of big data in supply chain. The third is the research on investment strategy in supply chain.

Regarding the operation problems of community group purchase, Geng Shuang Shuang et al^[2] emphasized the key role of refined operation for community group purchase platforms to occupy the future market by describing and comparing two community group purchase supply chain operation modes exemplified by Ten Aloe Tuan and Koala Select. Zhang Wei^[3] points out that the development modes of community group purchasing have their own advantages and disadvantages, and affirms the ability of community group purchasing to make profits regionally. However, from an overall point of view, in order to realize the profitability of community group purchasing on a cross-regional scale, it is still necessary to solve the problems of recruitment management of group leaders, operation of community shopping scenarios, supply chain optimization and management, warehousing and distribution. Xu H^[4] pointed out that the degree of completeness of the product information affects the consumer experience, and that in order to increase the profitability of the group purchasing platform, it is possible to consider providing more information to the consumers. In the study of community group-buying flat group strategy, consumers' group-buying strategy is influenced by the guidance of the platform. Lan C et al^[5] by establishing the decentralized and centralized game model of the community group-buying supply chain, the treatment of the key factors affecting the optimal community group-buying demand are sales effort and service level. Especially under the decentralized decision-making model, the higher the sales effort and service level, the higher the demand for community group purchasing. Wen Bing S et al^[6] argued that

the drawbacks of community group purchasing enterprises cannot be ignored when studying the long-term development of community group purchasing sustainability.

With the further development of cloud computing, Internet of Things and new information technology, how to apply big data has gradually become one of the topics of research in various industries. The application of big data in supply chain cost management is particularly prominent, and Gu Ming Hua^[7] describes the cost management methods adopted by enterprises in production, procurement, inventory, sales and transportation in the context of big data. Liu Yang^[8] conducted a study on the cost management of manufacturing enterprises in the era of big data, proposing that big data technology can be utilized to track the costs of product design, procurement, production, inventory, sales and transportation in real time, and to improve the deficiencies in cost management in a timely manner, in order to enhance the level of cost management. With the help of big data information service providers, it is easier for sales companies to obtain the diversified behavioral characteristics of consumers, which also provides a reliable basis for sales companies to carry out all kinds of marketing activities for decision-making^[9]. Jiao Z et al^[10] use big data prediction and analysis technology and cloud computing and other technologies to analyze multi-channel big data, and are able to carve out the user's consumption portrait, help the marketing department to make segmentation decision-making, and help the advertising department to improve the accuracy of advertisement placement, further improving the return on investment of advertising and marketing. Ma De Qing et al^[11] found that in the dynamic supply chain involved in the Internet platform of big data marketing, when considering the consumer's price reference effect, the synergy of supply chain members in production and sales can, to a certain extent, promote the level of marketing efforts of the Internet platform, and also optimize the consumer's experience. Xiang Z et al^[12] took big data marketing as an important operational tool for the Internet platform, and studied the cooperation strategy between enterprises in the closed-loop supply chain, and found that big data marketing can effectively promote the improvement of product sales and recovery rate, and enterprises should support the online platform for big data marketing more.

For the research on supply chain investment strategies, Liang Kai Rong et al^[13] discussed the impact of investment in low-carbon technologies on product pricing in a low-carbon product supply chain that can choose between cooperation

and non-cooperation. It was found that the level of low-carbon technology, the cost-sharing ratio that maximizes the profit of supply chain members under all three models is unique. Lu Lin^[14] constructed four big data investment models for a two-level supply chain and solved the corresponding equilibrium solutions to obtain the constraints under which investing in big data can increase supply chain returns. Qiu Ruo zhen et al^[15] introduced a revenue sharing strategy for a two-level supply chain and built a related big data business investment game model, and obtained the constraints and patterns that promote the supply chain to achieve Pareto improvement. Qiu Ruozhen et al [15] consider the scenario of uncertain demand information in supply chains, and derive the big data investment cost constraints that enable supply chains to be improved by establishing and solving the optimal profit of supply robust optimization models with centralized and decentralized decision making.

In summary, this paper investigates the big data information service investment strategy for community group-buying supply chain. Combined with the background of big data information service, three investment decision models are constructed, the optimal profits of the gaming parties under different models are compared, and the problem of choosing the optimal investment strategies for suppliers, community group-buying platforms, and headmen is analyzed.

2. Model Description and Assumptions

2.1. Model Description

Community group-buying platforms such as Mei Tuan Preferred and Duo Duo Grocery Buying, backed by the data resources and platform resources of their parent companies, often have first-hand information about consumers. Therefore, the platforms will deeply clean and analyze these data to get an accurate portrait of consumers, and such big data precision marketing often requires financial support. In this chapter, consider the following scenario: in a community group-buying supply chain, only one type of product is sold, the base sales volume of the product is, and the platform can convert a portion of the potential audience into actual purchasers of the product by using big data analytics to increase the sales volume of the product. In this process, all parties in the supply chain have to make corresponding efforts for the marketing of the product. The scenario is schematized in Figure 1, where the solid line is the logistics process and the dashed line is the marketing service flow.

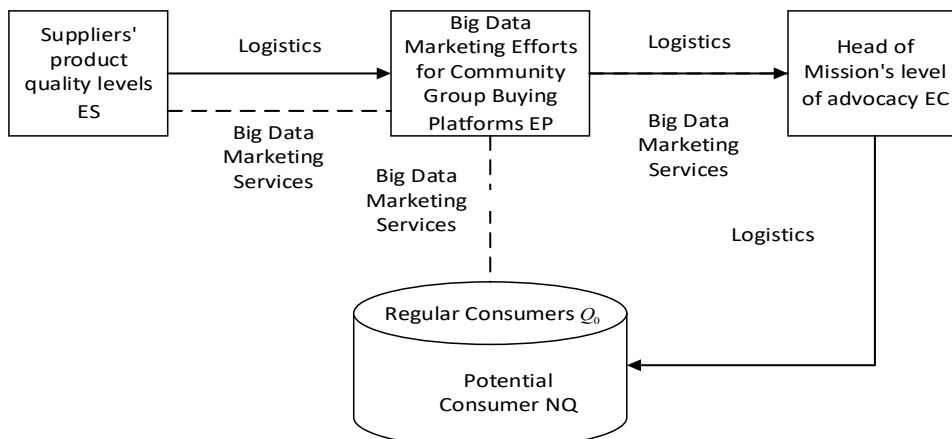


Figure 1. The Big Data Marketing Service Scene Sketch Map of Community Group Purchase Supply Chain

2.2. Symbol Description

J_b^a represents the long-term profit of supply chain member b participating in the game in mode a. It is denoted by J_b^a , which represents the long-term profit of the supplier at time t. $ES(t)$ denotes the level of quality management efforts exerted by the supplier at moment t; $EP(t)$ is used to denote the level of big data marketing efforts of the community group purchasing platform; and $EC(t)$ denotes the level of marketing publicity by the group leader in order to improve its influence. x , x , and x are the main decision variables corresponding to the members, respectively, and x , the consumer conversion rate is the state variable of the model, and the values may be different at different moments.

2.3. Basic assumptions

(1) Considering that the input cost of product quality management level has convex characteristics, referring to the existing research^[16] the supplier product quality management level input as a one-time input, independent of the impact of production, set as a quadratic function of the form $C_s(ES) = \eta_s ES(t)^2 / 2$, $\eta_s > 0$ indicates the cost function coefficients of the input.

(2) The input cost of the platform's big data marketing effort level also has convex characteristics, its effort level input as a one-time input, independent of the impact of production, also assumed to be a quadratic function $C_p(EP) = \eta_p EP(t)^2 / 2$, $\eta_p > 0$ represents the cost function coefficients of the platform input.

(3) The propaganda cost of the head is an incremental function about the propaganda effort level, again assuming a quadratic function $C_c(EC) = \frac{1}{2} \eta_c EC(t)^2$, $\eta_c > 0$ represents the cost function coefficients of the head's input.

(4) In the long run, the conversion rate of big data marketing to consumers depends on several aspects. The level of big data marketing effort invested by the platform, the level of quality management of the supplier and the level of promotional effort of the head are positively related to the consumer conversion rate. At the same time, if big data marketing is not consistently invested in, consumers may be lost, resulting in lower conversion rates. In summary, the long-term dynamic change equation of consumer conversion rate can be expressed as

$$\dot{X}(t) = \beta_s ES(t) + \beta_c EC(t) + \beta_p EP(t) - \lambda x(t) \quad (1)$$

Where $x(t)$ represents the consumer conversion rate at moment t, $0 < x(t) < 1$, the initial conversion rate is 0. $\beta_s > 0$ represents the influence coefficient of the supplier's quality management level on the consumer conversion rate, $\beta_c > 0$ represents the influence coefficient of the consumer conversion rate of the head publicity level, and $\lambda > 0$ represents the natural decline rate of the consumer conversion rate.

(5) Assuming that some consumers in the market demand for the product is fixed per unit of time, the demand of such consumers is represented by Q_0 . Meanwhile, the effect of price factor on the total demand for the product can be ignored, and the actual sales volume increased by big data marketing per unit of time is denoted by NQ . In summary, the total market demand function of the product can be obtained as follows:

$$Q(x(t), t) = Q_0 + x(t)NQ \quad (2)$$

(6) When the supply and the head of the large order big data marketing business from the platform, let the head's share of the ordering cost be $z(t)$ and $0 \leq z(t) \leq 1$.

(7) This chapter examines a long-term process that requires a discount rate that translates future revenue into current value in order to facilitate the supply chain members to make decisions based on the criterion of maximizing current benefits. The platform, supplier, and head of the supply chain system all use profit maximization over the long term (infinite time interval) as the primary principle for making decisions, and for ease of handling, the discount rate for each participant in the supply chain is set to ρ , where $\rho > 0$.

(8) This chapter studies community group-buying supply chains, and each supply chain sells only one product. The supply chain members are all risk neutral and fully rational.

3. Investment Strategy Analysis of Big Data Information Service for Community Group Buying Supply Chain under S-mode

Under the supplier payment model, the big data precision marketing services provided by the platform are ordered independently by the suppliers, and the supply chain members make decentralized decisions based on the principle of maximizing their respective profits. The game process in this section is divided into three phases (Figure 2):

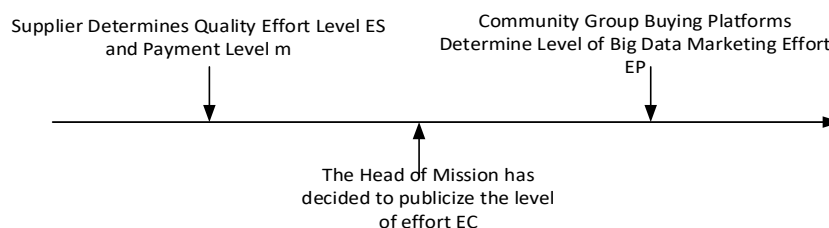


Figure 2. Investment Decision Sequence Diagram of Big Data Information Service of Community Group-Buying Supply Chain Under S Mode

The decision function of the supplier is:

$$J_p^S(x) = e^{-\rho t} V_p^S(x) \quad (8)$$

$$\max_{ES;m} J_s^S = \int_0^\infty e^{-\rho t} (\pi_s Q - C_s - mEP) dt \quad (3)$$

The decision function of the head of the mission is:

$$\max_{EC} J_c^S = \int_0^\infty e^{-\rho t} (\pi_c Q - C_c) dt \quad (4)$$

The decision function of the platform is:

$$\max_{EP} J_p^S = \int_0^\infty e^{-\rho t} (mEP - C_p) dt \quad (5)$$

Proposition 3-1: When a supplier independently subscribes to the platform's big data precision marketing service, the optimal decisions of each member of the community group-buying supply chain are respectively:

$$EP^{*S} = \frac{NQ\pi_s\beta_p}{2(\rho+\lambda)\eta_p}, \quad EC^{*S} = \frac{NQ\pi_c\beta_c}{(\rho+\lambda)\eta_c},$$

$$ES^{*S} = \frac{NQ\pi_s\beta_s}{(\rho+\lambda)\eta_s}, \quad m^{*S} = \frac{NQ\pi_s\beta_p}{2(\rho+\lambda)}$$

At this point, the optimal consumer conversion rate trajectory is

$$x = x^{*S} - (x^{*S} - x(0))e^{-\lambda t},$$

$$x^{*S} = \frac{NQ\pi_s\beta_s^2}{\lambda(\rho+\lambda)\eta_s} + \frac{NQ\pi_s\beta_p^2}{2\lambda(\rho+\lambda)\eta_p} + \frac{NQ\pi_c\beta_c^2}{\lambda(\rho+\lambda)\eta_c};$$
 the most

profitable for the platform, the head and the supplier are:

$$V_p^{*S} = \frac{NQ^2\pi_s^2\beta_p^2}{8(\rho+\lambda)^2\eta_p}, \quad V_c^{*S} = \frac{NQ\lambda\pi_c}{\rho+\lambda}x + b_1,$$

$$b_1 = \frac{Q_0\pi_c}{\rho} + \frac{NQ^2\pi_c^2\beta_c^2}{2\rho(\rho+\lambda)^2\eta_c} + \frac{\pi_c\pi_sNQ^2\beta_s^2}{\rho(\rho+\lambda)^2\eta_s} + \frac{\pi_c\pi_sNQ^2\beta_p^2}{2\rho(\rho+\lambda)^2\eta_p}$$

$$V_s^{*S} = \frac{NQ\lambda\pi_s}{\rho+\lambda}x + b_2,$$

$$b_2 = \frac{Q_0\pi_s}{\rho} + \frac{NQ^2\pi_c\pi_s\beta_c^2}{\rho(\rho+\lambda)^2\eta_c} + \frac{\pi_s^2NQ^2\beta_s^2}{2\rho(\rho+\lambda)^2\eta_s} + \frac{NQ^2\pi_s^2\beta_p^2}{4\rho(\rho+\lambda)^2\eta_p}$$

respectively.

Proof: in accordance with the order of the game, through the inverse induction method to analyze the game, then first analyze the platform's decision-making, remember that after the moment t the platform's total profit when the optimal value of the function is:

$$V_p^S(x) = \max_{EP} \int_0^\infty e^{-\rho(y-t)} (mEP - C_p) dy \quad (6)$$

According to the order of the game, the game is analyzed by inverse push induction method, and the decision of the platform is analyzed first, and the optimal value function of the total profit of the platform after time t is as follows:

$$V_p^S(x) = \max_{EP} \int_0^\infty e^{-\rho(y-t)} (mEP - C_p) dy \quad (7)$$

Remember that the optimal value function of the platform after time t is:

Then $V_p^S(x)$ must satisfy the Hamilton-Jacobi-Bellman equation in the following equation for all $x > 0$:

$$\rho V_p^S(x) = \max_{EP} (mEP - C_p) \quad (9)$$

It is easy to know that $\rho V_p^S(x)'' < 0$, so there exists a maximum about EP and the maximum is obtained at the partial derivative equal to 0. The result can be obtained by taking the partial derivative with respect to the right end of the HJB equation:

$$EP = \frac{m}{\eta_p} \quad (10)$$

The optimal total profit value function of the leader after time t is:

$$V_c^S(x) = \max_{EC} \int_0^\infty e^{-\rho(y-t)} (\pi_c Q - C_c) dy \quad (11)$$

The optimal value function of the total profit of the leader is:

$$J_c^S(x) = e^{-\rho t} V_c^S(x) \quad (12)$$

Then $V_c^S(x)$ must satisfy the Hamilton-Jacobi-Bellman equation in the following equation for all $x > 0$:

$$\rho V_c^S(x) = \max_{EC} (\pi_c Q - C_c + V_c^{S'}(x)(\beta_s ES + \beta_c EC + \beta_p EP - \lambda x)) \quad (13)$$

When the above formula is maximized, the conditions that the decision variable should be satisfied are as follows:

$$EC = \frac{V_c^{S'}(x)\beta_c}{\eta_c} \quad (14)$$

The optimal value function of the supplier after time t is:

$$V_s^S(x) = \max_{ES;m} \int_0^\infty e^{-\rho(y-t)} (\pi_s Q - C_s - mEP) dy \quad (15)$$

The optimal function of the present value of the total profit is:

$$J_s^S(x) = e^{-\rho t} V_s^S(x) \quad (16)$$

Then $V_s^S(x)$ must satisfy the Hamilton-Jacobi-Bellman equation in the following equation for all $x > 0$:

$$\rho V_s^S(x) = \max_{ES;m} (\pi_s Q - C_s - mEP + V_s^{S'}(x)(\beta_s ES + \beta_c EC + \beta_p EP - \lambda x)) \quad (16)$$

When the above formula can be maximized, the criteria of the supplier are:

$$ES = \frac{V_s^{S'}(x)\beta_s}{\eta_s} \quad (17)$$

$$m = \frac{V_s^{S'}(x)\beta_p}{2}$$

Substituting (9), (13), and (17) into equations (8), (12) & (16), and after collapsing, it get:

$$\rho V_C^S(x) = x(-V_C^{S'}(x)\lambda + NQ\pi_c) + Q_0\pi_c + \frac{NQ^2\pi_c^2\beta_c^2}{2(\rho+\lambda)^2\eta_c} + \frac{\pi_c\pi_sNQ^2\beta_s^2}{(\rho+\lambda)^2\eta_s} + \frac{\pi_c\pi_sNQ^2\beta_p^2}{2(\rho+\lambda)^2\eta_p} \quad (18)$$

$$\rho V_S^S(x) = x(-V_S^{S'}(x)\lambda + NQ\pi_s) + Q_0\pi_s + \frac{NQ^2\pi_c\pi_s\beta_c^2}{(\rho+\lambda)^2\eta_c} + \frac{\pi_s^2NQ^2\beta_s^2}{2(\rho+\lambda)^2\eta_s} + \frac{NQ^2\pi_s^2\beta_p^2}{4(\rho+\lambda)^2\eta_p} \quad (19)$$

$$\rho V_P^S(x) = \frac{m^2}{\eta_p} - \frac{m^2}{2\eta_p} = \frac{m^2}{2\eta_p} \quad (20)$$

By observing the characteristics of the differential equation in the above formula, one can speculate that the unary linear function about x is the solution of the above Hamilton-Jacobi-Bellman equation. a surname:

$$V(x)_C^S = a_1x + b_1; \quad V(x)_S^S = a_2x + b_2 \quad (21)$$

where a_1, b_1, a_2 and b_2 are constants. The first order derivative with respect to x can be found as follows:

$$a_1 = V_C^{S'}(x); \quad a_2 = V_S^{S'}(x) \quad (22)$$

And then get:

$$a_1 = \frac{NQ\lambda\pi_c}{\rho+\lambda}, \quad a_2 = \frac{NQ\lambda\pi_s}{\rho+\lambda};$$

$$b_1 = \frac{Q_0\pi_c}{\rho} + \frac{NQ^2\pi_c^2\beta_c^2}{2\rho(\rho+\lambda)^2\eta_c} + \frac{\pi_c\pi_sNQ^2\beta_s^2}{\rho(\rho+\lambda)^2\eta_s} + \frac{\pi_c\pi_sNQ^2\beta_p^2}{2\rho(\rho+\lambda)^2\eta_p},$$

$$b_2 = \frac{Q_0\pi_s}{\rho} + \frac{NQ^2\pi_c\pi_s\beta_c^2}{\rho(\rho+\lambda)^2\eta_c} + \frac{\pi_s^2NQ^2\beta_s^2}{2\rho(\rho+\lambda)^2\eta_s} + \frac{NQ^2\pi_s^2\beta_p^2}{4\rho(\rho+\lambda)^2\eta_p}.$$

Substituting a_1, b_1, a_2 and b_2 into (9), (13), (17) can find the optimal decision set is $(EP^{*S}, EC^{*S}, ES^{*S}, m^{*S})$. substituting into (20), (21) can get the optimal present value value function of the supply chain members are $V_S^{*S}(x), V_C^{*S}(x), V_P^{*S}(x)$. bringing into (7), (11), (15) can get the optimal present value value function $J_S^{*S}(x), J_C^{*S}(x), J_P^{*S}(x)$, at this time, the value of $V_P^{*S}(x), EP^{*S}, EC^{*S}$ and ES^{*S} substituting into the equation (1), after the Organize can be found optimal potential consumer conversion rate of x^{*S} , can be further found optimal consumer conversion rate trajectory equation. So far Proposition 3-1 is proved.

4. Investment Strategy Analysis of Big Data Information Service for Community Group Buying Supply Chain under C-mode

In this section of the model, the big data precision marketing service provided by the platform is jointly ordered by the head and the supplier, and the supply chain members make decentralized decisions based on the principle of maximizing their respective profits, and the game process in this section is divided into three stages (Figure 3):

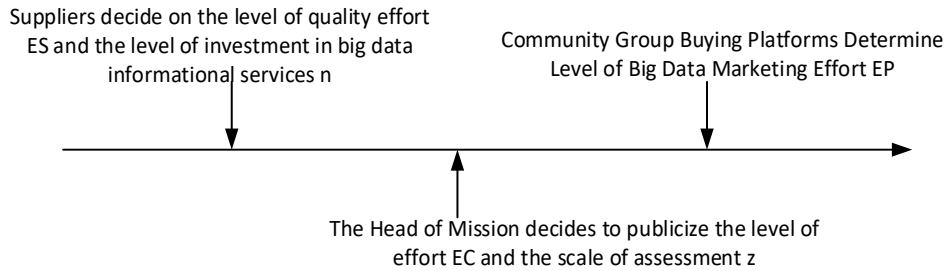


Figure 3. Investment Decision Sequence Diagram of Big Data Information Service of Community Group-Buying Supply Chain Under O Mode

The decision function of the supplier is:

$$\max_{ES; z} J_S^S = \int_0^\infty e^{-\rho t} (\pi_s Q - C_S - n(1-z)EP) dt \quad (23)$$

The decision function of the leader is:

$$\max_{EC; n} J_C^S = \int_0^\infty e^{-\rho t} (\pi_c Q - C_C - nzEP) dt \quad (24)$$

The decision function of the platform is:

$$\max_{EP} J_P^S = \int_0^\infty e^{-\rho t} (nEP - C_P) dt \quad (25)$$

Proposition 3-2: Under the joint payment mode, the optimal decision of each member of the community group purchase supply chain is as follows:

$$EP^{*O} = \frac{NQ(2\pi_c + \pi_s)\beta_p}{4(\rho + \lambda)\eta_p}; \quad EC^{*O} = \frac{NQ\pi_c\beta_c}{(\rho + \lambda)\eta_c};$$

$$ES^{*O} = \frac{NQ\pi_s\beta_s}{(\rho + \lambda)\eta_s}; \quad n^{*O} = \frac{NQ(2\pi_c + \pi_s)\beta_p}{4(\rho + \lambda)};$$

$$z^{*O} = \frac{2\pi_c - \pi_s}{2\pi_c + \pi_s};$$

The optimal consumer conversion rate trajectory is:

$$x = x^{*O} - (x^{*O} - x(0))e^{-\lambda t},$$

$$x^{*O} = \frac{(\pi_s + \pi_c)NQ\beta_p^2}{2\lambda(\rho + \lambda)\eta_p} + \frac{NQ\pi_c\beta_c^2}{\lambda(\rho + \lambda)\eta_c} + \frac{NQ\pi_s\beta_s^2}{\lambda(\rho + \lambda)\eta_s};$$

The most profitable companies of the platform, the leader and the supplier are:

$$V_p^{*O} = \frac{NQ^2\rho^2(2\pi_c + \pi_s)^2\beta_p^2}{32(\rho + \lambda)^2\eta_p}; \quad V_c^{*O} = -\frac{NQ\lambda\pi_c}{\rho + \lambda}x + b_3;$$

$$b_3 = \frac{\pi_c Q_0}{\rho} + \frac{NQ^2\pi_c^2\beta_c^2}{2\rho(\rho + \lambda)^2\eta_c} + \frac{NQ^2\beta_p^2(\pi_s/2 + \pi_c)^2}{4\rho(\rho + \lambda)^2\eta_p} + \frac{NQ^2\beta_s^2\pi_s\pi_c}{\rho(\rho + \lambda)^2\eta_s};$$

$$V_s^{*O} = -\frac{NQ\lambda\pi_s}{\rho + \lambda}x + b_4,$$

$$b_4 = \frac{\pi_s Q_0}{\rho} + \frac{NQ^2(\pi_s^2 + \pi_c^2)\beta_p^2}{8\rho(\rho + \lambda)^2\eta_p} + \frac{NQ^2\pi_c\pi_s\beta_c^2}{2\rho(\rho + \lambda)^2\eta_c} + \frac{NQ^2\pi_s^2\beta_s^2}{2\rho(\rho + \lambda)^2\eta_s}.$$

5. Investment Strategy Analysis of Big Data Information Service for Community Group Buying Supply Chain under T-mode

In this section, the consideration is that the supplier, the platform and the leader are fully cooperative. The supply chain system takes the overall profit maximization as the primary criterion, and is decisions by the unified control center. At this time, the objective function of the supply chain system is:

$$\max_{ES, EP, EC} J_A^T = \int_0^\infty e^{-\rho t} (Q(\pi_s + \pi_c) - C_s - C_c - C_p) dt \quad (26)$$

Proposition 3-3: Under the overall cooperation mode of the supply chain,

$$EP^{*T} = \frac{NQ(\pi_c + \pi_s)\beta_p}{(\rho + \lambda)\eta_p}, \quad EC^{*T} = \frac{NQ(\pi_c + \pi_s)\beta_c}{(\rho + \lambda)\eta_c},$$

$$ES^{*T} = \frac{NQ(\pi_c + \pi_s)\beta_s}{(\rho + \lambda)\eta_s};$$

The optimal consumer conversion rate trajectory is:

$$x = x^{*T} - (x^{*T} - x(0))e^{-\lambda t},$$

$$x^{*T} = \frac{(\pi_c + \pi_s)NQ\beta_c^2}{\lambda(\rho + \lambda)\eta_c} + \frac{(\pi_c + \pi_s)NQ\beta_p^2}{\lambda(\rho + \lambda)\eta_p} + \frac{(\pi_c + \pi_s)NQ\beta_s^2}{\lambda(\rho + \lambda)\eta_s};$$

The optimal profit of the overall supply chain is:

$$V_A^{*T} = \frac{NQ\lambda\pi_c + NQ\lambda\pi_s}{\rho + \lambda}x + b_5,$$

$$b_5 = \frac{Q_0(\pi_s + \pi_c)}{\rho} + \frac{(\pi_s + \pi_c)^2 NQ^2\beta_c^2}{2\rho(\rho + \lambda)^2\eta_c} + \frac{(\pi_s + \pi_c)^2 NQ^2\beta_p^2}{2\rho(\rho + \lambda)^2\eta_p} + \frac{(\pi_s + \pi_c)^2 NQ^2\beta_s^2}{2\rho(\rho + \lambda)^2\eta_s}.$$

6. Comparative Analysis of Investment Strategies

As can be seen from Table 1, $\pi_c > \frac{\pi_s}{2}$ is a necessary

condition for the establishment of the O model, that is, when the supplier's marginal profit is more than twice the marginal profit of the leader, the supplier is willing to enter into a

argument, remember $\omega = \pi_c - \frac{\pi_s}{2}$. Based on the above

proposition and the content of Table 1, the following inferences can be drawn:

(1) $ES^{*T} > ES^{*S} = ES^{*O}$, $EC^{*O} = EC^{*S} < EC^{*T}$ hold when $\omega > 0$;

(2) $EP^{*T} > EP^{*O} > EP^{*S}$, $m^* < n^*$ hold when $\omega > 0$;

(3) $V_p^{*O} > V_p^{*S}$ holds when $\omega > 0$.

From the inference, it can be seen that the effort level of the platform is at the lowest level when the supplier invests in big data information services alone. In the case of joint payment between the supplier and the head, the platform's level of effort in big data marketing is higher. This is because the total level of payments received by the platform under the joint payment contract is greater than the level of payments under the supplier's separate payment model (i.e., $m^* < n^*$). The

platform thus receives higher revenues and is induced by the high revenues to raise its level of big data marketing effort. For suppliers, choosing either the individual payment model or the O model requires the same level of quality effort. For the head, it is possible to choose the co-investment model as long as the marginal profit is satisfied to be more than half of the supplier's marginal profit. For suppliers, chiefs, and the supply chain as a whole, the optimal profit they can make is closely related to the trajectory of the consumer conversion rate, and since x^* varies over time for all three models, the

change in each party's optimal profit will be further analyzed by means of an arithmetic analysis in Section 7.

7. Numerical Analysis

The optimal strategy choices under different big data information service investment modes have been obtained in the above model solution, and the relationship between the effort levels of the game parties under different modes has been obtained through the method of comparative analysis. In order to show and explain the research results more intuitively, this section adopts the way of calculating examples to rationalize and assign values to the relevant parameters in the model, so as to satisfy the constraints that the model is established with optimal solutions. MATLAB software is utilized to draw the corresponding pictures as shown in Figure 4, Figure 5 and Figure 6.

Table 1. Part of the solution result of the investment model of community group purchase supply chain large data information service

	S-mode	O-mode	T-mode
ES^*	$\frac{NQ\pi_s\beta_s}{(\rho+\lambda)\eta_s}$	$\frac{NQ\pi_s\beta_s}{(\rho+\lambda)\eta_s}$	$\frac{NQ\beta_s(\pi_c+\pi_s)}{\eta_s(\rho+\lambda)}$
EP^*	$\frac{NQ\pi_s\beta_p}{2(\rho+\lambda)\eta_p}$	$\frac{NQ(2\pi_c+\pi_s)\beta_p}{4(\rho+\lambda)\eta_p}$	$\frac{NQ\beta_p(\pi_c+\pi_s)}{\eta_p(\rho+\lambda)}$
EC^*	$\frac{NQ\pi_c\beta_c}{(\rho+\lambda)\eta_c}$	$\frac{NQ\pi_c\beta_c}{(\rho+\lambda)\eta_c}$	$\frac{NQ\beta_c(\pi_s+\pi_c)}{(\rho+\lambda)\eta_c}$
m^*	$\frac{NQ\pi_s\beta_p}{2(\rho+\lambda)}$	\	\
z^*	\	$\frac{2\pi_c-\pi_s}{2\pi_c+\pi_s}$	\
n^*	\	$\frac{NQ(2\pi_c+\pi_s)\beta_p}{4(\rho+\lambda)}$	\
V_p^*	$\frac{NQ^2\pi_s^2\beta_p^2}{8(\rho+\lambda)^2\eta_p}$	$\frac{NQ^2(2\pi_c+\pi_s)^2\beta_p^2}{32(\rho+\lambda)^2\eta_p}$	\

The following parameter values are given: $\eta_s=20$, $\eta_p=16$, $\eta_c=12$; $\beta_s=1.3$, $\beta_c=1.2$, $\beta_p=1.6$, $\lambda=1.5$; $Q_0=100$, $NQ=500$; $\rho=0.7$; $\pi_s=7$, $\pi_c=4$, $x(0)=0$. The above parameter values satisfy the necessary condition $\pi_c > \frac{\pi_s}{2}$ for the establishment of the O model.

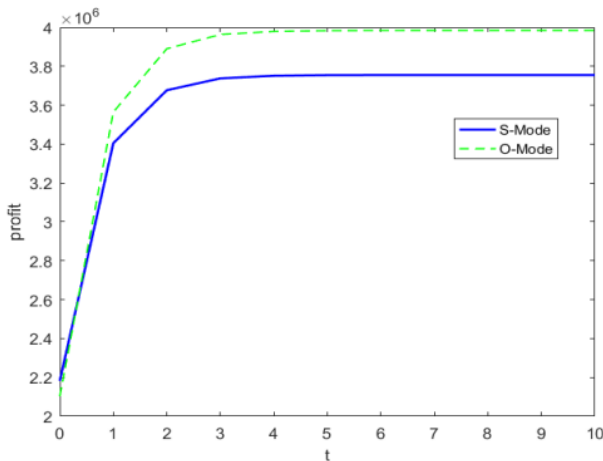


Figure 4. the Change of the Supplier's Profit under the Two Models

From Figure 4, it can be seen that the supplier's profit function tends to stabilize at $t=5$, which indicates that the impact on the supplier's profit after investing in big data information services is controllable within a certain period of time. For the convenience of analysis, let $t=5$. It can be seen that the optimal profit of the supplier choosing to invest in the big data information service model alone is lower than the optimal profit when it chooses to invest in cooperation with the head. In fact, the chief chooses the O model precisely because it can obtain greater profits, as in Figure 5.

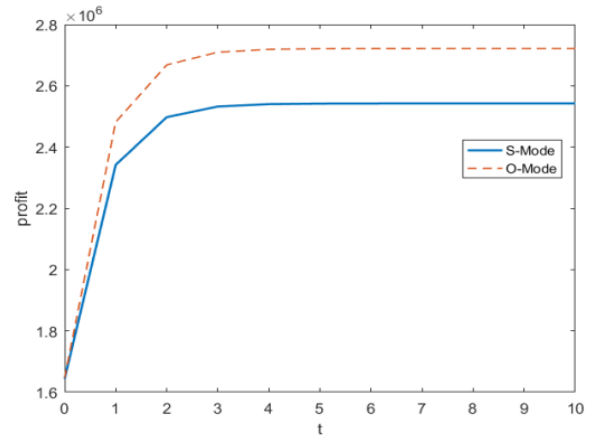


Figure 5. The Change of Captain's Profits Under Two Models

For the captain, the profit under the O model is much higher than the S model. In reality, although the captain has signed a treaty with the supplier to cooperate and invest in big data and new information services, the captain himself has not invested more promotional efforts at the end of the supply chain, which makes the captain only need to invest a smaller part of the cooperation to obtain more abundant profits.

From Figure 6, it can be seen that when the whole supply chain is taken as the object of study, the overall profit of the supply chain tends to stabilize at $t=5$ and after. $t=5$, the profit of the supply chain of O mode is higher than that of S mode, which is due to the fact that the cooperation between the supplier and the head of the group increases the platform's revenue to a certain extent, which makes the platform willing to put in more effort on the big-data marketing, and the greater the platform's effort, the higher the consumer conversion rate is, and the more the platform invests in the cooperation. The higher the efforts of the platform, the higher the consumer conversion rate, which promotes the growth of sales, making the overall profit of the supply chain higher. For the supply chain as a whole, when investing in big data information services, the profit of the supply chain first increases gradually and then remains stable, therefore, it is feasible and

necessary to invest in big data information services.

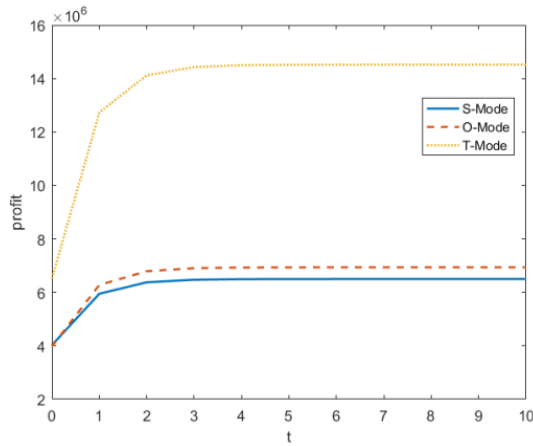


Figure 1. Profit Change of Community Group Purchase Supply Chain System Under Three Modes

8. Conclusion

In this paper, we study a three-tier supply chain consisting of a supplier, a community group-buying platform and a leader, in which the supplier and the leader invest in big data and information services, and the supplier can choose either to invest alone (S-mode) or to cooperate with the leader (O-mode). The role of the platform here is that of a big data service provider, sharing data and information for suppliers and the chief, providing reference suggestions for suppliers in product quality control, and providing decision support for the chief in marketing. Based on the differential game theory, three contract models are constructed: S-mode, O-mode and T-mode. By analyzing the equilibrium solution, and the analysis of the profit change of the interested parties, the following conclusions are obtained:

1) The total profit of the supply chain in T-mode is the highest, followed by O-mode. This means that the cooperation of supply chain members will promote the supply chain to realize higher benefits.

2) The level of supplier's optimal quality management, the level of platform's big data marketing efforts, and the level of marketing efforts of the head of the group are the highest in O-mode. The profit of suppliers and group leaders under this model increases, and the overall profit of the supply chain is also better than the S model. This means that when the community group-buying supply chain invests in big data information services, the cooperative investment between suppliers and headmen is beneficial to the supply chain system to achieve a win-win situation in the long run. When certain conditions are met and at the same time, the supply chain members have a certain negotiation ability that makes the profit gained under the cooperative investment mode greater than the supplier's individual investment mode, the supplier and the head can obtain the optimal profit value.

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