RESEARCH ON OPERATING MECHANISM FOR CREATIVE PRODUCTS SUPPLY CHAIN BASED ON GAME THEORY

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Abstract. In order to solve the problems of insufficient resource utilization, high cost and overstocking of commodities in the creative products supply chain, this paper establishes a supply chain enterprises operating mechanism model from the perspective of game theory, uses repeated game, individual game and group of evolutionary game, verifies the importance of cooperation in creative products supply chain through theoretical proof and examples, puts forward the method to make a win-win game party, and finds the way to coordinate supply chain.

1. Introduction. With the development of science and technology, peoples living standard is rising, and demands and tastes are also changing. Creative products, as one of the necessities of high quality life, get the favor of the masses of consumers gradually. According to the response in the commodity market, creative products suppliers, manufactures and retailers are emerging. Therefore, it is a major concern to deal with the relationships between various enterprises appropriately.

Creative products have the characteristics of short life cycle and rapid market response, so their manufacturers and retailers need to transfer the products to the downstream in a short time to obtain ideal profits. The longer the dead time is, the lower the goods value will be. Besides, with the increase of time, commodity warehousing costs will also increase. Thus each enterprise makes efforts to transfer creative products rapidly. (For instance: cutting price, advertisement, after service, etc.).

Protocol creative products supply chain mode is “supplier → manufacturer → retailer → consumer”, and there are game relations among the enterprises. If all of them consider only their own interests to choose operation plan, Nash equilibrium, and even the prisoner’s dilemma will occur. This paper uses repeated game, individual game and group of evolutionary game, verifies the importance of cooperation in creative products supply chain, puts forward the method to make win-win game party, and finds the way to coordinate supply chain.

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2. Literature review. About game theory, there are already a lot of people have done research in this field. Literature [35] studied individual game and group of evolutionary game, and put forward a method to enhance the cooperation efforts. It has widely used in many fields such as wireless networks [4, 19, 25, 40], conflict analysis [17], evolutionary theory [7, 10], supply chain management [2, 31, 39], cognitive radio networks [12, 20, 28, 37], Intelligent Patrolling [1], streaming traffic management [33], power control [9, 26, 29], urban public traffic networks [32], Process evaluation [16, 24, 27, 30], and so on. However, this paper didn’t make the discussion on indirect game parties. Literature [11] used game theory to study reversing supply chain pricing strategy, obtained two non-cooperative games equilibrium and a cooperative game equilibrium, analyzed the efficiency of various pricing strategies, and eventually concluded that “when manufacturers are the leaders and retailers are the followers, the recycling price is optimal”. But because the reverse supply chain system is based on a single manufacturer and a single retailer, it does not apply to the problem of multiple manufacturers and retailers. Literature [5, 15, 14] used intelligent algorithms to search, and improved the global optimal search method. Literature [14] introduced antibody concentration inhibitory mechanisms and immune memory function of immune algorithm into BPSO (Basic Particle Swarm Optimization), and put forward the IPSO (Immune Particle Swarm Optimization) to solve Nash Equilibrium Problem, it can solve n-person non-cooperative game Nash equilibrium problem well. Besides, the algorithm is simple, easy to implement, and can find the optimal solution quickly. Literature [5] used Stackelberg game based on bidding mechanism, put forward resource allocation strategies to solve single relay node for multi-user node collaboration bandwidth allocation problem. Literature [6] used intelligent algorithms and cooperative game to research the transmission loss allocation. Literature [3] put forward the peaking hydroelectric generating cost-sharing method based on cooperative game theory, analyzed the monotonicity, super add features and convex game features of the sharing mechanism. Besides, it put forward some methods to overcome the combinatorial explosion problem in Shapley value calculation, analyzed and validated the validity of the allocation method by simulation. Literature [8, 13, 15, 18, 21, 34, 38] systematically introduced the basic ideas and operation method of game theory, and expounded with examples vividly. Based on the consistency algorithm, literature [3] studied decisions which are related to the liquefied natural gas (LNG) project work in the framework of game theory, and reduced the investment risk. Literature [23] used game theory to analyze the cooperation and non-cooperation behaviors in operation environment, and considered that the doctor who knew game theory can understand and manipulate complex operating system better, so as to provide a better medical service.

On the basis of predecessors’ researches, this paper bases upon the characteristics of creative products, combines repeated game and group of evolutionary game, studies the relationship among suppliers, manufacturers and retailers, and proposes creative products supply chain operation mechanism works program at last, thus solves the problems of waste and the cost of backlog in supply chain.

3. Operation mechanism based on game theory.

3.1. Analysis of the problems of creative products and its characteristics. Creative products supply chain is a Complex Adaptive System (CAS), which is in a constantly changing dynamic process. The manufacturers need to modify their behavior strategies according to the previous behavior effect. Because of the drive
of interests, manufacturers interact with each other, and take interactions according to the local information which they have mastered. When they are participating in activities, it is hard to avoid making mistakes for manufacturers, and result in some problems such as waste of resources, increased costs and product backlog. The supply chain management of creative products which are combined with several popular markets is often more complicated than functional products. It has the following features:

1) Short life cycle of products. Products design reflects the characteristics of popular elements in the period which products are being sold. With the progress of the product technology, the products will be replaced by new products quickly, so the products sales cycle may be very short and changes from season to season.

2) Strong uncertainty of the environment. Creative products supply chain, which is difficult to predict its development in the future, has characteristics of technological uncertainty, market uncertainty and competition volatility.

3) Quick response of the market. Creative products have high additional value but the value declines quickly. If the listed time delays or has been delayed, it will lead the product value goes into a recession and even result in large backlog until scrapped.

Creative products characteristics can be specifically expressed in figure 1:

![Creative product features](image)

**Figure 1. Creative product features**

As a result of above characteristics, the shorter the time of creative products from production to consumers is, the more obvious of the popular element characteristics it embodies, and the more profit will be generated by the supply chain.

3.2. **The model for operation system process.** Game Theory is mathematical theories and methods which study competitive phenomenon, it considers individual
predictable behavior and actual behavior in the game, and studies their optimization strategy.

Game theory includes non-cooperative game and cooperative game, this paper uses the thought of cooperative game, assumes that the creative products supply chain enterprises game is Super additive game (which is: the overall interests of the union are greater than the sum of the individual interests), and studies its operation mechanism by modeling.

First of all, this paper takes examples of different manufacturers retailers, illustrates the importance of cooperation referred by the model in literature [35]. In the same way, this paper deduces the importance of cooperation in different or same suppliers manufacturers. Then, this paper deduces the importance of cooperation in enterprises which are in the same product line by applying this model. Finally, this paper concludes that “cooperation is the key for the creative products supply chain enterprises to make profit”. At the same time, this paper puts forward methods to promote supply chain enterprises cooperation, and solves the problems such as resource waste, cost increase and the backlog of goods, and finds a way to coordinate supply chain.

(1) The individual game of enterprises

In the individual game of partners and non-partners, assuming that there are two strategies for game party 1 and party 2 to choose: cooperation (C) or non-cooperation (D), as shown in table 1, between them, $c > d > 0$.

|      | C   | D   |
|------|-----|-----|
| C    | (c,c) | (0,d) |
| D    | (d,0) | (d,d) |

Assume that in a game, if both sides cooperate the benefits are both c; if one party cooperates but the other party does not cooperate, the benefits of the former is 0, and the latter is d; if both sides do not cooperate, both sides gain benefits of d. Obviously, if both sides choose to cooperate, the parties can gain maximum profits, and the Pareto optimal is achieved. But it is easy to find that the cooperative party will get nothing if the other party does not cooperate, whereas the interests of the party which does not choose cooperation is guaranteed, so choose cooperation has great risk. For the game party, it is not the best choice to cooperate without knowing the other’s decisions. If the game party expects that other game parties use the two strategies at the same probability, the risk of selecting cooperation is bigger, so the cautious often choose not to cooperate. The probability of both sides choose not to cooperate is greater than the probability of cooperation, and when both sides choose not to cooperate, it reaches Nash equilibrium.

(2) The group of evolutionary game of enterprises

In the above static individual game, the cooperative party is at a disadvantage. But in real life, creative products supply chain enterprises often need cooperation to use resources effectively and reasonably, save cost, and avoid the backlog of goods. Therefore, this paper expands the static individual game model into the group of evolutionary game model.

When group of evolutionary game follows individual evolutionary game, the individual hypothesis in the game still valid: if both sides cooperate the benefits are both c; if one party cooperates but the other party does not cooperate, the benefits
of the former is 0, and the latter is \( d \); if both sides do not cooperate, both sides gain benefits of \( d \).

Assumes that the retailer’s total number is \( M \), and turns it into \( n \) groups (according to the manufacturer they belong to, namely the number of producers is \( n \)), each group has retailers. Set \( m_i = m \) The parties in group game have two strategies to choose: cooperation and non-cooperation. Use \( P \) to represent the total proportion of collaborators, \( p \) to represent the proportion of collaborators in each group.

According to the hypothesis, the number of the cooperative retailers in the group is \( m_i \times p \), number of the uncooperative is \( m_i \times (p - 1) \). During a game interaction, the expected interest (average interest) each cooperative retailer can get from other retailers is \( mp - 1 \times c \), and the expected interest (average interest) each uncooperative retailer can get from other retailers is \( d \). That is, each cooperative and uncooperative retailers expect interest (average interest) in a game interaction respectively are

\[
E_c = \frac{mp - 1}{m - 1} \times c. \tag{1}
\]

\[
E_D = d. \tag{2}
\]

Where \( c > d > 0 \).

From Darwin’s biological evolution theory and survival of the fittest in the law of nature, we know only the retailers who obtain higher profits can survive in active products sales market for a long time. Assume that after a game interaction, the new group size is \( m' \), then

\[
m' = pmE_c + (1 - p)mE_D = pm \times \frac{mp - 1}{m - 1} \times c + (1 - p)m \times d = \frac{m^2 p^2 - mp}{m - 1} + (1 - p)m \times d. \tag{3}
\]

Set the proportion of altruistic behaviors after an interaction in the group is \( p' \), and \( p' \) is expressed as follows:

\[
p' = \frac{pmE_c}{m'}. \tag{4}
\]

After an interaction, set the first \( i \) groups group size is \( m'_i \), the proportion of altruistic behaviors (the cooperators) in the group is \( p'_i \), then after a game interaction, the total quantity of the group becomes \( M' = \sum_{i=1}^{n} m'_i \), the total proportion of cooperators is \( P' \), from the previous hypothesis, this game is homogeneous group (\( m_i = m \)), then:

\[
M' = \sum_{i=1}^{n} \left[ \frac{m^2 p_i^2 - mp_i}{m - 1} \times c + (1 - p)m \times d \right]. \tag{5}
\]

\[
p' = \frac{\sum_{i=1}^{n} m'_i p'_i}{M'} = \frac{pmE_c}{m'}. \tag{6}
\]

From the assumptions and formulas (6), we can know that:

\[
\frac{P'}{P} = \frac{\frac{pmE_c}{m'}}{p} = \frac{mE_c}{m - 1} = \frac{mE_c}{m'}. \tag{7}
\]

So, so as to make \( P' > P \), \( \frac{P'}{P} = \frac{mE_c}{m'} > 1 \) is needed. If we substitute (1) and (3) into (7), we can get:

\[
\frac{mp - 1}{m - 1} > \frac{d}{c} \tag{8}
\]

That is:

\[
P' > P \iff \frac{mp - 1}{m - 1} > \frac{d}{c}. \tag{9}
\]
Use $M$ to represent the total number of manufacturers in the above model, and turn it into $n$ groups (according to the suppliers the CPU or other raw materials belong to, namely the number of CPU suppliers is $n$), and each group has $m_i$ producers. Then we can create manufacturers operating mechanism model similarly, and the principle and the conclusion are consistent with the retailers operating mechanism model. So this paper will not repeat modeling.

According to the different product lines, this paper divides manufacturers in the supply chain into $n$ groups (that is, there are $n$ kinds of creative products), and each group has $m_i = 3$ enterprises (i.e., suppliers, manufacturers, retailers). The total number of enterprises in the creative products supply chain is $M$ (because $m_i = 3$, we can obtain $M = 3n$). Then we can use the above model to analyze the operation mechanism of suppliers, manufacturers and retailers at the same time, finally come to a conclusion that only when enterprises in the supply chain cooperate, can the benefits be maximized. Due to the similar principle, this paper will not elaborate too much.

4. Case study.

4.1. The simulation process. The smart phone is a typical example of creative products. More and more companies want to share the mobile phone market, and makes competition increasingly fierce. With the development of technology, they are making efforts on both hardware and software of the smart phone. Operating system is constantly updated, processor is evolved from a-core, dual-core to quad-core, the appearance is gradually improved, as well as the memory, the GPU, camera, battery and so on, makes the smart phone market change constantly.

Smart phone enterprises competition is mainly from the following three aspects: the first is advertising, to increase brand awareness; the second is the hardware and software to ensure product quality; and the third is the product price. And it needs cost to make advertising and research of the product, use the total income from advertising and research (price $\times$ quantity) minus its cost, is the profits. Obviously, with the investment of cost and the concessions of price, sales will increase, but not the profits. If the enterprises invest and reduce the price blindly, the profits may be reduced and even lead to deficit.

With the decay of Nokia and Motorola, Apple is prospering but can not pull it alone. And many domestic mobile phone businesses are booming. This paper bases on three domestic mobile phone manufacturers which are MIUI, MX and HTC ($n = 3$) and their retailers in Hangzhou to instantiate the model.

(I) Set $m = 10$, $p = 0.5$, $c = 0.6$, $d = 0.4$, then:

Expected interest of cooperative behavior is:

$$E_{C1} = \frac{10 \times 0.5 - 1}{10 - 1} \times 0.6 = 0.27$$

After interaction, the new group size is:

$$m'_i = \frac{10^2 \times 0.5^2 - 10 \times 0.5}{10 - 1} + (1 - 0.5) \times 10 \times 0.4 = 4.2$$

After interaction, the proportion of collaborators is:

$$P'_1 = \frac{0.5 \times 10 \times 0.27}{4.2} = 0.32 < p \Rightarrow P' < P$$
In this case:
\[
\frac{d}{c} = \frac{2}{3} > \frac{mp - 1}{m - 1} = \frac{4}{9}
\]

(II) Set \(m = 10, p = 0.5\) and others are the same to the first situation, and \(c = 0.8, d = 0.2\), then:
Expected interest of cooperative behavior is:
\[
E_{C2} = \frac{10 \times 0.5 - 1}{10 - 1} \times 0.8 = 0.36
\]
After interaction, the new group size is:
\[
m'_2 = \frac{10^2 \times 0.5^2 - 10 \times 0.5}{10 - 1} + (1 - 0.5) \times 10 \times 0.2 = 3.2
\]
After interaction, the proportion of collaborators is:
\[
p'_2 = \frac{0.5 \times 10 \times 0.36}{3.2} = 0.56 > p_1 \Rightarrow P' > P, p'_2 > p'
\]
In this case:
\[
\frac{d}{c} = \frac{2}{3} > \frac{mp - 1}{m - 1} = \frac{9}{19}
\]

4.2. **Analysis and discussion.** Table 1 shows that when both the game parties choose cooperation, the total profits is maximum, as \(c + c = 2c\). When it is applied into group of evolutionary game, the bigger the proportion of cooperation is, the bigger the total profits are. That is, in the view of the whole creative products supply chain, only choose to cooperate will the interests of the whole supply chain be biggest. However, game parties prefer choosing not to cooperate and get certain guarantee to cooperation because of the lack of transparency and the limited level of trust among them.

From the formula (1), we can get \(E_C = \frac{mp - 1}{m - 1} \times c \leq c\). That is to say some game parties do not choose cooperation \((p \leq 1)\) makes the total profit be reduced. From model instance (I) and (II), we know, in the condition of constant \(m\), increasing the benefits of cooperation \((c)\) and reducing the benefits of noncooperation \((d)\) can improve the cooperation rate of the group (collaborators proportion in the group: \(P\)). And from model instance (I) and (III), we know, if \(c\) and \(d\) are unchanged but the game number \(m\) becomes bigger, then the group cooperation rate reduces. Namely as the game progresses, finally the game parties which still leave behind will become less and less.

Therefore, in creative products supply chain, because of the short product life cycle, the number of repeated game is more than other supply chain, only when enterprises (creative products supply chain enterprises) cooperate, can the benefits (the total benefits of the creative products supply chain) be maximized. If suppliers cooperate, the procurement of raw materials will be simplified, and the cost will be reduced, and the saved cost can be transferred to suppliers. So, the suppliers can get the same or even more interests than uncooperative ones, while manufacturers can save manpower, financial resources and time.

If manufacturers cooperate, they become more initiative when buying raw materials, and can save some advertising costs. And if they share the market information, they can grasp customer needs timely, and manufacture suitable number of proper products to satisfy consumers, consequently reduce the backlog of goods.
If retailers cooperate, they can reduce the promotion cost, find more potential customers, reduce the backlog of goods, and shorten the dead time.

If supply chain enterprises cooperate, the upstream can receive the feedbacks of market information from the downstream timely, and use the appropriate raw materials to produce the appropriate products to meet consumers demands. Thus, the use of resources is reasonable, total cost of supply chain is reduced, and dead time is lower. The interests of the whole creative products supply chain will be increased, and Pareto optimality is closer.

Methods to promote cooperation awareness are as follows:

First, increase the punishment for non-cooperators. Such as, set the upper limit on advertising and set the lower limit on price (especially when deal with economies of scale), the punishment which violators receive will be greater than the benefits they gain from violation. Thus, on the one hand, it will ensure that enterprises will not cost too much to attract customers, also put an end to situation that undesirable businessman contrary to convention to surpass their peers; on the other hand, it will increase the benefits of cooperation indirectly, so that the enterprises cooperation awareness will also increase.

Second, set up cooperation mechanism to promote group game cooperation, such as supervision mechanism, social benefit mechanism, reputation mechanism and so on.

In addition, we can use SPA marketing mode or multi-brand collection shop mode [22] to improve the transparency of different products, make more information be public, thus it is conducive for creative products supply chain enterprises to make wise decisions.

5. Conclusions. According to game theory, this paper verifies the importance of cooperation in creative products supply chain through theoretical proof and examples, and finds the way to coordinate supply chain. It should be noted that this paper conducts a qualitative analysis mainly on the creative products in the supply chain cooperative relations. To carry on the quantitative analysis, a new model will be needed to build. Anyone who is interested in this issue will always be welcome to continue an in-depth study.

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