Research on supply chain competition advantage under repeated games

Yu Yue[1]*, Hu Yong-shi[2], Xu Ming-xing[1, 3]

[1]*School of Economics & Management, Fuzhou University, Fuzhou City, Fujian Province, China, 350108*

[2]*Department of Traffic and Transportation, Fujian University of Technology, Fuzhou City, Fujian Province, China, 350108*

[3]*Concord University College of Fujian Normal University, Fuzhou City, Fujian Province, China, 350117*

Received 8 January 2014, www.tsi.lv

Abstract

To reveal whether the order of supply chains' competition exerts an effect on the their profits and whether the repeated game interferences this effect, the paper builds a Stackelberg game model constructed by two supply chains with each containing a supplier and a retailer based on the previous studies. Through comparing respective profits of the leading and following supply chain represented by 'Copycat', this paper concludes that the following supply chain is more likely to gain more profits than the leading one in this case, and this advantage is determined by the order of decision-making itself. Under repeated games, the possibility of the following supply chain to be more profitable and the approaches to make decisions will be related to the substitutable coefficient.

Keywords: leading-following supply chain, Stackelberg game, repeated games, later-mover advantage

1 Introduction

Along with the development of economy in China, the competitions between the enterprises have become the rivalries between the supply chains. In the real market, some leading companies in the industry often dominate in the decision-making and set up the standards for the smaller companies to follow. In other words, the competition between supply chains is actually the competition between leading and following supply chains. Tengxun, which built up by imitating ICQ, provides a good example. A game called 'vegetable stealing' launched in Kaixin network was once a sweeping trend in the virtual community, followed by QQ farm which has similar features. It turned out that Tengxun achieved an outright win in this battle with Kaixin network, ending up taking over it reversely. Another prototypical example is that the copycatting mobile phones, which participate in the competition with low pricing strategy, have strongly impacted the industry and hit the brand products when they entered the market. However, the copycatting netbooks are not in a close game, the low shipments and profit margin, the long cycle length as well as the high risk are the contributing factors to the bankruptcy of new entrants who have been forced to retreat from the market. Even within the copycatting industry, the results of market selection and elimination can be widely divergent. For instance, Tianyu, once an unknown manufacturer, which started out doing copycatting products, used to be one of the most promising emerging domestic mobile phone brands due to its rapid growth of market share. Its sales volume once outnumbered those of Samsung, Sony Ericsson, Motorala and LG. However, some brands such as TCL, Konka and Bird might enjoy the popularity for a time but they were doomed to fail and eventually disappeared from the scene. Therefore, a clear understanding of the main competition mechanism and the profit analysis of the leading and following supply chain is of significant importance to companies that participate in this fierce competition, especially for those being dominated.

The research on the competition mechanism between the supply chains can be divided into two categories including single game and repeated game. Abundant theoretical results regarding research on the single game between leading and following supply chains have been obtained. According to Yang Daojian and Qi Ershi [1], through the analysis of the effect of the product substitution degree has on the overall profit of the supply chain in the competitive environment, the extent to which this effect influences the information sharing can be assessed. Based on Zhang Jianghan and Yuan Zuofang [2], by comparing the performance of the Bertrand game conducted among different supply chains under the market demand of power function structure, a conclusion that traditional 'the first-mover advantage' could not hold can be drawn. Although this literature provides a good insight on analysing competition and performance between supply chains, the authors failed to consider the fact that not all companies are doing the game at the same time because leading companies are more likely to make decisions in advance, leaving other smaller companies no

* ***Corresponding author*** e-mail: yu_fish86@126.com

choices but to follow. As such, the paper still needs to be improved. A research conducted by Li Boxun [3] accentuates how to choose between centralized and decentralized strategy under the leading-following Stackelberg game and identifies the relationship between strategy selection and product substitution degree. This paper analyses the existing competition between the leading and following supply chains in the marketplace, however, it concerns more about the impact of business decisions made by each member in a supply chain has on the performance than unveiling the profit differences that result from the leading-following supply chain competition mechanism itself. Moreover, the authors also failed to discuss the consequences in the case where the market demand is uncertain.

Researches on repeated game between the leading and following supply chain are still relatively unnoticed, while more attention are paid to the repeated game within one single supply chain or between duopoly supply chains. A study conducted by Qi Guiqing [4] illustrates the competitive and cooperative relationship between the supply chains in a cluster network under the repeated game. Besides, through the application of the dynamic repeated game theory, this paper carries a prudent study on the members of one single supply chain among the various supply chains in a cluster network; it also demonstrates the competing and cooperating status of node firms in the parallel supply chains with the same value chain and illustrates the conditions of the cooperative equilibrium. According to Wang Ruoying and Chen Hongmin [5], the dynamic contact equation has been confirmed under the repeated game in the duopoly market. Moreover, a conclusion that the outcomes of the finitely repeated game will deviate from the Nash equilibrium to cooperation is verified. Through analysing repeated game towards synergistic competing and collaborating relationship between the node firms in a supply chain under the conditions of asymmetric information, Yan Guangquan [6] obtains a payoff matrix in relation to the likelihood of cooperation among the node firms and proposes a hypothesis regarding the settings of the ruthless strategy and incentive mechanism under the repeated game.

Based on the previous studies, this paper seeks to build a Stackelberg game model constructed by two supply chains with each containing a supplier and a retailer. By comparing revenues generated from the existing leading-following supply chain in a common market, the paper aims to demonstrate whether the competition mechanism has an effect on the supply chain revenues and to discuss whether it will continue its influence under the repeated game in order to provide the following companies with future references.

2 Model assumptions

This paper analyses the leading-following supply chain competition in the real market. To further discuss the main impact of the supply chain competitive mechanism has on the profits and to eliminate the interference of corporate decision-making in the supply chain such as information sharing, the study is under the condition of complete information where the game between leading-following supply chains takes place; this means that retailers would always faithfully report the market demand to the suppliers. Ideally, each supply chain includes a supplier S and a retailer R. As such, this article assumes that supply chain *i* (SCi) is the leading supply chain that dominates the market to make the first moves, while supply chain *j* (SCj) is the following supply chain that observes and follows the trend accordingly. In other words, both of them are participating in the Stackelberg game. Hypothetically, suppliers on these two supply chains offer products to the retailers with price w_i, w_j respectively, and accordingly their retailers provide consumers with the retailing price p_i, p_j, while the market demands present q_i, q_j correspondingly. The structures of these two supply chains are shown below.

$$\begin{array}{l} S_i \xrightarrow[q_i]{w_i} R_i \xrightarrow[q_i]{p_i} C \\ S_j \xrightarrow[q_j]{w_j} R_j \xrightarrow[q_j]{p_j} C \end{array}. \tag{1}$$

Based on the principles of economics [7], this paper assumes that the basic needs of the market are corresponding to a linear uncertain demand,

$$q_i = \alpha_{Di} - p_i + \gamma * p_j , \quad q_j = \alpha_{Dj} - p_j + \gamma * p_i , \tag{2}$$

where γ represents the alternative coefficient of the two price supply chains while α_D acts as the initial needs of the market. As such, the dynamic contact equation is as follows.

$$\begin{array}{l} \alpha_{Dj}^1 = \alpha_{Di}^1 = \alpha_D \\ \alpha_{Dj}^{t+1} = \alpha_{Dj}^t - \dfrac{p_j^t - p_i^t}{2}, \quad t = 1, 2, ..., n . \\ \alpha_{Di}^{t+1} = \alpha_{Di}^t - \dfrac{p_i^t - p_j^t}{2}, \quad t = 1, 2, ..., n \end{array} \tag{3}$$

Recording Π as the revenues that correspond to each part, as such the retailer's earnings are as follows:

$$\Pi_{Ri} = (p_i - w_i) * q_i , \quad \Pi_{Rj} = (p_j - w_j) * q_j . \tag{4}$$

Suppliers' earnings are:

$$\Pi_{Si} = w_i * q_i , \quad \Pi_{Sj} = w_j * q_j . \tag{5}$$

Supply chain overall revenues are:

$$\Pi_{SCi} = \Pi_{Si} + \Pi_{Ri} , \quad \Pi_{SCj} = \Pi_{Sj} + \Pi_{Rj} . \tag{6}$$

3 Model solutions of repeated games

After observing the pricing and sales of leading supply chain *i*, supply chain *j* will make the decisions correspondingly; later in the supply chain *i / j*, given the wholesale price of supplier *i / j*, the retailer *i / j* then will make the decisions accordingly.

So reverse induction is used to calculate the maximum benefits of the retailer *j*, that is $\Pi'_{Rj}=0$, it can be formulated as follow:

$$p_j^t=\frac{\alpha_{Dj}^t+\gamma * p_i^t+w_j^t}{2}. \tag{7}$$

To maximize the benefits of supplier *j*, that is when $\Pi'_{Sj}=0$, therefore

$$w_j^t=\frac{\alpha_{Dj}^t+\gamma * p_i^t}{2}. \tag{8}$$

Substituting equation (7) into equation (8) it can be obtained that,

$$p_j^t=\frac{3}{4}(\alpha_{Dj}^t+\gamma * p_i^t),\ q_j^t=\frac{1}{4}(\alpha_{Dj}^t+\gamma * p_i^t). \tag{9}$$

For retailer i, given that:

$$q_i^t=\alpha_{Di}^t-p_i^t+\gamma * p_j^t. \tag{10}$$

In order to maximize the benefits of retailer i, that is when $\Pi'_{Ri}=0$, it can be obtained that

$$p_i^t=\frac{\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t+(1-\frac{3}{4}\gamma^2)w_i^t}{2(1-\frac{3}{4}\gamma^2)}. \tag{11}$$

Based on the results summarized above in reverse order, we forward projected and substituted equation 3-5 into supplier *i*'s revenue equation expression. According to the principle of maximizing the interests of supplier *i*, that is when $\Pi'_{Si}=0$, it can be obtained that

$$w_i^t=\frac{\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t}{2(1-\frac{3}{4}\gamma^2)}. \tag{12}$$

Substituting equation (12) into equation (11), it can be obtained that

$$p_i^t=\frac{3}{4}\frac{(\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t)}{(1-\frac{3}{4}\gamma^2)},\ q_i^t=\frac{1}{4}(\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t). \tag{13}$$

Therefore, the revenues of each part of the supply chain *i* are:

$$\Pi_{Si}=\frac{(\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t)^2}{8(1-\frac{3}{4}\gamma^2)},\quad \Pi_{Ri}=\frac{(\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t)^2}{16(1-\frac{3}{4}\gamma^2)},\quad \Pi_{SCi}=\frac{3(\alpha_{Di}^t+\frac{3}{4}\gamma\alpha_{Dj}^t)^2}{16(1-\frac{3}{4}\gamma^2)}. \tag{14}$$

Substituting the result of equation (13) into equation (9), it can be obtained that

$$p_j^t=\frac{3}{4}\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)},\quad q_j^t=\frac{1}{4}\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)},\quad w_j=\frac{1}{2}\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)}. \tag{15}$$

Therefore, the revenues of each part of the supply chain *j* are:

$$\Pi_{Sj}=\frac{1}{8}\left[\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)}\right]^2,\quad \Pi_{Rj}=\frac{1}{16}\left[\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)}\right]^2,\quad \Pi_{SCj}=\frac{3}{16}\left[\frac{(1-\frac{3}{16}\gamma^2)\alpha_{Dj}^t+\frac{3}{4}\gamma\alpha_{Di}^t}{(1-\frac{3}{4}\gamma^2)}\right]^2. \tag{16}$$

According to equation (3), it can be concluded that

$$\alpha_{Dj}^{t+1}=\frac{(\frac{5}{8}+\frac{9}{32}\gamma-\frac{87}{128}\gamma^2)\alpha_{Dj}^t+(\frac{3}{8}-\frac{9}{32}\gamma)\alpha_{Di}^t}{1-\frac{3}{4}\gamma^2},$$

$$\alpha_{Di}^{t+1}=\frac{(\frac{3}{8}-\frac{9}{32}\gamma-\frac{9}{128}\gamma^2)\alpha_{Dj}^t+(\frac{5}{8}+\frac{9}{32}\gamma-\frac{3}{4}\gamma^2)\alpha_{Di}^t}{1-\frac{3}{4}\gamma^2}. \quad (17)$$

4 Analyses of product substitutable factor and initial market demand

By comparing the respective profits of the leading and following supply chain, this article targets the revenue difference as the objective function to achieve the equation shown below.

$$F(\text{t},\gamma)=\Pi_{SCj}-\Pi_{SCi}=\text{p}_j^t\,q_j^t-p_i^t q_i^t. \quad (18)$$

4.1 INFLUENCE OF PRODUCT SUBSTITUTABLE FACTOR

Substituting the objective function and dynamic contact equation into MATLAB to iterate repeatedly for 50 times, the outcome can be seen in the following diagrams. To calculate conveniently, we assign value 1 to the initial demand α_D. Besides, for the purpose of distinguish one from another readily, the blue lines in the figures are used to represent the game proceed from the 7th to the 50th.

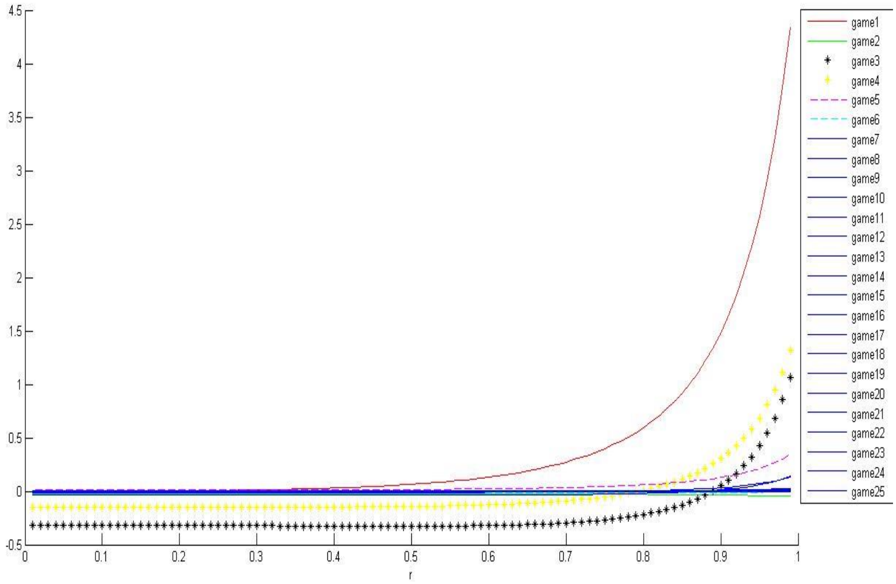

FIGURE 1 Games repeated 25 times while initial demand is 1

As it can be seen clearly from the chart, when the product substitution coefficient $\gamma\in(0,\ 0.5)$, which means the products of two supply chains do not possess high similarity, it is difficult to achieve a higher profit or late-mover advantage via competitions. This result is consistent with our cognition that rivalry is not likely to occur between supply chains that yield different types of products.

When the product substitution coefficient $\gamma\in(0.5,\ 0.9)$, that is, the products generated from two supply chains have relatively high similarity, the following supply chain is able to take advantage of the late moves in an extremely limited number of the game, and moreover this advantage will be offset or even outstripped by the revenue effects resulted from the price differences. Consequently, the profits of the first-mover and the late-mover supply chain will reach an equilibrium state.

When the product substitution coefficient $\gamma\in(0.9,\ 1)$, which means there are striking similarities in the products of two supply chains (products can basically be considered to be identical), it is feasible for late-mover supply chain to observe the market responses aroused by the first movers in order to reduce the market uncertainty. This action enables the followers to attain more profits until a state of equilibrium is reached ultimately.

4.2 INFLUENCE OF INITIAL MARKET DEMAND

Considering the alterations of initial market demand, we assume the original demand α_D to be 1, 10 and 100, respectively. Substituting these values into the objective function to calculate over 25 iterations, the profits difference between leading and following supply chains can be acquired as exhibited in the following figures.

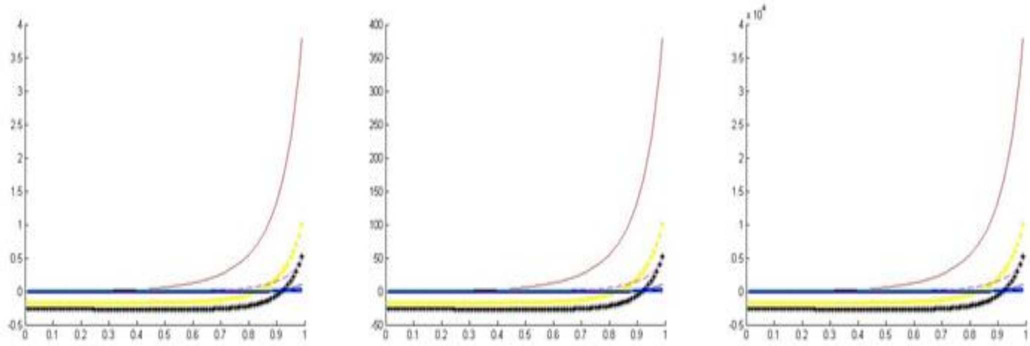

FIGURE 2 Games repeated 25 times while initial demand is 1, 10 and 100

The figure 2 reveals that the function curves of revenue differences between leading and following supply chains are not affected by the variations on the initial market demand, which means the changes are without impact on the late-mover advantage. However, the relationship between the values of profit differences and the alterations of initial market demand demonstrates the quadratic complexity. On the other hand, due to the deficiency of product awareness for the first entry into the market, the original demand of those followers is normally lower than that of the dominant ones. Given that the level of initial demand has no impact on the function curve of late-mover advantage, we presume the value of original demand of the leading and following supply chain to be 10 and 0-10, accordingly. The function curves are illustrated by the diagrams.

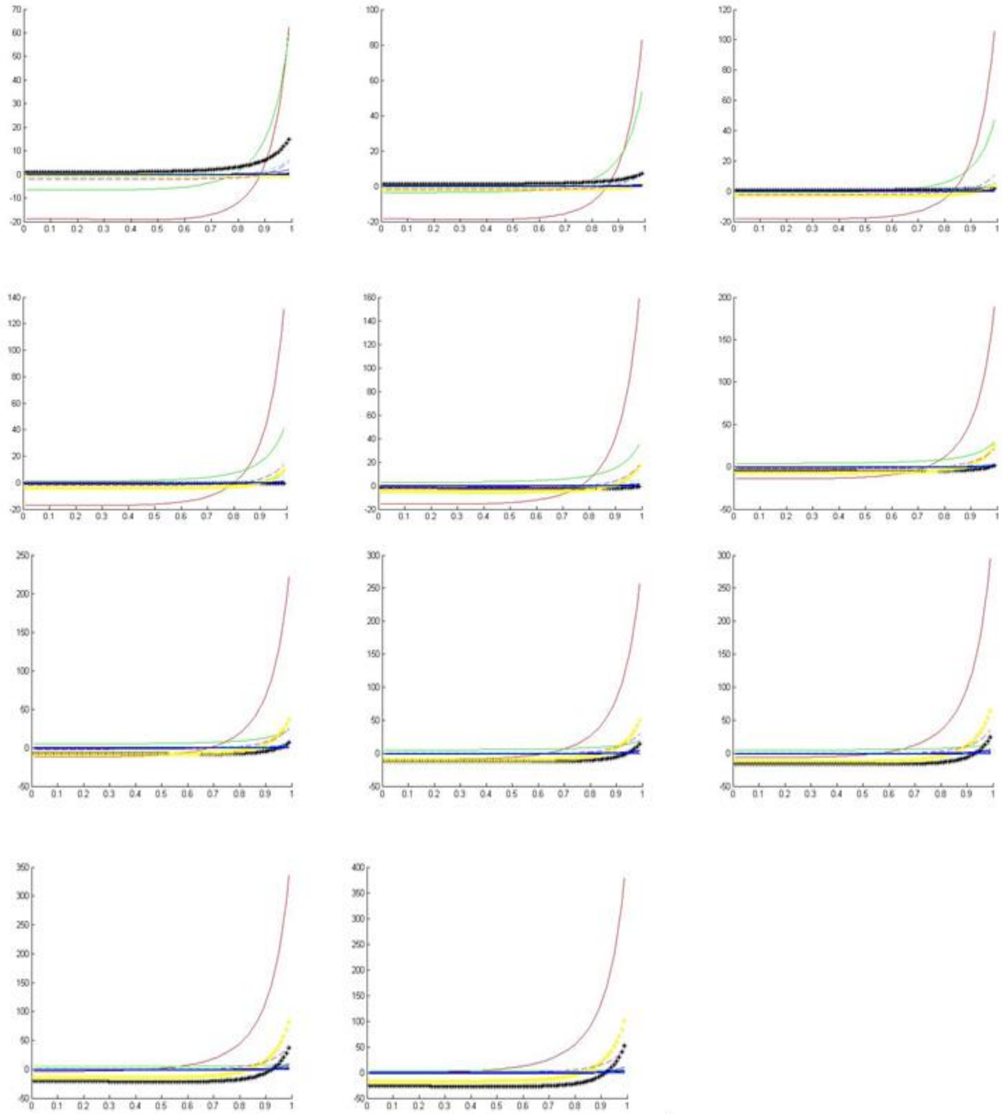

FIGURE 3 Games repeated 25 times while the initial demands of leading and following supply chain are 10 and 0-10 respectively

It can be obviously observed from the Figure 3 that the lower recognition of the following supply chains is while entering into the market, that is, the weaker the initial demand is, the less likely for them to attain the late-mover advantage on previous occasions of the game. However, as for long-term repeated game, the profits of leading and following supply chains will ultimately revert to the equilibrium state, verifying parts of conclusion in terms of product substitution coefficient as mentioned above.

4.3 ANALYSIS OF PRACTICAL PROBLEMS

As we go back to the copycatting issues proposed in the foreword, we can find out the causes behind the failure of copycatting netbooks to secure a competitive foothold in the marketplace and to duplicate the success of the copycatting mobile phones. The primary reason is that the attributes of copycatting netbooks with higher technical contents and greater differentiation are alien from those of the copycatting mobile phones, leading to the difficulty in imitating. Therefore, when companies are in a certain industry with high-tech or wide product differentiation, more efforts should be directed towards the technological innovation and R&D on products to distinguish themselves in the established industries through technological breakthrough rather than price competition.

Generally speaking, the profits of leading and supply chains will ultimately achieve a balanced state in the case of repeated game, namely, the observation of information will counteract the late-mover advantage of the followers attained from surveying the market response and restricting the market ambiguity under the repeated game. Therefore, in order to secure the long-term success, both supply chains and enterprises are supposed to strengthen the awareness of innovation even in some industries with high product similarities such as mobile phone, battery and commodity, and additionally to further reinforce the late-mover advantage derived from the low price strategy in the preliminary stage of competition through imitative innovation.

5 Conclusions

By comparing the revenues of leading and following supply chains under the condition of repeated game, we can reach the following conclusions:

Generally, the later-mover advantage of the following supply chain has been seen in the leading-following supply chain competition. This is mainly because the following supply chain is able to observe the outcomes of the decisions and actions made by the leading supply chain, thereby reducing the market uncertainty to gain more revenues.

In the case of repeated game, whether the following supply chain is able to increase benefit and what takes to make proper decisions largely relate to the substitution coefficient γ. When $\gamma \in (0, \ 0.5)$, the difficulty in augmenting revenues or acquiring the late-mover advantage via competition enables each supply chain to concentrate on their own business to avoid unnecessary rivalry. When $\gamma \in (0.5, \ 0.9)$, the following supply chain can take advantage of the late moves, but in the long term companies ought to ensure the enhancement of the service and technology. When $\gamma \in (0.9, \ 1)$, through observing the market response of the leading supply chain, those followers are capable of decreasing the market uncertainty to achieve more profits. As such, costs on the marketing to compete with rivals should be increased. However, the respective revenues generated from the leading and following supply chains will reach an equilibrium state eventually, which means the late-mover advantage of the following supply chain obtained from observing the market reaction and lessening the market uncertainty will be offset by the information observation under the repeated game.

The change of initial market demand are without impact on the late-mover advantage and the relationship between the values of profit differences and the alterations of initial market demand demonstrates the quadratic complexity. The lower recognition of the following supply chains is while entering into the market, that is, the weaker the initial demand is, the less likely for them to attain the late-mover advantage on previous occasions of the game. And as for long-term repeated game, the profits of leading and following supply chains will ultimately revert to the equilibrium state.

The above conclusions provide a theoretical verification for some economic theories such as freebie and sunk costs and also offer inspiration for specific companies to make decisions. In the low product-differentiated industries, those followers who face the dilemma in entering or surviving in the business dominated by a certain number of leading companies with technological advantages can manage to decrease the market uncertainty through observing the consequences of the first moves taken by leading companies, and hence take advantages of appropriate later moves in order to develop the capabilities to catch up. Therefore, technological innovation and high quality of the products are the secure guarantees to the development and success of the copycatting industry in the long run.

Thru the comparison of revenues generated from the leading-following supply chains in the repeated game, a profound finding that the following supply chain can take advantage of the late moves, with profits and decision-making varying in relation to the product substitution coefficient, can be acquired. This can provide references for the further research regarding the competition between supply chains and for the followers that urge to gain footholds in the target market. However, there are still a number of incomplete information and multi-chains games in the real world that need to be taken into consideration in the future studies. Additionally, for further research it should also be interesting to investigate how to adjust reasonably the contracts offered by suppliers, how to boost the competitive advantages of a supply chain and how to coordinate effectively within a supply chain.

References

[1] Yang Daojian, Qi Ershi 2009 Product differentiation and information sharing under supply chain competition *Systems engineering and electronics* **31**(9) 2141-5 *(In chinese)*

[2] Zhang Jianghan, Yuan Zuofang 2010 Analysis of behaviour performance and competition mechanism between two supply chains *System Engineering* **28**(8) 81-4 *(In chinese)*

[3] Li Boxun, Zhou Yongwu, Wang Shengdong 2012 The longitudinal structure decision model between supply chains under Stackelberg game *The management of scientific research* **33**(12) 50-7 *(In chinese)*

[4] Qi Guiqing, Yang Xihuai, Li Sen 2006 Coopetition analysis of clustered network supply chain by repetitive game theory *Journal of North-eastern University* **27**(2) 233-6

[5] Wang Ruoying, Chen Hongmin 1998 Countermeasures of duopoly in repeated game: an experimental study *Quantitative and technical economic* **15**(11) 23-8

[6] Yan Guangquan, Wu Qinglie, He Yong 2008 Analysis of repeated game of supply chain coordination under asymmetric information *Industrial economy* **27**(2) 33-7 *(In chinese)*

[7] Choi S C 1991 Price Competition in a Channel Structure with a Common Retailer *Marketing Science* **10**(4) 271-97 *(In chinese)*

[8] Holt C A 1996 *Journal of Economic Perspectives* **10**(1) 193-203

[9] Pasternack B A 1985 *Marketing Science* **4**(2) 166-76

[10] Bernstein F, Federgruen A 2005 *Management Science* **51**(1) 18-29

[11] Zhou Y W 2007 *European Journal of Operational Research* **181**(2) 686-703

Author

Yu Yue, born in August, 1986, Fuzhou City, Fujian Province, P.R. China

Current position, grades: Ph. D. student of School of Economics & Management, Fuzhou University, Fuzhou, China.
University studies: received his Bachelor of Science from Nanjing University of Science and Technology in China. He received his Master of management from Fuzhou University in China.
Scientific interest: His research interest fields include logistics, supply chain management
Experience: He has completed four scientific research projects.

Hu Yong-shi, born in April, 1982, Fuzhou City, Fujian Province, P.R. China

Current position, grades: Teacher of Fujian University of Technology, Fuzhou, China.
University studies: received his Bachelor of Management from Fuzhou University in China. He received his Master of management from Fuzhou University in China. He received his Doctor of management from Fuzhou University in China.
Scientific interest: His research interest fields include logistics, supply chain management
Experience: He has completed twenty scientific research projects.

Xu Ming-xing, born in February, 1982, Fuzhou City, Fujian Province, P.R. China

Current position, grades: Ph. D. student of School of Economics & Management, Fuzhou University, Fuzhou, China; teacher of Fujian Normal University, Fuzhou, China.
University studies: received his Bachelor of Engineering from Fujian Normal University in China. He received his Master of Management from Fuzhou University in China.
Scientific interest: logistics and supply chain management, E-economics
Experience: He has completed a dozen scientific research projects and many academic papers.