The Research on the Competitive Advantage of Supply Chain under Demand Uncertainty

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Abstract: To reveal whether the order of supply chain competition exerts an effect on the profits of supply chains and whether the uncertainty of the market demand interferes this effect, we build a Stackelberg game model constructed by two supply chains with each containing a supplier and a retailer on the basis of previous studies. Through the comparison of revenues generated from the leading-following supply chain under the complete information game, we draw a conclusion that is different from the first-mover advantage of the traditional Bertrand game; that is, the following supply chain can benefit from the later-mover advantage, which is determined by the order of decision making itself and will not change as initial market demand or the degree of product substitution varies.

Key words: Leading-following supply chain, Stackelberg game, market demand uncertainty, later-mover advantage

INTRODUCTION

Due to the development of globalization and information technology, great changes have taken place in the present day business environment. The increasing market uncertainty and diversified demand have shortened the product life cycles and accelerated the products’ updating rates. Given the increasingly fierce market competition and rapidly changing market demands, the traditional mode of running companies independently is unable to meet today’s economic environment, tending to be replaced by a mode required more collaboration to reach a win-win situation. To rival against the competitors, enterprises need to develop close collaboration with partners in a supply chain and strengthen their competitive advantages rather than just focusing on the competition against individual enterprises. 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 among supply chains are actually the competition among leading and following supply chains. Therefore, a clear understanding of them a in competition mechanism of the leading and following supply chain is of significant importance to companies that participate in this fierce competition, especially for those being dominated.

Research on supply chain competition can be divided into two main categories including the studies towards the game among different node companies in an internal supply chain and the studies regarding the competition among different supply chain sundervarious market demand and environment.

Abundant theoretical results of the first category of research on internal supply chain have been obtained by discussing how to use price, service and other factors or select related contracting strategies to achieve a well-coordinated supply chain. For example, (Paseltan, 1985) firstly proposed the use of the return policy contract to coordinate behavior of suppliers and vendors from news boy problem. (Bernstein and Federgruen, 2005) pointed out that if the who lesaleprice and the repurchase price satisfy a linear relationship with the retail price, the supply chain can be coordinated. Zhou (2007) compared quantity discount policy in two different stages under the randomized market demand and asymmetric information.

The second category of study has extended the research scope from single-chain to double-chain or even multi-chain, not only taking the vertical competition within the supply chain into account but also the horizontal competition outside the supply chain. According to (Jian and Ersha, 2009) 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 and Yuan, 2010) 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 "first mover advantage" could not hold can be drawn. Although this literature provides a good insight on analysing competition and performance in a supply chain, the authors failed to consider the fact that not all companies are doing the same game at the same time because leading companies are more likely to make decisions in advance, leaving other smaller companies
no choices but to follow. As such, the study still needs to be improved. A research conducted by Boxun et al. (2012) accentuates how to choose between centralized and decentralized strategy under the leading-following Stackelberg game and identifies the relationships between strategy selection and product substitution degrees. This study analyzes the existing competition between the leading and following supply chains in the market place, however, it concerns more about the impact of business decisions of each node company in a supply chain has on the performance than unveiling the profit differences that result from the leading-following supply chain competition mechanism it self. Moreover, the authors also failed to discuss the consequences in the case where the market demand is uncertain.

Based on the previous studies, this study 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 more common market, the study aim is to determine whether the competition mechanism has an effect on the supply chain revenues and whether market demand uncertainty interferes this effect. Finally, a conclusion that is different from the view that leading supply chain would take advantage of first moves in traditional Bertrand game is drawn.

**MODEL ASSUMPTIONS**

This study analyzes 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, we assume that supply chain i (SCi) is the leading supply chain that dominates the market to make the first move, 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 \( w_i \) and \( w_j \), respectively and accordingly their retailers provide consumers with the retailing price \( p_i \) and \( p_j \) while the market demands present \( q_i \) and \( q_j \), correspondingly.

The structures of these two supply chains are shown below:

\[
S_i \xrightarrow{\alpha_i} R_i \xrightarrow{\beta_i} C \\
S_j \xrightarrow{\alpha_j} R_j \xrightarrow{\beta_j} C
\]

Based on the principles of economics (Choi, 1991), we assume that the basic needs of the market are corresponding to a linear uncertain demand:

\[
q_i = \alpha_i \cdot \gamma^* \cdot p_i, \quad q_j = \alpha_j \cdot \gamma^* \cdot p_j
\]

(1)

Where \( \gamma \) represents the alternative coefficient of the two price supply chains while \( \alpha_i \) acts as the actual needs of the market (that is, all prices were zero). There are \( \alpha_i \) (high initial demand) and \( \alpha_j \) (low initial demand) in both cases whereby the probabilities of each are \( b \) and \( 1-b \), respectivelySciicific:

\[
\alpha_i = \begin{cases} 
\alpha_i, & P(\alpha_i) = b \\
\alpha_j, & P(\alpha_j) = 1-b 
\end{cases}
\]

(2)

Recording \( \Pi_i \) as the revenues that correspond to each part, as such the retailer's earnings are as follows:

\[
\Pi_i = (p_i - w_i) \cdot q_i, \quad \Pi_j = (p_j - w_j) \cdot q_j
\]

Suppliers' earnings are:

\[
\Pi_i = w_i \cdot q_i, \quad \Pi_j = w_j \cdot q_j
\]

Supply chain over all revenues are:

\[
\Pi_{SCi} = \Pi_i + \Pi_{iSC}, \quad \Pi_{SCj} = \Pi_j + \Pi_{jSC}
\]

The expected revenues of supply chain are:

\[
E(\Pi_{SCi}) = E(\Pi_i) + E(\Pi_{iSC}), \quad E(\Pi_{SCj}) = E(\Pi_j) + E(\Pi_{jSC})
\]

MODEL SOLUTION

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\( f \), given the whole sale 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 i\( j \), that is \( \Pi_{iSC} \), we can get:

\[
p_i = \frac{\alpha_i \cdot \gamma^* \cdot p_i + w_i}{2}
\]

(4)

To maximize the benefits of supplier j, that is when \( \Pi_{jSC} \), we can get:
\[ w_i = \frac{a_0 + \gamma \cdot p_i}{2} \]  

(5)

Substituting Eq. 4 in to Eq. 5 we can obtain that:

\[ p_i = \frac{3}{4} (a_0 + \gamma \cdot p_0), q_i = \frac{1}{4} (a_0 + \gamma \cdot p_1) \]  

(6)

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

\[ \Pi_{bi} = \frac{3}{16} (a_0 + \gamma \cdot p_0)^2, \Pi_{bi} = \frac{1}{8} (a_0 + \gamma \cdot p_0)^2, \Pi_{bo} = \frac{3}{16} (a_0 + \gamma \cdot p_1)^2 \]  

(7)

For retailers i, given that:

\[ q = a_0 - \gamma \cdot p_0 = \frac{3}{4} a_0 - \frac{3}{4} \gamma \cdot p_0 \]  

(8)

In order to maximize the benefits of retailer, that is when \( \Pi_{bi} \), it can be obtained that:

\[ p_i = \frac{1}{4} \left( \frac{3}{4} \gamma \cdot a_0 + \frac{3}{4} \gamma \cdot p_0 \right), q_i = \frac{1}{4} \left( \frac{3}{4} \gamma \cdot a_0 - \frac{3}{4} \gamma \cdot p_0 \right) \]  

(9)

Based on the results summarized above in reverse order, we forward projected and substituted Eq. 9 in to supplier’s revenue equation expression. According to the principle of maximizing the interests of supplier j, that is when \( \Pi_{bo} \), it can be obtained that:

\[ w_i = \frac{a_0 + \frac{3}{4} \gamma \cdot a_0}{2 \gamma} \]  

(10)

Substituting Eq. 10 in to Eq. 9, it can be obtained that:

\[ p_i = \frac{1}{4} \left( \frac{3}{4} \gamma \cdot a_0 - \frac{3}{4} \gamma \cdot a_0 \right), q_i = \frac{1}{4} \left( \frac{3}{4} \gamma \cdot a_0 - \frac{3}{4} \gamma \cdot a_0 \right) \]  

(11)

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

\[ \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]  

(12)

Substituting the result of Eq. 11 in to Eq. 6, it can be obtained that:

\[ \Pi_{bi} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bi} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]  

(13)

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

\[ \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right), \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]  

(14)

**ANALYSIS**

By comparing the revenues of each part of leading and following supply chains, a result can be achieved through subtracting Eq. 14 and 12:

\[ \Pi_{bi} - \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) - \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]

\[ \Pi_{bo} - \Pi_{bo} = \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) - \frac{3}{16} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]

(15)

Revenue expectations for each part of both supply chains can be observed by substituting the Eq. 12 and 14 in to Eq. 3 that:

\[ \text{E}(\Pi_{bi}) - \text{E}(\Pi_{bi}) = \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) - \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]

\[ \text{E}(\Pi_{bi}) - \text{E}(\Pi_{bo}) = \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) - \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]

\[ \text{E}(\Pi_{bi}) - \text{E}(\Pi_{bo}) = \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) - \frac{3}{8} \left( \frac{117}{256} \gamma^2 + \frac{3}{8} \right) \]

(16)

It is obvious that b>0, 1-b>0,

\[ \frac{117}{256} \gamma^2 + \frac{3}{8} > 0 \]

Therefore:

\[ \text{E}(\Pi_{bi}) > E(\Pi_{bi}), E(\Pi_{bi}) > E(\Pi_{bi}), E(\Pi_{bi}) > E(\Pi_{bi}) \]

\[ \Pi_{bi} > \Pi_{bo}, \Pi_{bi} > \Pi_{bo}, \Pi_{bi} > \Pi_{bo} \]
CONCLUSION

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

- Conclusion 1. Unlike the first-mover advantage of leading supply chain in the traditional Bertrand game, 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.

- Conclusion 2. When the market demand is uncertain, the following supply chain will always be more profitable regardless of the changes with respect to the value of market demand \(\alpha_0\) and product alternative coefficient \(\gamma\). This means that the later-mover advantage is determined by the order of decision-making itself and is not likely to change as initial market demand or the degree of product substitution varies.

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. For those followers who face the difficulties in entering or surviving in an industry dominated by a certain number of leading companies with technological advantages, they can manage to reduce 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.

Thru the comparison of revenues generated from the leading-following supply chain in the complete information game, a profound finding that the following supply chain can take advantages of the later moves, which will not vary in relation to the changes in market demand, can be acquired. This can provide references for the further research regarding the competition among the supply chains and for those 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 the contracts offered by suppliers reasonably, how to boost the competitive advantages of a supply chain and how to coordinate effectively within a supply chain.

REFERENCES


