Study on the Decision Condition of Nodal Enterprise' Tacit Knowledge Conversion in Supply Chain in Multi Periods[*]

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Abstract:

Knowledge has been the most important engine of economy, and it can advance the enterprise's competitiveness, but the roles of tacit knowledge and explicit are different in enterprise's operation of supply chain. The mutual conversion of tacit knowledge and explicit knowledge in supply chain forms the spiral rising process of value creation. Tacit knowledge is the core factor. Considering the circumstance of knowledge content is negative linear correlation to costs in a two-echelon supply chain which is consists of multi manufacturers and multi retailers in multi periods, the paper studies on the decision conditions of nodal enterprise' tacit knowledge conversion, and gain the discount rate of their making tacit knowledge conversion decision in multi periods. At last a numerical example is put forward to explain the decision conditions.

Key Words: Supply chain, Tacit knowledge, Decision, Game theory

1. INTRODUCTION

With the development of market economy, the traditional mode of achieving economy growth that depends on the resources such as production, labor and other resources has been changed. Knowledge has been the most important engine of economy, and then formed the so-called knowledge economy. Knowledge has been often mentioned by people, but what is knowledge? It is difficult for many people to define it. On the other hand, supply chain has been paid more attention to by people, as it is consists of many nodal enterprises, such as manufactures, sellers, multi modal transporters. There are lots of knowledge management actions among them. In order to know the role of knowledge in supply chain, we need to understand what the knowledge is.

Knowledge of the nodal enterprise in supply chain is divided into exogenous knowledge (professional) and endogenous knowledge (occurring from practice). The exogenous knowledge refers to the purpose of organized scientific research, technological inventions, technology development and other activities created and accumulated by accepting the disseminated knowledge from other organizations or by knowledge spillovers. From the perspective of exogenous knowledge, we can see that the enterprise can acquire knowledge by learning from other organizations' introduction of technology. At this time, knowledge accepted from others is usually the effect of knowledge spillovers from the external knowledge networks. On the other hand, the extensive cooperation and technical union among enterprises can create and accumulate knowledge. The knowledge alliances among enterprises is a form of organization's knowledge innovation. Endogenous knowledge refers to the rational experience accumulated in the process of practice and the transaction, and continuous accumulation of knowledge through such processes. Seen from endogenous knowledge, we know that knowledge occurs from practice, that is so-called "Truth comes from practice", which is from the practice of knowledge sharing and trading among enterprises.

From the perspective of knowledge generation, we can gain knowledge from the communication among enterprises in supply chain, which has a higher degree of transparency. The general knowledge has been normative and standard, and which can be displayed by the means of physical form or data attached to the entity. Thus the uncertainty of the expected value is usually relatively small. While the opacity of knowledge acquired from the member enterprises is strong, or to be translucent. A lot of knowledge has not been full normative and standard, mainly in the form of making knowledge tacit. Although the uncertainty of the translucent knowledge's value is not strong, but once it does good to enterprises to create competitive advantage, the sustainability of this competitive advantage is often likely longer than the outsourcing of knowledge. There are characters such as causal ambiguity of knowledge for the outer competitors of enterprise. As for the opaque knowledge can only be identified within the smaller range in enterprise. Once it is converted into the source of

competitive advantage, its persistence will be stronger. The main purpose of knowledge sharing is to dig out the translucent knowledge and opaque knowledge to make knowledge innovation and form a sustainable competitive advantage for enterprises.

But how does the knowledge innovation occur and how does the process form? In fact knowledge can be divided into tacit knowledge and explicit knowledge. They play different roles in enterprise of supply chain. As the conversion process of them will advance the competitiveness. But people and enterprise in supply chain won't convert their tacit knowledge and explicit knowledge. The paper studied on the knowledge conversion conditions of nodal enterprise in supply chain with game theory models. And the author gave some models and conclusions about the knowledge conversion process.

2. LITERATURE REVIEW

2.1 Connotation of knowledge

In China, two explanations are given in Ciyuan Dictionary. First, met to see and know people; second, people'sunderstanding of things. Knowledge is defined as the results and crystallization of human knowledge in Cihai Dictionary, and it pointed out that human's knowledge is the reflection of reality and it is acquired in the social practice. The definition of knowledge in Modern Chinese Dictionary is that the sum of knowledge and experience in the practice of changing the world. We can see that knowledge include with human knowledge, understanding of the results of practice and experience.

In foreign countries, knowledge management has been paid more attention to by people, About the concept of knowledge, Nonaka (1994) considered that knowledge is a recognized faith belief, is created, organized and delivered by the knowledge holder and is the recipient's belief mode and constraints. At the same time it delivers the total cultural system and the related background system. Hedlund, (1994) believes that knowledge is the cognitive knowledge in people's minds and ideas, technology, and knowledge embedded in products, services or other carrier. The cognitive knowledge is the main experience of the surrounding environment, its existing form is a personal experience, which is the first hand knowledge to respond to environment and necessary to complete the work. The technology is the normative, embedded and disciplinary knowledge which is refined on the basis of cognitive knowledge. Davenport, ect. (1998) considered that knowledge is the mixture of experience, important value, contextualized information and insight which provides a framework for evaluation and integration of new experiences. Leonard, et al. (1998) considered that knowledge is the relevant and actionable information that is based upon experience and which is a subset of information, It is a concealed ingredients that is subjective, conscious act. O, Dell (1998) pointed out that knowledge is information put into action. Knowledge is the organizational staff's understanding about customers, products, procedures, past mistakes, successful experience, regardless of

whether it is tacit or explicit. Zack (1999) pointed out that the information become knowledge after understanding its rules. Seviby (1999) pointed out that knowledge has multifaceted significance, it can be referred as news, perception, knowing, cognition, intelligence, identification, science, experience, skills, insight, competence, know-how, learning and confirmation, etc. Its definition should be considered by the application of the content. And he pointed out that there are four characteristics about knowledge: ① Knowledge is tacit. ② Knowledge is action-oriented. ③Knowledge is supported by the law (practice).④ Knowledge is changed. And he put forward that competence represent the definition of knowledge. Long & Fahey (2000) pointed out that knowledge is a product of people's thinking and spirit, it is a kind of resources rooted in a particular individual or a collective, or embedded in a process, it is contextualized, knowledge is embedded in language, stories, concepts, rules and tools. Alavi (2001) divided the definition of knowledge into five categories such as state of mind, target, a process, information usage as well as capacity over the years, experts and scholars view's knowledge, then the definition of knowledge is different. Bhagat, Kedia, Harveston & Triandis (2002) considered that knowledge is gained from the unrelated information's changes, reconstruction and creation. Which is broader, deeper and richer than information or data is. Peter Drucker considered that knowledge is the information which can change some people or subject, which is different with general information, it include with the mode that cause the information to be a action, and the information used to make the individual or organization to have the ability to change behavior more effective.

So knowledge can be attributed to as a capacity carrier, which is a driving force to enhance the ability of corporate value. It has the characteristics such as awareness, dissemination, update and value creation. Knowledge is the flow combination of structured experience, the values associated with information and expert insight. Knowledge is rooted in the daily work, procedures, practices and norms of enterprise. For specific business activities of enterprises, the knowledge provides the solution on the basis of the information analysis for a particular user's needs and problems, it involved with more tacit knowledge, in addition to the need for explicit knowledge. In practice, we have a number of different ways to add to the data's value such as association, classification, computation, correction, compression, etc. and make it to convert to information. Wide range of applications of computer technology today, you can make use of computer to classify, calculate data, but the computer cannot be deeply associated, corrected and activities inducted, which must make use of human's help. Similarly, we can convert the information to be knowledge by the modes of comparison, inference, contact, dialogue. In the knowledge management, in fact, the scheme that put the data, information, knowledge as a whole, rather than clear hierarchical division is the most practical, those are the principles adopted in this article.

2.2 Tacit knowledge and explicit knowledge

The enterprise's knowledge is divided into tacit knowledge and explicit knowledge, and tacit knowledge plays a dominant role. Tacit knowledge refers to the knowledge that cannot be clearly expressed, which existing in the minds of people, and can only be expressed by action. Tacit knowledge is defined as a highly personalized and difficult formatted knowledge such as the understanding of director, intuition and premonition by Nonaka and Takeuchi. The original concept explained by polanyi in the book of personal knowledge published in1958. OECD clearly give the classification of explicit knowledge and tacit knowledge, in which the factual knowledge and principle knowledge can be expressed in the knowledge that we are generally talking about explicit knowledge; Skills knowledge and human knowledge is difficult to be expressed in words, that is tacit knowledge. Explicit knowledge is relatively easy to deal with, is tangible, and can be identified, you can express and transfer by language, text, digital, transmission. Thus it can be relatively easily integrated into the organizational strategy by the use of information and communication technologies, while tacit knowledge is more difficult to deal with. Tacit knowledge comes from the individual judgments and perceptions of the outer world, such as judgment, and perception which has a strong individuality, it is difficult to be clearly expressed by language, and it is difficult to be identified, often remain in the minds of individuals in the form of personal knowledge, which is the basis of individual skills. The management of explicit knowledge is to codify, database, while the management of tacit knowledge is to make it to be explicit. Of course, not all of the explicit knowledge should be encoded, and not all tacit knowledge should be explicit one. According to Nonaka and Takeuchi's definition, tacit knowledge referred to the knowledge that is highly personalized and difficult formatted such as the director's understanding, intuition and premonition. The explicit knowledge such as the edited procedures or universal principles which can be expressed by text and numbers, easily exchanged and shared in the form of hard data. In general, tacit knowledge is better than explicit knowledge, and can create more value, the mining and utilization of tacit knowledge will be the key to gain success for the individuals and organizations. The tacit knowledge is divided into four categories: difficult constraint skills, knowledge of know how, mental models (including with ways of thinking and value, etc.), problem-solving and organizational practices. Experience, skills and mental mode are the important wealth of enterprise, is the specific form of tacit knowledge, is the most core capabilities of the enterprise, and as this knowledge is often tacit, not coded, and therefore it cannot easily be to be imitated. We can make the valuable tacit knowledge convert to be explicit knowledge by the use of secret codes, metaphors, analogies and models. On the other hand, the explicit knowledge should be able to quickly convert to tacit knowledge, otherwise the true value is no existing. Because the process of employees' explicit knowledge conversion to be tacit knowledge are generally the process of knowledge application or knowledge to become productive process.

2.3 Knowledge conversion

As the tacit knowledge is tacit, not encoded, making it difficult to be imitated and stolen. The process of making tacit knowledge to be explicit can widen its scope, which achieves greater value of knowledge in practice, from this perspective, tacit knowledge conversion process is the process of value creation. The mutual conversion's process of explicit knowledge and tacit knowledge is the knowledge interaction and the quality and quantity are both advanced. The SECI model is proposed by Nonaka and which consists of four components: socialization (conversion of tacit knowledge to tacit knowledge), externalization (conversion of tacit knowledge to explicit knowledge), combination (conversion of explicit knowledge to explicit knowledge), internalization (conversion of explicit knowledge to tacit knowledge). The knowledge creation of supply chain and enterprise realize in the mutual conversion's process of explicit knowledge and tacit knowledge. In Nonaka's spiral rising model of knowledge creation, knowledge moves from the bottom to upper in the organization, from the individual level to the team level of knowledge, and finally into the knowledge of the organization. With the spiral rising of knowledge in the organization, the total spiral rising knowledge is enhanced and enlarged by the interaction between individuals and their interactions in the organization. Where the organization can be seen as a enterprise, or can also be seen as a supply chain. Although completion of the entire organization knowledge creation needs the dynamic action among the four knowledge conversion modes, only when the coordination and form a continuous spiral rising knowledge that the process of knowledge creation can be completed by the organization, thereinto the tacit knowledge is the core factor of the total knowledge creation.

3. HYPOTHESES AND MODELS

3.1 Hypotheses

There are two levels about the supply chain considered in this article, which is consists of manufacturers and retailers and includes with m manufacturers, are expressed by Mj ($j = 1,2,\cdots,m$). π_{Mj} represents the profit of manufacturer Mj, W represents product sales price, C_{Mj} represents unit production cost, X_{Mj} represents the quantity of tacit knowledge, ΔX_{Mj} represents the quantity of making tacit knowledge to be explicit ($0 \leq \Delta X_{Mj} \leq X_{Mj}$, if $\Delta X_{Mj} = 0$, then means that manufacturer Mj doesn't make its tacit knowledge to be explicit, if $\Delta X_{Mj} = X_{Mj}$, then means that manufacturer Mj will totally make its tacit knowledge to be explicit.). The sales quantity of manufacturer Mj is q_j. Sum of all manufacturers' sales is represented by Q_M, and assuming the manufacturers can meet the needs of retailers. There are n retailers expressed by Ri ($i = 1,2,\ldots,n$) and π_{Ri} represents its profit. The market price of the product is

$$P = a - b \sum_{k=1}^{n} q_k \ ,$$

in which q_k represents the sales quantity of retailer k. $a > 0, b > 0$. C_{Ri} represents unit operation cost, X_{Ri} represents quantity of tacit knowledge and ΔX_{Ri} represents quantity of its explicit knowledge ($0 \leq \Delta X_{Ri} \leq X_{Ri}$, if $\Delta X_{Mj} = 0$, then means that retailer Ri doesn't make its tacit knowledge to be explicit, if $\Delta X_{Mj} = X_{Mj}$, then means that retailer Ri will totally make its tacit knowledge to be explicit.). The sales quantity of retailer Ri is q_i. Sum of all retailers' sales is represented by Q_R. Assuming a product of one manufacturer corresponds to the product of one retailer, so the equation $Q_M = Q_R$ could be set up. For ease of modeling, two special hypotheses are set up here:

Hypothesis 1: There are a negative linear correlation between the knowledge content and the cost.

Hypothesis 2: There are object of making the tacit knowledge to be explicit, and only the object can accept it.
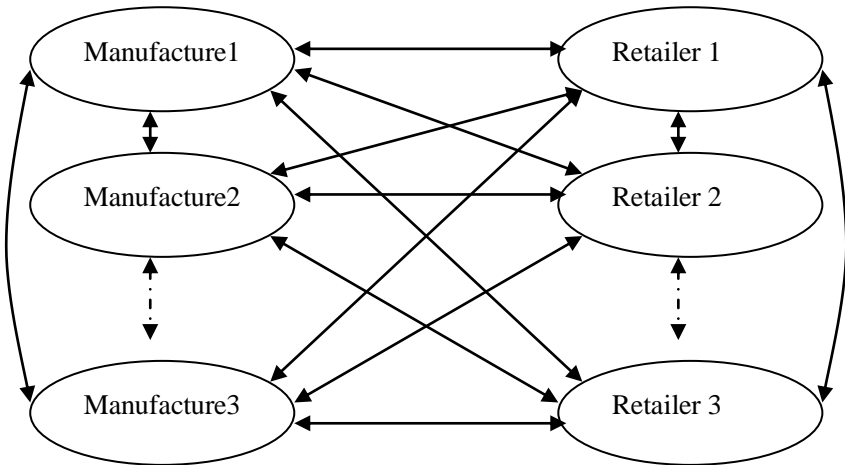

Fig.1 The conversion and delivering process of tacit knowledge and explicit knowledge in a two-echelon supply chain

3.2 The game models for tacit knowledge conversion of nodal enterprise in supply chain

(1) The game models for tacit knowledge conversion of nodal enterprise in single period

The supply chain is composed of m manufacturers and n retailers in a single period. There is Cournot competition between the manufacturers, so are the retailers, and there is Stackelberg game between retailers and manufacturers. The game process is as follows:

Step one: Each manufacturer and retailer determines whether to make their tacit knowledge to be explicit, manufacturers and retailers decide whether to obtain that knowledge which have been explicit.

Step two: Each manufacturer and retailer could observe the explicit knowledge.

Step three: According to the available knowledge, the manufacturers start Cournot competition and form the equilibrium price to the retailers.

Step four: Based on the equilibrium price, each retailer decides sales quantity.

Step five: Manufacturers meet the retailers' order quantity.

$$\pi_{Mj} = (W - C_{Mj} + X_{Mj} + \sum_{\substack{k=1 \\ k \neq j}}^{m} \Delta X_{Mk} + \sum_{k=1}^{n} \Delta X_{Rk}) q_j \tag{1}$$

$$\pi_{Ri} = (a - b\sum_{k=1}^{n} q_k - W - C_{Ri} + X_{Ri} + \sum_{k=1}^{m} \Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i}}^{n} \Delta X_{Rk}) q_i \tag{2}$$

Then utilize formula (2) to obtain the derivation for any retailer Ri's sales quantity (q_i) by using $\dfrac{\partial \pi_{Ri}}{\partial q_i} = 0$ and get the formula (3):

$$\therefore \quad W = \frac{1}{n}[na - b(n+1)\sum_{k=1}^{n} q_k - \sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + n\sum_{k=1}^{m} \Delta X_{Mk} + (n-1)\sum_{k=1}^{n} \Delta X_{Rk}] \tag{3}$$

$\because Q_M = Q_R$ $\therefore$ We could get the formula (4) by taking formula (3) into formula (1):

$$\pi_{Mj} = [a - \frac{b(n+1)}{n}\sum_{k=1}^{m} q_k - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + 2\sum_{k=1}^{m} \Delta X_{Mk} + \frac{2n-1}{n}\sum_{k=1}^{n} \Delta X_{Rk} - C_{Mj} + X_{Mj} - \Delta X_{Mj}] q_j \tag{4}$$

Then utilize formula (4) to obtain the derivation for any manufacturer Mj's sales quantity (q_j) by using $\dfrac{\partial \pi_{Mj}}{\partial q_j} = 0$ and get the formula (5):

$$Q_M = \sum_{k=1}^{m} q_k = \frac{n}{b(n+1)(m+1)}[ma - \frac{m}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + (2m-1)\sum_{k=1}^{m} \Delta X_{Mk} + \frac{(2n-1)m}{n}\sum_{k=1}^{n} \Delta X_{Rk} - \sum_{k=1}^{m}(C_{Mk} - X_{Mk})] \tag{5}$$

Take the formula (5) into $\dfrac{\partial \pi_{Mj}}{\partial q_j} = 0$ and get formula (6):

$$q_j = \frac{n}{b(n+1)(m+1)}[a - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + 3\sum_{k=1}^{m} \Delta X_{Mk} + \frac{(2n-1)}{n}\sum_{k=1}^{n} \Delta X_{Rk}$$

$$+ \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (m+1)(C_{Mj} - X_{Mj}) - (m+1)\Delta X_{Mj}] \tag{6}$$

Take the equation $Q_M = Q_R$ and formula(5) into formula(3) and get the formula (7):

$$W = \frac{1}{m+1}[a - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + (2-m)\sum_{k=1}^{m}\Delta X_{Mk} + \frac{(-mn+n-1)}{n}\sum_{k=1}^{n}\Delta X_{Rk} + \sum_{k=1}^{m}(C_{Mk} - X_{Mk})] \qquad (7)$$

Take the equation $Q_M = Q_R$ and formula (7) into formula (3) and get formula (8):

$$q_i = \frac{1}{b(n+1)(m+1)}[ma + (m + \frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + (2m-1)\sum_{k=1}^{m}\Delta X_{Mk} + (3m+1+\frac{1}{n})\sum_{k=1}^{n}\Delta X_{Rk}$$

$$- \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (n+1)(m+1)(C_{Ri} - X_{Ri}) - (n+1)(m+1)\Delta X_{Ri}] \qquad (8)$$

Take the formula (5) and (6) into the formula (4) and get formula (9):

$$\pi_{Mj} = \frac{n}{b(n+1)(m+1)^2}[a - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + 3\sum_{\substack{k=1 \\ k \neq j}}^{m}\Delta X_{Mk} + \frac{(2n-1)}{n}\sum_{k=1}^{n}\Delta X_{Rk}$$

$$+ \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (m+1)(C_{Mj} - X_{Mj}) - (m-2)\Delta X_{Mj}]^2 \qquad (9)$$

Take the formula (5), (7) and (8) into the formula (2) and get formula (10):

$$\pi_{Ri} = \frac{1}{b[(n+1)(m+1)]^2}[ma + (m + \frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + (2m-1)\sum_{k=1}^{m}\Delta X_{Mk} + (3m+1+\frac{1}{n})\sum_{\substack{k=1 \\ k \neq i}}^{n}\Delta X_{Rk}$$

$$- \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (n+1)(m+1)(C_{Ri} - X_{Ri}) - (mn+n-2m-\frac{1}{n})\Delta X_{Ri}]^2 \qquad (10)$$

(2) The game models for tacit knowledge conversion of nodal enterprise in multi periods

Considering decisions in multiple periods, manufacturers and retailers can also firstly make the decision that not to make their tacit knowledge to be explicit, but on the basis of their respective interests to decide its knowledge management activities. As the enterprise management and operation of supply chain are continuous, the nodal enterprises in supply chain will inevitably suffer revenge in subsequent periods because they don't cooperate with each other at the beginning. In this way, it will form multi periods game model. In such cases, the relationship between enterprises will become complex. For ease of modeling, here we assume that manufacturer Mj and retailer Ri are two specific nodal enterprises. (Note: when we get that specific game result, we could analyze any manufacturer and retailer by promoting j

and i.), and assuming that they don't make their tacit knowledge to be explicit. The game is divided into two periods, as follows:

First period: Manufacturer Mj and retailer Ri don't make their tacit knowledge to be explicit, and other retailers and manufacturers could not expect it and continue to make their tacit knowledge to be explicit.

Second period: Other manufacturers and retailers decide to punish manufacturer Mj and retailer Ri after observing their action in the first period. During the follow-up cooperation, other manufacturers and retailers make their knowledge tacit to manufacturer Mj and retailer Ri and make their tacit knowledge to be explicit to others, until manufacturer Mj and retailer Ri make their tacit knowledge to be explicit.

First period: There are five steps about the game process as above and takes inverse method in solving the question.

$$① \quad \pi_{Mj} = (W - C_{Mj} + X_{Mj} + \sum_{\substack{k=1 \\ k \neq j}}^{m} \Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i}}^{n} \Delta X_{Rk}) q_j \tag{11}$$

$$\pi_{M\alpha} = (W - C_{M\alpha} + X_{M\alpha} + \sum_{\substack{k=1 \\ k \neq j \\ k \neq \alpha}}^{m} \Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i}}^{n} \Delta X_{Rk}) q_\alpha \tag{12}$$

$$② \quad \pi_{Ri} = (a - b\sum_{k=1}^{n} q_k - W - C_{Ri} + X_{Ri} + \sum_{\substack{k=1 \\ k \neq j}}^{m} \Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i}}^{n} \Delta X_{Rk}) q_i \tag{13}$$

$$\pi_{R\beta} = (a - b\sum_{k=1}^{n} q_k - W - C_{R\beta} + X_{R\beta} + \sum_{\substack{k=1 \\ k \neq j}}^{m} \Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i \\ k \neq \beta}}^{n} \Delta X_{Rk}) q_\beta \tag{14}$$

Note: j and i are specific numbers which represent the serial number of manufacturer and retailer that don't make their tacit knowledge to be explicit in the first period, but α and β are not specific numbers which represent the serial number of other manufacturers and retailers that make their tacit knowledge to be explicit in the first period.

$$1 \leq \alpha \leq m \text{ , and } \alpha \neq j \text{ ; } 1 \leq \beta \leq n \text{ , and } \beta \neq i \text{ .}$$

We can also get the formula (15) and (16) by taking inverse method:

$$\pi_{Mj} = \frac{n}{b(n+1)(m+1)^2} [a - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + 3\sum_{\substack{k=1 \\ k \neq j}}^{m}\Delta X_{Mk} + \frac{(2n-1)}{n}\sum_{\substack{k=1 \\ k \neq i}}^{n}\Delta X_{Rk}$$

$$+ \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (m+1)(C_{Mj} - X_{Mj})]^2 \tag{15}$$

$$\pi_{Ri} = \frac{1}{b[(n+1)(m+1)]^2} [ma + (m + \frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + (2m-1)\sum_{\substack{k=1 \\ k \neq j}}^{m}\Delta X_{Mk} + (3m + \frac{1}{n} + 1)\sum_{\substack{k=1 \\ k \neq i}}^{n}\Delta X_{Rk}$$

$$- \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (n+1)(m+1)(C_{Ri} - X_{Ri})]^2 \tag{16}$$

Second period: Other manufacturers and retailers take punitive action. In this case, the game model is shown as formula (17), (18), (19) and (20):

③ $$\pi_{Mj} = (W - C_{Mj} + X_{Mj})q_j \tag{17}$$

$$\pi_{M\alpha} = (W - C_{M\alpha} + X_{M\alpha} + \sum_{\substack{k=1 \\ k \neq j \\ k \neq \alpha}}^{m}\Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i}}^{n}\Delta X_{Rk})q_\alpha \tag{18}$$

④ $$\pi_{Ri} = (a - b\sum_{k=1}^{n}q_k - W - C_{Ri} + X_{Ri})q_i \tag{19}$$

$$\pi_{R\beta} = (a - b\sum_{k=1}^{n}q_k - W - C_{R\beta} + X_{R\beta} + \sum_{\substack{k=1 \\ k \neq j}}^{m}\Delta X_{Mk} + \sum_{\substack{k=1 \\ k \neq i \\ k \neq \beta}}^{n}\Delta X_{Rk})q_\beta \tag{20}$$

Note: j, i, α and β have the same meaning and value as the first period.

It can also get the formula (21) and (22) by taking inverse method:

$$\pi_{Mj} = \frac{n}{b(n+1)(m+1)^2} [a - \frac{1}{n}\sum_{k=1}^{n}(C_{Rk} - X_{Rk}) + \frac{(-mn-2\ n-1)}{n}\sum_{\substack{k=1 \\ k \neq j}}^{m}\Delta X_{Mk} + \frac{(-mn+2n-2)}{n}\sum_{\substack{k=1 \\ k \neq i}}^{n}\Delta X_{Rk}$$

$$+ \sum_{k=1}^{m}(C_{Mk} - X_{Mk}) - (m+1)(C_{Mj} - X_{Mj})]^2 \tag{21}$$

$$\pi_{Ri} \quad = \quad \frac{1}{b[(n+1)(m+1)]^2}[ma+(m+\frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk}-X_{Rk})+(-mn+2m-n+\frac{1}{n}-1)\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}+(-mn+3m-n+\frac{2}{n})\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}$$

$$-\sum_{k=1}^{m}(C_{Mk}-X_{Mk})-(n+1)(m+1)(C_{Ri}-X_{Ri})]^2 \tag{22}$$

3.3 The decision condition when nodal enterprise doesn't deviate from the conversion of tacit knowledge firstly

Assuming the discount rate is δ in multi periods' decision, the profit comparison under two situations that whether the specific manufacturer and the specific retailer make their tacit knowledge to be explicit are shown as follows.

By the formula (5), (15) and (21), we can know, in multi periods, for the specific manufacturer Mj, the condition that there is no departure from the externalization of the tacit knowledge management activities is:

formula (9) $\times\dfrac{1}{1-\delta}$ >formula(15) +formula(21) $\times\dfrac{\delta}{1-\delta}$.

The result by calculating as formula (23):

$$\delta < \frac{\begin{array}{c}[-(m-2)\Delta X_{Mj}][2a-\dfrac{2}{n}\sum_{k=1}^{n}(C_{Rk}-X_{Rk})+6\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}+\dfrac{2(2n-1)}{n}\sum_{k=1}^{n}\Delta X_{Rk}\\[4mm]+2\sum_{k=1}^{m}(C_{Mk}-X_{Mk})-2(m+1)(C_{Mj}-X_{Mj})-(m-2)\Delta X_{Mj}]\end{array}}{\begin{array}{c}[\dfrac{(-mn-1)}{n}\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}+\dfrac{(-mn-1)}{n}\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}][2a-\dfrac{2}{n}\sum_{k=1}^{n}(C_{Rk}-X_{Rk})+\dfrac{(-mn+6n-1)}{n}\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}\\[4mm]+\dfrac{(-mn+4n-3)}{n}\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}+2\sum_{k=1}^{m}(C_{Mk}-X_{Mk})-2(m+1)(C_{Mj}-X_{Mj})]\end{array}} \tag{23}$$

By the formula (10), (16) and (22), we can know, in multi periods, for the specific retailer Ri, the condition that there is no departure from the externalization of the tacit knowledge management activities is:

formula (10) $\times\dfrac{1}{1-\delta}$ >formula(16) +formula(22) $\times\dfrac{\delta}{1-\delta}$.

The result by calculating as formula (24):

$\delta <$

$$[-(mn+n-2m-\frac{1}{n})\Delta X_{Ri}][2ma+2(m+\frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk}-X_{Rk})+2(2m-1)\sum_{k=1}^{m}\Delta X_{Mk}$$

$$+2(3m+1+\frac{1}{n})\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}-2\sum_{k=1}^{m}(C_{Mk}-X_{Mk})-2(n+1)(m+1)(C_{Ri}-X_{Ri})-(mn+n-2m-\frac{1}{n})\Delta X_{Ri}]$$

$$[(-mn-n+\frac{1}{n}-1)\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}+(-mn-n+\frac{1}{n}-1)\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}][2ma+2(m+\frac{n+1}{n})\sum_{k=1}^{n}(C_{Rk}-X_{Rk})+(-mn+4m-n+\frac{1}{n}-3)\sum_{\substack{k=1\\k\neq j}}^{m}\Delta X_{Mk}$$

$$+(-mn+6m-n+\frac{3}{n}+1)\sum_{\substack{k=1\\k\neq i}}^{n}\Delta X_{Rk}-2\sum_{k=1}^{m}(C_{Mk}-X_{Mk})-2(n+1)(m+1)(C_{Ri}-X_{Ri})]$$

(24)

Conclusion: In complex supply chain which is consists of multiple manufacturers and retailers, the specific manufacturer who doesn't deviate from making the tacit knowledge to be explicit in single period, needs to meet the condition (23), and specific retailer needs to meet the condition (24).

4. NUMERICAL EXAMPLE

4.1 Data collection and sample

In order to visually illustrate the models, assuming a two level supply chain which is consists of six manufacturers and eight retailers, and each nodal enterprise data is shown in Tab. 1.

Tab. 1 Data of Each Nodal Enterprise in Supply Chain

Nodal enterprise	Manufacturer Mj						Retailer Ri							
Serial number	1	2	3	4	5	6	1	2	3	4	5	6	7	8
Cost	105	96	113	108	92	90	107	106	85	112	110	99	87	108
Original knowledge content	18	13	11	17	18	12	8	9	7	8	9	9	7	12
Explicit knowledge content	5	7	4	5	3	4	3	2	4	6	7	5	2	5
Total number	Q_M =1000						Q_R =1000							
Other parameters	——						a =60, b =0.03							

The article analyzes the specific situation that is consists of manufacturer Mj and retailer Ri, so the discount rate of their making tacit knowledge conversion decision are effected by the two decision subjects.

4.2 Analysis

(1) Analysis of manufacturer

When we analyze the manufacturer, as the discount rate is affected by the quantity of its making tacit knowledge to be explicit, but also by the retailer's quantity of making tacit knowledge to be explicit, in order to calculate the discount rate threshold of the manufacturer, we must first determine the combination of the retailers who doesn't making their tacit knowledge to be explicit. The results by calculation are shown in Tab.2. When the discount rate in practice is greater than the corresponding discount rate threshold, manufacturers will not make their tacit knowledge to be explicit, but make them tacit. Note that, as the discount rate is greater than or equal to zero in practice, in some combinations the discount rate is negative, which indicates that manufacturers will make their tacit knowledge to be tacit under the combination.

Tab. 2 The Discount Rate Threshold of Manufacturer j' s Tacit Knowledge Decision

Manufacturer / Discount rate / Retailer	M1	M2	M3	M4	M5	M6
R1	0.0016	-0.0087	0.0183	0.0101	-0.0454	-0.0295
R2	0.0016	-0.0085	0.0179	0.0099	-0.0439	-0.0286
R3	0.0016	-0.0090	0.0188	0.0104	-0.0469	-0.0304
R4	0.0017	-0.0095	0.0196	0.0109	-0.0504	-0.0323
R5	0.0018	-0.0098	0.0201	0.0112	-0.0522	-0.0334
R6	0.0017	-0.0092	0.0192	0.0106	-0.0486	-0.0313
R7	0.0016	-0.0085	0.0179	0.0099	-0.0439	-0.0286
R8	0.0017	-0.0092	0.0192	0.0106	-0.0486	-0.0313

Note: When the discount rate is negative, it indicates that manufacturer will make its tacit knowledge to be tacit.

(2) Analysis of retailer

When we analyze the retailer, as the discount rate is affected by the quantity of its making tacit knowledge to be explicit, but also by the manufacturer 's quantity of making tacit knowledge to be explicit, in order to calculate the discount rate threshold of the retailer, in order to calculate the discount rate threshold of the retailer, we must first determine the combination of the manufacturers who make their tacit knowledge to be explicit in different extent, The results by calculation are shown in Tab.3. When the discount rate in practice is greater than the

corresponding discount rate threshold, retailers will not make their tacit knowledge to be explicit, but make them tacit. Note that, as the discount rate is greater than or equal to zero in practice, in some combinations the discount rate is negative, which indicates that retailers must make their tacit knowledge under the combination.

Tab. 3 The Discount Rate Threshold of Retailer i's Tacit Knowledge Decision

Discount rate Retailer / Manufacturer	R1	R2	R3	R4	R5	R6	R7	R8
M1	0.0060	0.0014	-0.1363	0.0303	0.0313	-0.0147	-0.0474	0.0067
M2	0.0064	0.0015	-0.1538	0.0320	0.0332	-0.0158	-0.0523	0.0072
M3	0.0058	0.0013	-0.1287	0.0294	0.0304	-0.0143	-0.0452	0.0065
M4	0.0060	0.0014	-0.1363	0.0303	0.0313	-0.0147	-0.0474	0.0067
M 5	0.0057	0.0013	-0.1217	0.0286	0.0295	-0.0138	-0.0431	0.0063
M6	0.0058	0.0013	-0.1287	0.0294	0.0304	-0.0143	-0.0452	0.0065

Note: When the discount rate is negative, it indicates that retailer will must make its tacit knowledge to be tacit.

5. CONCLUSION

Considering their own interests to make tacit knowledge to be explicit is frequently used in making decisions in many enterprises. It's easy to make the decision in single period, but the business is under the situation of multi periods, the behavior of deviation from group in single period will lead to other nodal enterprises to take punitive measures to give tit for that. This article takes a two level supply chain, which is composed of multiple manufacturers and retailers as an example, analyzes the tacit knowledge management decision of specific manufacturer Mj and retailer Ri, and gets the critical condition when specific manufacturer Mj and retailer Ri could deviate from making tacit knowledge to be explicit. It could be seen that the analysis of this article is under the circumstance that there are only one manufacturer and one retailer who make the tacit knowledge management decision, but how the final result will be if it is extended to any quantity of manufacturers and retailers. This will be the further topic of research.

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