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Wave-particle Duality and Institutional Arrangement on Division in Supply Chain Cluster

Guojun Ji and Yi He

***Abstract*—This paper is based on the practice in China, takes the coupling between industrial cluster and supply chain as the new angle using by the modern supply chain theory and industry theory, considering the supply chain cluster as such a organization: "originated but not limited to the enterprise, based on but not localized to the cluster". Based on the physical theory and the wave-particle duality, the supply chain cluster is the special organization whose characteristic has wave-particle duality. There exists sophisticated division of labor between upstream and downstream enterprises in a supply chain cluster, and the cost-benefit computing is the main factor to determine the selection of institutional arrangement on division of labor. By enforcing different vertical relations of supply chain cluster, supply chains and their enterprises can optimize the selection and integration of different institutional arrangement on division of labor. A case study is verified our conclusions.**

***Index Terms*—Supply chain cluster; Wave-particle duality; Institutional arrangement on division of labor; Vertical relationship**

I. Introduction

ALONG with the development of technology, productivity and globalization, there are the uncertainty, dynamics and complexity of market demand increase that the consumption level of customer enhancing continuously, the competition among enterprises intensifying and the greatly change of the economy and social environment. The uncertainty change of internal and external environment caused by "3C" (customer, competition, change), makes enterprises carry on the organization and the system form innovation, in order to enhance the international competitive competence themselves, especially during the progress of economy transforming and being melted into the global economic system. In fact, under the today's technical and market condition, the internal structure starts to change. First, enterprise's relationship and the cooperation enter to the network stage, and the production method is primarily modulation. The supply chain alliance starts to substitute for the traditional vertical integration enterprise. Adapts with it, in industrial cluster, it starts to appear supply chain cluster (SCC) form. The industrial cluster and the supply chain management, as the effective development carrier of region economy and the model of organization management, is becoming the key of survival and development for many economic entities or enterprises. Since the reform and open policy, cluster economy in China has developed fleetly and emerged many small and medium-sized enterprises' clusters, take the "block economy" in Zhejiang Province and the "specialized town economy" in Guangdong Province, for example. They accelerate the local economy development enormously, and cause the high recognition for many local authorities and the enterprises. In fact, the enterprises in the industrial cluster only collect simply to share the resources and information. There lacks of one highly effective supply chain system to integrate the enterprises, and exists more competition than cooperation in cluster. Viswanadham, N. (2005) analyzed that simultaneous development of the SCC companies is possible with planning and aggressive marketing to attract multi-national companies in manufacturing and third-party logistics providers. Additionally, while the supply chain process integrates all activities from product development to sales of a product, the integration of the service phase, physically, informationally and organizationally, with the rest of the supply chain is an emerging trend. According to above mentioned viewpoint, a SCC is a geographically concentrated, self-flourishing ecosystem comprising of Shippers, Suppliers, Logistics Service Providers, IT Vendors, Infrastructure Providers of land, sea and air logistics facilities, Financial Institutions, Regulatory Agencies, Research Institutions, Consultants and other logistics-related organizations that leverages on the interdependencies between them to provide highly efficient and effective logistics solutions and create innovative new solutions. Therefore, using by such system can improve competitiveness through linkages and integration, within a cluster, as well as between industrial clusters.

There exists large numbers of vertical relationships between upstream and downstream enterprises in a SCC, so the SCC evolvement is quite complex. Some researchers have studied from different angles. Viswanadham, N (2002) concluded that the cluster can develop only with the Government attention. This can be in developing three or four strategic routes and ports and then upgrading them to world class standard; and, identifying selected vertical industrial cluster and developing the physical infrastructure to meet their unique needs. The phased SCC development strategy can balance investment of IT and physical infrastructure, developing vertical industrial clusters, and developing logistics sectors. Vertical integration

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causes can be materialized in different ways, such as technological factor (Seabright and Tirole, 2001), economized transaction cost (Coase, 1937), incomplete market (Carlton, 1979) etc. As far as study on the vertical restriction, more attention is based on relationship between manufacturer and retailer, for example, transfer price control (Tirole, 1988), exclusive dealing (Salop and Sheffman, 1983), exclusive region (Klein and Murphy, 1988) etc. Some Chinese authors have studied the vertical relations based on the industrial chain, typically such as relationships between the vertical control and the economical institution (Lihong Yu and Yihong Yu, 2006), vertical relations of industrial chain versus integration of institutional arrangement on division of labor (Huixin Yang *et al.,* 2007) and so on. Industrial chain's research is always in the slot between industries and enterprises because its characteristic is still unknown to us, just like its research and definition come from China, in addition, its orientation is not clear. However, most authors mainly emphasize particularly on problems based on the vertical integration of enterprises or supply chains or the resources combination of inter-organization. In fact, with the social division quicken, IT and knowledge economy development, the vertical integration decomposed and the enterprises' cooperation has became a notable economical phenomenon, nowadays market is no longer single competitive relationship among enterprises, instead of among networks (Jeff Cares, 2006). Jizi Li *et al.* (2004) suggested the diversity of core enterprises and the difference division result in the different SCCs. The core enterprises clustered can be regarded as stretch to classification of the quasi hierarchies supply chains. Many researchers pay attention to study on the "competition-cooperation" relationships among enterprises. Certainly, no division will be no a supply chain, as well as an enterprise, even a SCC. In fact, the division results in the SCC formed (Holti *et al.*, 1999). N. Viswanadham (2003) represented the relationship management with their supply chain partners is important for global players. Nations should develop SCCs, not just manufacturing facilities. Feser and Bergman (2000) have developed a set of SCC benchmarks based on national input-output data that can be applied in the regional level. Although useful in many respects, such an approach is limited to the extent that the trading relationships detected in national-level data may not necessarily hold true for industries at the regional level. Moreover, industrial interdependence within a cluster can be manifested in ways other than direct input-output relations, or supply chain linkages between firms. Interdependence relations among cluster firms are based on mutual learning, innovation, or specialized labor demand, which is equally important for economic development purposes. If geographically concentrated firms do not trade with each other and fail to consciously exploit localization economies then "looking for actual evidence of interdependence is less important than discovering potential for interdependence" (Feser and Luger, 2002). There exists division and cooperation between upstream and downstream in a SCC, how to coordinate and organize the cluster becomes quite important. In an industrial cluster, the institutional arrangement on division of labor includes division if intra-enterprise, division of quasi-integration contract and market division (Huixin Yang *et al.,* 2007). From the presented works, those did not seize the characteristics of SCC, just like as "hanging" with supply chains or enterprises, so far, some basic problems still have not a uniform answer, such as characteristics, framework and formed mechanism of a SCC. There is lesser study on integration of vertical relations and division than for the single angles of a SCC. In fact, a SCC is different from the traditional single chain supply chain, which is located in the industrial cluster region, with the relation of "supply-client", through the link of formal or informal contract of 'trust and commitment', is formed by organizations containing different firms of the same industry such as research organizations, supplier, manufacturer, wholesaler, retailer, and even end users. A SCC system consists in one or more paralleled single supply chains in the agglomeration location, not only presents all enterprises in one single supply chain cooperate with one another internally, but cooperation and coordination exists across different supply chains externally too (J. Z. Li, 2006). Thus, the SCC emphasizes on the collaborative relationship between supply chains and enterprises, which is an ecosystem by the supply chain or enterprise incubating and synthesizing continually.

The structure of this paper is as follows: the "wave-particle duality" of SCC is discussed in section II; Vertical relations of SCC versus integration of institutional arrangement on division of labor is represented in section III; a case study is shown in section IV; In last section, some conclusions are given.

II. WAVE-PARTICLE DUALITY AND ENTANGLEMENT OF QUANTUM OF SUPPLY CHAIN CLUSTER

A. Wave-particle duality of a SCC

In allusion to dispute for light is "wave" or "particle" has lasted out more than 300 years, since "wave theory" and "particle theory" of light is opposite, the final result ascribes light is neither wave nor particle, and is the substance of wave and particle duality properties. If we call "a SCC" is "wave-motion", and supply chains or enterprise cluster are "particle-motion", then separation of a SCC and supply chains or enterprises is similar to antinomy for light is wave or particle on earth. The wave-motion of a SCC means that different node enterprises integrated result. There are two describing variables for "wave-motion", i.e., "nodes" and "nodes centralized degree". With more the social division fine, more complicated and length the supply chain is. Essence of the SCC's wave-motion is that process of "explicit transmission" of the tangible semifinished product and "implicit transmission" of the intangible assets (e.g., information, brand, knowledge), which transmission scope is between semifinished product market and final product market or within SCC, as well as it is the process of supply chain innovation and value realization. In such transmission process, there exists the definite fluctuation like as "wave-motion" among every SCC's nodes, so the SCC can be described as "wave-motion". Otherwise, the organizational model of a supply chain cluster is a network structure formed by upstream and downstream correlative

enterprises, every supply chain or enterprise is just like as a "particle" in a SCC. There are two describing variables for "particle-motion", i.e., "node position" and "innovation ability". Enterprises often are changing in a supply chain's node position, then results in every supply chains are changing, as well as the SCC. And enterprises whether or not find, search, hold or change their node position to reach "robustness" of the SCC, which entirely depends on their innovation ability. Movement or determination of the node position together with magnitude of innovation ability, are closely relative to cooperation and competitive competence of a SCC. Therefore, the "particle-motion" denotes the integration competence of different enterprises along with supply chains.

In quantum physics, "quantum particle" and "quantum wave" is uniform, quantum of particle must depends on "wave-motion", and quantum of wave must depends on "particle-motion" too (Shifan Wang, 2007). In fact, "wave-motion" and "particle-motion" in a SCC is uniform. "Particle-motion" indicates the production innovation of a SCC or enterprises is drive of the cluster innovation and value actualization. The "wave-particle duality" of a SCC shows the cluster is an organization by way of social division and the division coordination to come true, which is integration of supply chains and enterprise cluster, to implement the effective disposition resources and operation in the SCC, and ensure division and collaboration favoringly. Based on the quantum physics, the Bohr atomic model has three hypotheses, i.e., energy level, jump and orbit. Correspondingly, the Bohr atomic model of a SCC also has three hypotheses as follows: (1) Energy level. Supply chains or enterprises in a SCC always are in a series of discontinuous innovative states, synchronously the product in a supply chain or its enterprises is in a series of discontinuous value state too, such case is called stationary state. Transformation from one state to another often needs definite energy, so this will engenders the different energy levels. (2) Jump. Transformation of different supply chains, different enterprises or different product from one stationary state to another usually needs definite energy, in order to offset their shortage of technical and innovative competence, so this likes as jump. At the same time, the process of increase or decrease value likes as jump too. (3) Orbit. What is called orbit means nodes of a SCC. There exists energy of technical innovation and difference value among the nodes of a SCC, those nodes often are discontinuous.

Therefore, the meaning of the model is interpreted as follows: (i) Nucleus can denote the final product supply chains or enterprises. In Bohr atomic model, proton and neutron likes as the final product supply chain or enterprises in a SCC, there usually exists a large number of proton and neutron in the cluster. (ii) Electron can show the matching enterprise, core enterprise even supply chain or the cluster bottleneck. In a SCC, electrons located in orbit are semifinished product supply chains, enterprises or matching enterprises, which they are situated in the cluster's nodes. Same node may has many enterprises, which form the different multi-level supply chains, and a SCC can regards as the dynamic network formed by several multi-level supply chains. (iii) Orbit can denote chain, node or matching radius. Orbit in a SCC likes as nodes of the cluster. Based on these orbits are away from nucleus distance difference, they in turn can hanger together from far till close to form the SCC. Since nodes often are located in different position of the SCC, if technical innovation competence is stronger and value-added is greater, the "energy level" is higher. (iv) "Quantum jump" can denote displacement of the semifinished product. The semifinished product between node orbits can move via logistics activities namely "quantum jump". "Quantum jump" shows semifinished product along with its SCC to pursues consummate continuously, transmission often is from low-node (far from the final enterprise) to high-node (close with the final enterprise), then the cluster can implement the whole "jump" process from R&D to production then to consumption. In nature, the "quantum jump" process is process of innovation and value-added in a SCC.

B. "Entanglement of quantum" and "quantum jump" in a SCC

In the quantum physics, "entanglement of quantum" shows an phenomena, i.e., whether how far two particles, one particle's change will affect another, they are interactional radically (Dekui Wang, 2004). There is an especial "entanglement of quantum" phenomena in a SCC, whether government or enterprises themselves, are all encircled some of enterprises like as "entanglement of quantum", then they foster and optimize the cluster. "Entanglement of quantum" indicates the relationship between supply chains, supply chain and enterprises or enterprises, which they are neither the entire independent market transaction relations, nor the relative close interior relations within the cluster, and is a "keep it at an arm's length" entanglement relation, such relation shows change of one supply chain or a enterprise must affect other supply chains or enterprises even the cluster, so it may presents "entanglement of quantum". Change in "entanglement of quantum" incarnates the change of "quantum state". In the quantum physics, "quantum state" denotes the state of particles (such as atom, neutron, proton), can represents energy, rotation, motion, magnetic field of particles and other physical characteristics (Dekui Wang, 2004). "Quantum state" in a SCC can present the state of "implicit knowledge" in supply chains or enterprises. Implicit knowledge is the supply chains or enterprises own knowledge, technology, brand, information etc. In the quantum physics, study on "entanglement of quantum" objective is reach "implicit transmission" of quantum information. So, study on the SCC's objective is to actualize "implicit transmission" of quantum states of supply chains or enterprises. What is called "implicit transmission" that shows just to transmit carriers (semifinished product or product) of technology, information, brand, value etc., does not transmit themselves. In the SCC, "entanglement of quantum" objective of supply chains or enterprises is to implement "implicit transmission" of technology, band and so on. The explicit shape of the SCC is the "explicit transmission" of semifinished product, and the implicit shape is the "implicit transmission" of implicit knowledge. In addition, with increase

of the production factor price and global extension of supply chain, the government must understand its role (service, coordination or support), if it blindly issues some preference policies, the SCC will be difficult to develop and optimize. Apparently, using by government's preference policies to attracting enterprises, the objective should form "entanglement of quantum" and be easy to develop supply chains or enterprises ultimately. In this way, a SCC must depend on "entanglement of quantum" requirements to build a perfect cluster, or else, the clustered relations will can't maintain stability and long-term.

In the quantum physics, to carry through long-distance quantum communication or quantum state implicit transmission, we must allow long-distance particles together with short-distance particles can hold maximal "quantum entanglement state" (Dekui Wang, 2004). Similarly, in a SCC, we must try hard to impel the "quantum entanglement state" formed among supply chains and enterprises, i.e., such that "quantum state" presents entanglement state. In addition, the technical standard to the SCC's affection is self-evident, once a technical standard change, supply chains or enterprises in the SCC will change to fit a new standard. The process of constituting standard is the process of "quantum entanglement state" formed. And the process of driving standard is the process of SCC formed via the standard or implicit knowledge transmission. For example, Microsoft Inc. always perseveres in innovation over time. In fact, the technical innovative process is the process of "quantum entanglement state", once the "quantum entanglement state" engendered, it will drive other supply chains or enterprises change virtually, the "entanglement of quantum" will appear, then results in further integration of the "explicit transmission" of Microsoft Inc. and the cluster. In the quantum physics, because there are diversified unavoidable environmental noises in the communication channel, quality of the "quantum entanglement state" will decrease with the transmission distance increase (Dekui Wang, 2004). In a SCC, the quality of "entanglement of quantum" among supply chains and enterprise also decreases with their distance increase and environmental noises. In fact, many reasons can make the environmental noise of the SCC, such as the social economic environment, business strategies, matching model of enterprises etc. Therefore, keep the "quantum entanglement state" and achieve "quantum jump" are correlative important to the SCC. The process of "quantum jump" is the process of the "quantum entanglement state" kept.

III. VERTAICAL RELATIONS VERSUS INTRGRATION OF INSTITUTIONAL ARRANGEMMENT ON DIVISION OF LABOR

The vertical relation is behaviour for supply chains or their enterprises in a SCC what about choice and integration of institutional arrangement on division of labor, mostly involves three modes: vertical integration, vertical contract and vertical separation. Different vertical relations bring different institutional arrangement on division of labor, i.e., it namely is to optimize the institutional arrangement on division on labor to improve the SCC's stability: Vertical integration. The vertical integration based on enterprises division or supply chains division means the upstream (downstream) enterprises or supply chains, via purchase part or entire stockholder's rights of the downstream (upstream) enterprises or supply chains to obtain purchased stockholder's rights, this is called the vertical merge. When the upstream supply or the downstream demand is finite and there a great deal of uncertainties, signing the relative contract is difficulty, enterprises are difficult to establish the effective incentive mechanism, the vertical integration usually is used to solve the relative problems (Bolton and Whinston, 1993); Vertical contract. Under the quasi-integration contract on division, there are often a mass of semifinished product dealing. In a SCC, semifinished product dealing usually is in repeating process, the dealing relations maintain long-term at a certain extent. The signed contracts based on long-term cooperation have strong sanction restriction for both. The vertical contract relation is a mixed structure between enterprise and market. In such case, the coordinating division of upstream and downstream enterprises is based on the quasi-integration contract, and the techniques involve authority (the core enterprises' competence) and price; Vertical separation. The vertical separation shows a SCC or a chain peels off one or multi-node thereinto, it will result in transforming the division of supply chains or enterprises into the market division. For instance, using by price institution, we can organize and coordinate the division between supply chains and enterprises in a SCC. The price institution can help to reach cooperation and solve the conflict problems, is one of important institutions (Weiying Zhang, 1996).

Different institutional arrangement on division of labor not only brings different cost and benefit, and also it has different advantage and applicative scope. With the globalization development, the institutional arrangement on division in a SCC will be in integrating process continuously. A SCC formed by the division just is possible for effective production final product, enterprises in the SCC continue to adjust the vertical relations will result in further integration of institutional arrangement on division. Next, we will analyze the transaction cost change with environment and market structure how to affect further integration of institutional arrangement on division. (1) The transaction cost change. Transaction cost can be classified exogenous transaction cost and endogenous transaction cost. Exogenous transaction cost is the transaction cost, which occurs directly and in directly in the exchange and it includes the diversified costs (such as the negotiating cost of procured unit resource, transport cost, spoilage in transit, communication cost) in the transaction and various establishments. Endogenous transaction cost is the transaction cost, which comes from the opportunistic countermeasure action, and equals the balance between market equilibrium and Pareto Optimality. In practice, because of information asymmetry produces the opportunistic countermeasure action of moral hazard and adverse selection is the ultimate cause of endogenous transaction cost. The technical innovative activity will decrease exogenous transaction cost. Therefore, integration trend of institutional arrangement on division in a SCC will transform the division of supply chains or enterprises into the market division, i.e., the division can be finished within

enterprises. With development of globalization and IT, the former vertical integrated enterprises in a SCC much more pay attention to their core competence or core operation, they just take charge one or some node operation, other works use outsourcing model, i.e., the division is based on market. In conclusion, the transaction cost change makes enterprises to actualize the different vertical relations in a SCC, then it will results in further integration of institutional arrangement on division. For example, Nike Inc. organizes production and sale their product in global scope, its R&D and marketing department set up in native region, but manufacture is in the developing nation by outsourcing. (2) The market structure change. In a SCC, the market structure of upstream and downstream enterprises is an important factor, which determines further integration of institutional arrangement on division. Because the market structure change makes benefit from division, which needs anew distribute between the upstream and downstream enterprises, as well as results in integration of institutional arrangement on division in a SCC. In single market, the market behaviour of enterprises depends on their located market structure, but to upstream and downstream enterprises in a SCC, their behaviour selection must too considers the vertical market structure, i.e., the market structure of a SCC is integrated the enterprise market structure together with the vertical market structure. In such vertical relation, supply chains or their enterprises located in upstream of a SCC manufacture semifinished product to meet downstream supply chain or their enterprises demand, downstream supply chain or their enterprises manufacture final product to supply consumers. For the sake of briefness, we give the following hypotheses: there exist merely two supply chains in a SCC, where upstream supply chain A manufactures semifinished product, downstream supply chain B manufactures final product, product of A is input of B; production B in unit just needs 1 A in unit, A and B have the identical measurement units; A and B have m , n enterprises, respectively; All enterprises in every markets are homogeneous.

Based on Donald A.Hay and Derek J.Morris (2001) expatiated, the reverse demand function of downstream supply chain sadisfies: $P_B = f(Q)$, where $Q = \sum_{i=1}^{n} q_i$, q_i is output of i th enterprise. According to (iv), $Q = nq_B$, where q_B is the benefit function of supply chain B meet $\pi_B = (p_B - p_A - c_B)q_B - F_B$, then conditions of the benefit maximization have: $\frac{d\pi_B}{dq_B} = p_B + q_B \frac{dp_B}{dq_B} - p_A - c_B = 0$. Consider that Price elasticity $E_B = \frac{p_B dq_B}{q_B dp_B}$, thus we gain: $\frac{d\pi_B}{dq_B} = p_B\left(1 - E_B^{-1}\right) - p_A - c_B = 0$, and the sum of conditions of the n enterprises benefit maximization satisfies: $p_B\left[1 - (nE_B)^{-1}\right] = p_A + c_B$, where $p_A + c_B$ is cost.

Based on the above expression, we can deduce the induced demand of supply chain B for input. Using by (ii), the output Q of B is suitable for A, then: $p_A(Q) = p_B(Q)\left(1 - (nE_B)^{-1}\right) - c_B$, this is the demand function of supply chain B to supply chain A.

Thus is can be seen, when $p_B(Q), E_B$ and c_B are determined, with n increases, $p_A(Q)$ will increases. Now, we consider two extreme cases: when $n \to \infty$, supply chain B located market is a absolute competitive market, here $p_A(Q)$ reaches maximization; when $n = 1$, supply chain B located market is a absolute monopoly market, $p_A(Q)$ reaches minimization at this time. Similarly, it is easy to see every enterprise benefit function in supply chain A meets: $\pi_A = (p_A - c_A)q_A - F_A$, where $Q = mq_A$, and c_A, F_A is the marginal cost or fixed cost in the supply chain A, respectively. We have: $p_A\left[1 - (mE_A)^{-1}\right] = c_A$, i.e., $p_A = \frac{c_A}{\left[1 - (mE_A)^{-1}\right]}$.

Therefore, when c_A and E_A are determined, with m increases, p_A will decreases. Also, we consider two extreme cases: when $m \to \infty$, supply chain A located market is a absolute competitive market, here p_A reaches minimization; when $m = 1$, supply chain A located market is a absolute monopoly market, p_A reaches maximization at this time. In this way, the market structures of supply chain A and B are regarded as two cases, i.e., absolute monopoly market and absolute competitive, then there will exists 4 combination results as shown in Table 1. If two markets of supply chain A and B in a SCC belong to I, the semifinished product price of the supply chain B determined by a absolute competitive market is relative higher. And the product price of the supply chain A determined by a absolute competitive market is relative lower, both transactions can reach Pareto Optimality, on this condition, the upstream and downstream enterprise is inclined to using by market on division. If only such equilibrium doesn't break, there is short of incentive measure to renew the institutional arrangement on division in a SCC, even more integration of institutional arrangement on division.

Tab.1 Four combination results

	Competition	Monopoly
Competition	I（Competition, Competition）	II（Competition, Monopoly）
Monopoly	III（Monopoly, Competition）	IV（Monopoly, Monopoly）

Suppose that partial enterprises exit or horizontal merger in B, enterprise magnitude of supply chain A is invariable, and their market belongs to II, then $p_A(Q)$ reaches minimization determined by a absolute monopoly market in B, as well as p_A reaches minimization determined by a absolute competitive market in A; when enterprises in A has any market advantage, the lowest price is determined by B, it is also quite lower. Therefore, supply chain A has incentive of forward integration supply chain B. because supply chain B is in monopoly station, it can determine high price of downstream market, supply chain A can based on market division to gain high benefit. Analogously, when two markets belong to III, supply chain B has incentive of backward integration A, then supply chain B can based on further integration of institutional arrangement on division to win benefit. When two markets belong to IV, some enterprises exit or horizontal merger in two supply chains and form monopoly station in respective market, since both have

market advantage, then the market division can result them in internecine. The ordinary solution is to sign the vertical contract or integrate vertically, i.e., using by the quasi-integration contract or enterprises to organize division can ensure both benefit increase.

In a word, the transaction cost and benefit determine selection of institutional arrangement on division in a SCC, and such institutional arrangement on division absolutely is not static. In fact, because there are all kinds of uncertain, dynamic and complex factors under the global market, the institutional arrangement on division in a SCC is integrating continuously.

IV. CASE STUDY

As the largest stock company in the Guigang city of Guangxi province in China, Guangxi Guitang Group (GGG) was established in 1954 to produce cane sugar initially. Today it is the largest sugar-making company in China which has several other industrial enterprises, such as a pulp-making plant, an alcohol plant, a cement mill and a fertilizer plant together with forming an ecological supply chain cluster, which is a single centralized SCC. The annual total production includes sugar (120,000 tons), paper (85,000 tons), alcohol (10,000 tons), cement (330,000 tons) and fertilizer (30,000 tons) so on (Zhu and Cote, 2004). All these plants are based on by-products generated from the sugar refinery. The sugar industry has been a major polluter, especially in China, as most of the refineries with a small scale do not meet the existing environmental standards. In order to reduce resource consumption and environmental pollution, the sugar ecological supply chain cluster based on GGG is established to recycle these industrial wastes and returns from the end of pipe to gain simultaneously economical, environmental, and social benefits. Initially, the SCC was built within GGG and slowly extended to external firms. Now the sugar ecological SCC consists of an agriculturally ecological farm, a sugar refinery, sugar distributors and retailers and other firms acting as the reclaiming agents. Reclaiming agents include an alcohol-processing plant, a compound-fertilizer plant, a pulp plant, a thermoelectricity plant, a cement mill and other recyclers. The Figure 1 shows three main flows in the ecological SCC model of GGG: (1) the forward product flow from sugarcane farmers to end users, (2) the reverse supply chain from customers to suppliers. Some returns from consumers are processed within the sugar refinery, some useless wastes are send to recyclers, such as water recovering plant. (3) the by-products flow from sugar refinery to reclaiming agents, in which the by-products generated by the sugar refinery are reused.

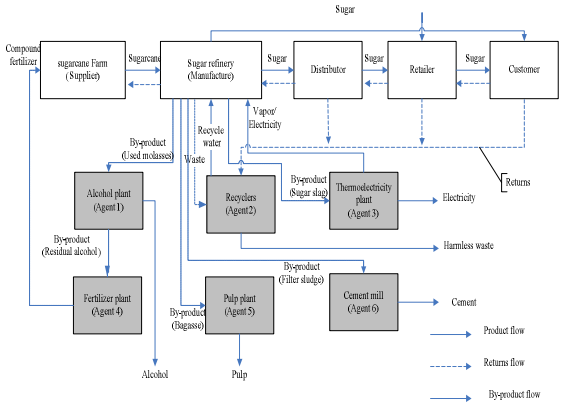

Fig.1 The ecological SCC of Guangxi Guitang Group

To optimize the environmental and economic performance of the whole network of companies within the Group, GGG complied with the ecological design principles to develop new technologies, optimize the production processing and adopt ecological management. Within the sugar chain, three approaches can be seen to treat the residual products, namely, reuse, volume reduction and disposal. By-products such as sugar slag, spent molasses and filter sludge, become the raw material of the pulp plant, the alcohol plant and the cement mill separately to produce pulp, alcohol and cement. The by-products of alcohol plant, residual alcohol can also be reused by the fertilizer plant to produce compound fertilizer that is sold to the raw material producer, the sugarcane farmers. To reduce the amount of residual products, cleaner production technologies are employed. And new technologies to improve water efficiency are developed, which is expected to reduce the wastewater between 30% and 40%. For other by-products produced during sugar refinery which are the most severe pollution problems for the sugar industry, GGG has collected them, and began to use as raw materials. In addition, the sugar refinery sent sugar slag to the thermoelectricity plant, and the reverse flow is electricity and vapor. The recycle resources from the recyclers, such as water, are also sent reversely to sugar refinery. Hence, there are some recycling flows in the sugar ecological SCC, which not only make the damage to environment minimum and the utilization of resource maximum, also improve the whole SCC financial performance. GGG also maintains close relationships with his primary suppliers, the sugarcane farmers. As mentioned above, the GGG sells the fertilizer produced from residual products back to the farmers. Thus, the chemical Fertilizer which can decrease the quality of sugarcane is avoided to be used by farmers. In addition, GGG gives technological and financial supports to farmers to improve the quality of sugarcane and resolve the production problems, encourage them to develop scale economics. The long-term contract with farmers also ensures the quantity of sugarcane and the benefit of farmers. All these efforts make sugar with a high quality and a low cost, which increase the competitive advantage of sugar in the international market. At the same time, GGG has worked on establishing better relationships with their customers. GGG produces the best quality sugar in China according to color, sulfur and impurity content, and thus shares a large market. Its average

sugar price was between 30% and 35% higher than that made by other Chinese sugar refineries because of the good quality. By taking full advantages of by-products and managing firms in an environmentally, socially and economically responsible manner, GGG has realized multi-win of human, nature and society. GGG consider traditional 'waste' as resources, which reduce the material cost. Besides ensuring cooperation, the ecological SCC also helps GGG to cut the transaction costs arising from interactions within different companies in the supply chains. They can share updated information and easily establish cooperative relationships. As a result, some transaction costs are reduced. Since all sugarcane is produced by the farmers in the Guigang city, GGG can also benefit from the low transportation cost. Coca-Cola and Pepsi-Cola have established joint ventures in China which used to purchase sugar from other countries, now begin to buy sugar from GGG. Many domestic soft drink companies such as the Wahaha Group also buy sugar only from GGG. The key reason is that the sulfur content in the sugar made by Guitang is lower than that made by other Chinese sugar plants. This is due to improved environmental technologies developed by the Group and the resulting higher quality of "green" sugar. Barriers related to information dissemination and communication are the key obstacles to ensure the effective performance of the supply chains. Fortunately, in our case, most enterprises in the supply chains are linked tightly around GGG, which facilitates communication among the actors. The government and employees of GGG also can benefit from the ecological SCC management, as they can get more revenue and salary. The problem of lacking water resource has been resolved and the quality of water from the rivers is ensured as a result of by-products reusing. Similarly air quality is improved as most CO2 and other toxic gas are treated. The rapid development of the firms in the sugar SCC drives the development of the relate service industry and increases the job opportunity and the living level of local people. Therefore, GGG can keep the "quantum entanglement state" and promote "quantum jump", and institutional arrangement on division in such SCC is integrating continuously, has made progress both economically and environmentally while most sugar companies in China are still struggling for survival.

V. CONCLUSIONS

Based on the physical theory and the wave-particle duality, a SCC is the special organization whose characteristic is wave-particle duality. There exists sophisticated division of labor between upstream and downstream enterprises in a SCC, and the cost-benefit computing is the main factor to determine the selection of institutional arrangement on division of labor. By enforcing different vertical relations of SCC, supply chains and their enterprises can optimize the selection and integration of different institutional arrangement on division of labor.

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