Research on supply chain surplus of low carbon supply chain coordination system

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Abstract

Supply chain coordination management plays an important role in reducing carbon emission in low carbon supply chain. This study introduces synergetics theory into the research of low carbon supply chain coordination management and reveals the operational mechanism and dynamic mechanism of low carbon supply chain management. Supply chain surplus is an order parameter of low carbon supply chain coordination management, which drives low carbon supply chain system to evolve and develop. It presents the formula of supply chain surplus based on its definition, analyses the components of supply chain surplus, proposes the approaches to realize supply chain surplus, supposes that allocation of supply chain surplus is a Pareto improvement issue, and discusses major basis of supply chain surplus allocation and the program of supply chain surplus allocation.

Keywords: supply chain surplus, low carbon, supply chain management, coordination management

1 Introduction

With the increasing warming of global climate, laws and regulatory policies on reducing the emissions of greenhouse gases are gradually strict worldwide which drive firms find new ways to reduce carbon emissions [1, 2]. Many new technologies and equipment have been applied to reduce the emissions of carbon dioxide, which has also obtained certain effect [3, 4]. Carbon emissions exist in the entire supply chain from the upstream firms to the downstream firms, reducing carbon emission not only need the efforts of a single enterprise, but also requires the joint efforts of all enterprises in supply chain [5]. Recently, there is a growing pressure on supply chain members for reducing the carbon emission of their supply chain. Supply chain coordination management, is the key to effective operation of the entire supply chain system to reduce carbon emission. Numerous enterprises make the target to reduce carbon emissions into the strategy of supply chain management, build low-carbon supply chain to reduce carbon emissions, enhance brand image and competitive advantages.

The concept of supply chain management (SCM) was first proposed in 1980s. It has been used widely in manufacturing industries, and becomes a new business model now. More and more enterprises have been convinced that no longer will enterprises compete against other enterprises, but total supply chains will compete against other supply chains [6]. Next generation of supply chain strategy is coordinated supply chain. Coordination is the key to the competition of supply chain [7].

Most of the earlier models have focused on cost, quality, lead time, etc. issues but not given enough importance to carbon emission for supplier evaluation. Supply chain coordination is that the enterprises in the supply chain coordinate each other to promote the whole supply chain's competition [8]. In the coordinative network, suppliers, manufacturers, distributors and customers can share information dynamically, coordinate smoothly, progress together to achieve their goals [9]. Supply chain coordination management can coordinate and optimize upstream and downstream enterprises' carbon emissions in the supply chain so as to achieve maximize targets for reducing carbon emissions.

Supply chain coordination management plays an extremely important role in carbon emission in low carbon supply chain. Now in academic research of supply chain coordination management, most researches are about method and technology of supply chain coordination, but seldom researches are about the mechanism and theory of supply chain coordination [10-14]. Supply chain surplus is a very important parameter in the study on supply chain coordination mechanism of low carbon supply chain. This paper will discuss the coordination mechanism of low carbon supply chain based on supply chain surplus and realize approaches and allocation program of supply chain surplus in low carbon supply chain.

2 The driven force of low carbon supply chain coordination management is to obtain more supply chain surplus

People have realized that low carbon supply chain is a network, which consists of several independent enterprises. These enterprises can belong to different

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supply chain. In order to analysis of low carbon supply chain coordination mechanism better, we must introduce new theory to grasp the essence of the low carbon supply chain collaboration mechanism.

2.1 THE OPERRATION MECHANISM OF LOW CARBON SUPPLY CHAIN SYSTEM

Low carbon supply chain management and supply chain management have the same system structure. The supply chain is the connected series of activities which is concerned with planning, coordinating and controlling material, parts and finished goods from supplier to customer. Supply chain consists of all the node enterprises including suppliers, manufacturers, distributors, retailers, etc., which generally has a core enterprise. The node enterprises under the drive of demand information to achieve supply chain added value unceasingly by cash flow, logistics flow and/or service as the media through the division of labour and cooperation of supply chain members.

There is a significant positive correlation between environmental action of enterprises and environmental pressures. Every low carbon supply chain management innovation can be traced to a specific environmental pressure. Environmental stress factors which influence low carbon supply chain management mainly including pressure from consumers, purchasing companies, shareholders and other stakeholders, environmental regulations, environmental groups and the social role of the enterprise and so on. The environmental pressure which plays the leading role in different contexts is different. Laws and regulations are the strongest factor which influences on the environmental innovation of product and process.

Environmental pressure is not direct impetus of low carbon supply chain management, enterprise's fundamental purpose of using part of enterprise's resources to solve environmental problems, is to reduce external risk and ensure maximum economic benefits. In the face of various environmental pressures, the reactions of the supply chain are not always timely and effectively. Only when the environment pressure (external factor) transfer into the supply chain (internal cause), the whole supply chain will bring the factors of environmental protection into the systematic and integrated management process, so as to implement low carbon supply chain management in whole supply chain.

Dynamic mechanism of low carbon supply chain management has two key points. First of all, core enterprises are the medium and bridges of transferring environmental pressure into supply chain pressure. The influence of the core enterprise and the environment pressure transformation ability determines the effectiveness of that transformation. Secondly, economic performance is the "prime movers" of the implementation of low carbon supply chain management. Only when environment pressure affects the core enterprise's economic performance, and impacts on the rest enterprise's economic performance through the pressure of supply chain, the problems of environmental performance transfer into questions on the economic performance, the whole supply chain has dynamic to response of external environment pressure, and to achieve the optimization of the overall economic performance of the whole supply chain through the low carbon supply chain management practices.

2.2 SUPPLY CHAIN SURPLUS IS THE ORDER PARAMETER OF LOW CARBON SUPPLY CHAIN COORDINATION MANAGEMENT

In essence, low carbon supply chain is a complex system. With the drastic market competition and various customers' demand, low carbon supply chain has been emerged system character of complexity, opening, dynamic and uncertainty. We need introduce new theories to study the mechanism of low carbon supply chain coordination management.

Synergetics is a cross science across nature science and social science, which was founded by German physical scientist H. Haken in 1970s [15]. It is based on the newest systems science theories, adopts the combined method of statistics and dynamics, through analogism it builds a whole set of mathematical model and method to study the evolution rules which how complex system from out-of-order state to order state.

H. Haken indicated that: "If we focus people's economic behaviours on an easiest question, beyond question the answer is profit." Supply chain surplus is borrowed from the conception of economics. Here it means the sum of margin that all enterprises', including core enterprises and node enterprises, profit which earn after supply chain formed subtracts from profit, which earn before supply chain formed. The precondition of forming supply chain cooperate partner relationship is profit increase. The creation of supply chain surplus don't require profit increase and cost drop happen at the same time, if only the extent of profit increase larger than cost increase or cost drop larger than profit drop, supply chain surplus can be created.

In synergetic, supply chain surplus is the order parameter of the whole supply chain system, it works through supply chain system evolution and development, gets the most subsystems' response and drives subsystem work, and so supply chain surplus determines the supply chain system's evolution speed and progress. It roots in coordination of subsystems, and reacts on dominating subsystems' behaviours.

2.3 THE PURPOSE OF LOW CARBON SUPPLY CHAIN COORDINATION MANAGEMENT IS TO GET MORE SUPPLY CHAIN SURPLUS

Enterprise as a rational "economic man", it is subordinate to the principle of self-interest, always pursues the lowest

cost and maximum profit. If participation in the low carbon supply chain is very convenient (assuming the cost tends to zero), assuming an enterprise faces two choices: participates in the low carbon supply chain or does not participate in the low carbon supply chain. If it is assumed that enterprise's profit before participating in the low carbon supply chain is π_{nsc}, enterprise's profit after participating the low carbon supply chain is π_{sc}, enterprise participates in the low carbon supply chain or not depends on the comparison between π_{nsc} and π_{sc}.

$$\pi_{nsc} = R_{nsc} - C_{nsc}, \tag{1}$$

$$\pi_{sc} = R_{sc} - C_{sc}, \tag{2}$$

where:
R_{nsc}= enterprise's revenue before participating the low carbon supply chain.
C_{nsc} = enterprise's cost before participating the low carbon supply chain.
R_{sc} = enterprise's revenue after participating the low carbon supply chain.
C_{sc} = enterprise's cost after participating the low carbon supply chain.

S is defined as one enterprise's supply chain surplus after participating in the low carbon supply chain

$$\begin{aligned} S &= \pi_{sc} - \pi_{nsc} \\ &= (R_{sc} - C_{sc}) - (R_{nsc} - C_{nsc}). \\ &= (R_{sc} - R_{nsc}) - (C_{sc} - C_{nsc}) \end{aligned} \tag{3}$$

The enterprise's choice is: it will not participate or quit from low carbon supply chain when S<0; it will participate or not participate the low carbon supply chain when S=0; it will participate the low carbon supply chain when S>0. Accordingly, prerequisite of participating the low carbon supply chain is S>0 or π_{sc}>π_{nsc}.

Supply chain surplus refers to the sum total of difference between enterprise's profit before participating in the low carbon supply chain and enterprise's profit after participating in the low carbon supply chain [16]. It assumes that there are several enterprises in low carbon supply chain, and supply chain surplus of the whole low carbon supply chain is defined as S_{sc}.

$$S_{sc} = \sum_{i=1}^{n} S_i = \sum_{i=1}^{n} (\pi_{sc} - \pi_{nsc}), \tag{4}$$

$$S_{sc} = \sum_{i=1}^{n} \left[(R_{sci} - R_{nsci}) - (C_{sc} - C_{nsc}) \right], \tag{5}$$

where:
S= one enterprise's supply chain surplus after participating in the low carbon supply chain.
i≥2, there are at least two companies in the low carbon supply chain, such as supplier and manufacturer.

Every enterprise in the low carbon supply chain wants more coordination profit, S_{sc}>0 is the prerequisite of formation of low carbon supply chain and the prerequisite of supply chain coordination. The purpose of the existence and coordination of low carbon supply chain is to obtain more supply chain surplus. Enterprises in low carbon supply chain can get more profit than before they participate low carbon supply chain.

3 Implementation approaches of supply chain surplus in low carbon supply chain

In order to facilitate implementation approaches of supply chain surplus in low carbon supply chain, we divide supply chain surplus into two parts: revenue surplus (S_R) and cost surplus (S_C) [16].

$$S_R = \sum_{i=1}^{n} (R_{sci} - R_{nsci}), \tag{6}$$

$$S_C = -\sum_{i=1}^{n} (C_{sci} - C_{nsci}) = \sum_{i=1}^{n} (C_{nsci} - C_{sci}). \tag{7}$$

From the two expressions above, it can be seen that supply chain surplus can be achieved by revenue surplus and cost surplus through cooperation of enterprises in the low carbon supply chain.

3.1 IMPLEMENTATION APPROACHES OF REVENUE SURPLUS

Revenue is determined by quantity of sales and prices, then

$$\begin{aligned} S_R &= \sum_{i=1}^{n} (R_{sci} - R_{nsci}) = \sum_{i=1}^{n} (Q_{sci}P_{sci} - Q_{sci}P_{sci}) \\ &= \sum_{i=1}^{n} \left[(Q_{nsci} + \Delta Q)(P_{nsci} + \Delta P) - Q_{nsci}P_{nsci} \right] \\ &= \sum_{i=1}^{n} (P_{nsci}\Delta Q + Q_{nsci}\Delta P + \Delta Q \Delta P). \end{aligned} \tag{8}$$

The above analysis shows that implementation of revenue surplus of supply chain surplus by two ways: increase of sales quantity and price [17]. According to management integration theory, the essence of low carbon supply chain management is an integrated management model based on process. In the formation process of low carbon supply chain, enterprises' integration and cooperation drive the whole function of low carbon supply chain system to be multiplier or emergence, to meet the needs of consumers better, provide value-added service, and create more supply chain surplus.

Revenue surplus of supply chain surplus can be achieved by following ways:

1) Meet more diversified needs of customers. The cooperation of the member enterprises of the low carbon supply chain can understand the needs of the consumer better, and meet the needs of more customers by means of

mass customization flexible manufacturing postponement manufacturing.

2) Present more value-added services and products to consumers. Supply chain is a pull production system based on consumer-centric. The cooperation of the members of the supply chain enterprises give consumers better services and bring higher utility to consumer.

3) Shorten new product development cycles. The cooperation of suppliers, manufacturers, distributors and customers will produce more new product development ideas, speed up the development of new products, and put new products to market more quickly.

4) Improve the quality of products and services. Quality of product and service involving all links of supply chain, such as suppliers, manufacturers, distributors and users, good partnership is good to implement total quality management of supply chain node enterprises.

5) Develop new market. Cooperation of node enterprise in low carbon supply chain will enable the development of new markets, opening up new distribution channels to obtain satisfactory results.

3.2 IMPLEMENTATION APPROACHES OF COST SURPLUS

In consideration of transaction costs, the cost of enterprise should include internal organization costs (C_o), market transaction costs (C_m), and costs of input factors (C_r) [17], then cost surplus can be divide into three parts:

$$S_c = \sum_{i=1}^{n}\left(C_{nsci} - C_{si}\right)$$

$$= \sum_{i=1}^{n}\left[\left(C_{nsci} - C_{sci}\right) + \left(C_{nscoi} - C_{scoi}\right) + \left(C_{nscmi} - C_{scmi}\right)\right].$$

Cost surplus of low carbon supply chain mainly comes from the saving of internal organization costs, market transaction costs, and costs of input factors. Cooperation of enterprises in low carbon supply chain can effectively reduce total costs of low carbon supply chain, then generate cost surplus.

Cost surplus of low carbon supply chain surplus can be achieved by following ways:

1) Reduce inventory cost. Inventory cost savings in the supply chain management are the most credible and most worth pursuing performance [18]. Vender manage inventory (VMI), joint manage inventory (JMI), and other inventory management means play significant roles in reducing inventory costs.

2) Decrease transaction cost. Supply chain member companies makes the transaction object stability, trust, information sharing, which reduce intermediate links, and reduce transaction costs.

3) Reduce organization cost. The internal organization of cost savings can be achieved at different stages of the supply chain more efficient by division of labour and collaboration. The members of the supply chain are independent to each other, cooperate and compete with each other, which helps to avoid the non-productivity of hierarchical organization, and reduces organizational costs.

4) Cut down production cost. Members of the supply chain companies can develop new products through cooperation to amortize the cost of R&D, the stabilization of the cooperation between member companies is conducive to achieve economies of scale, reduce the costs generated by the production of excessive volatility (bullwhip effect). Because enterprises in the supply chain have formed long-term, stable, and cooperative relations, enterprises in low carbon supply chain can invest in special assets, which can improve production efficiency and reduce production costs.

3.3 THE ALLOCATION OF SUPPLY CHAIN SURPLUS

Supply chain surplus is the result of all enterprises cooperation in low carbon supply chain, is the purpose of low carbon supply chain coordination management. Enterprises' purpose of participating in low carbon supply chain is to create "cooperation surplus", how to allocate the "cooperation surplus" and how much right of residue claim can participating in enterprises get from the low carbon supply chain are the focus of attention problems in modern firm theory. Allocation of supply surplus not only influences the profit allocation in low carbon supply chain, but also affects quantity of surplus, even influences the enterprises' participation. How to allocate the residual power between participants in the low carbon supply chain is the core issue of governance of low carbon supply chain.

Allocation of supply chain surplus is a Pareto improvement issue. How to allocate supply chain surplus fairly and reasonably to the enterprises in low carbon supply chain is a critical issue in low carbon supply chain management. The major basis of low carbon supply chain surplus allocation is mainly based on:

1) Degree of information sharing. Demand-side enterprises and supply-side enterprises in supply chain can achieve real-time information by sharing information to reduce the risk of supply-side enterprises' inventory. In the cooperation of Procter & Gamble Company and Wal-Mart, Procter & Gamble Company can call Wal-Mart's sales and inventory data at any time, and develops its production and shipping plans efficiently by sharing information from Wal-Mart. In return, Procter & Gamble Company transfers part of supply chain surplus to Wal-Mart by providing products at preferential prices.

2) The size of the risk. Each link of the low carbon supply chain bears a different risk. Generally, upstream enterprise's risk significantly dropped after the formation of the supply chain partnership. But the risk of end-consumers still cannot be reduced effectively (consumer demand is changing all the time). So the current trend of

allocation of the supply chain surplus is inclined to links directly to downstream consumer.

3) Loss of control. The members of the supply chain enterprises constrained by the core enterprises, and thus lose some control rights. Control rights are parts of the business utility, supply chain must give some income or usufruct as compensation of the loss of control rights, such as preferential pricing, granted exclusive powers, etc.

Correct and suitable process is the safeguards of supply chain surplus allocation. First, it can determine the need of resource and value which enterprises need put into by the need of low carbon supply chain, sign contracts according to various stakeholders' resources, risk and contribution. Then it will evaluate the profits by effects and actual performance of low carbon supply chain operation, diagnose problems, take supplementary adjustments to the contracts, and make the secondary allocation. The program of supply chain surplus allocation is shown in Figure 1.

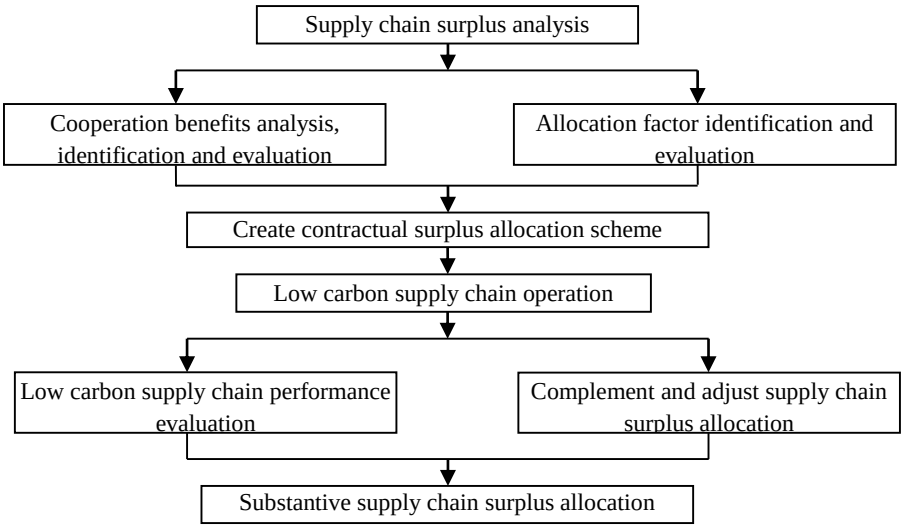

FIGURE 1 The program of low carbon supply chain surplus allocation

Since enterprises in the supply chain collaborative networks have formed a closely strategic alliance, the allocation of supply chain surplus must consider cooperative enterprise's fixed investment, contribution to the whole low carbon supply chain, effort level, and risk factors to achieve Pareto improvement. Factors affect influenced the distribution of supply chain surplus in low carbon supply chain can be concluded to four factors: specific assets investment, effort level, risk factors and substantial contributions, which are shown in Figure 2.

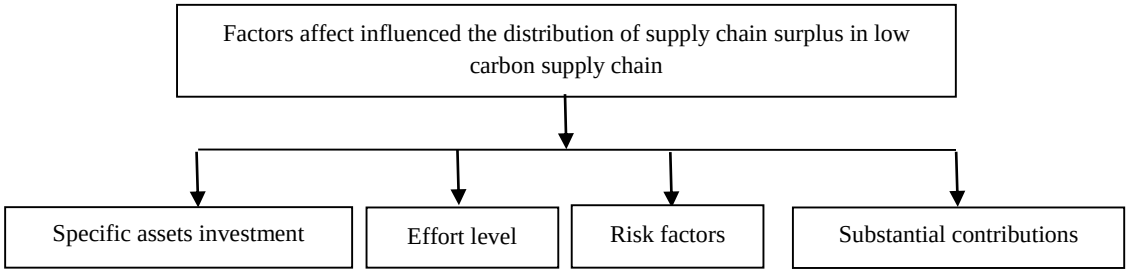

FIGURE 2 Factors affect influenced the allocation of supply chain surplus in low carbon supply chain

The allocation of the supply chain surplus is a game process between member enterprises of the low carbon supply chain, especially enterprises both are strong cooperation. The allocation of the supply chain surplus is a process of repeated game process. Therefore, negotiation mechanism is necessary in relational contract [11]. Supply chain as a network intermediates between market and hierarchy organization, allocation of supply chain surplus can be only realized by coordination and, including compensation of information sharing, risk-sharing, and loss of control right. Generalized supply chain members also include the end users and consumers, and supply chain surplus also need be allocated to the end-users and consumers to enhance the competitiveness of the whole low carbon supply chain.

4 Conclusions

With the increasing warming of global climate, people pay more attention to reduction carbon dioxide emission. Reducing carbon dioxide emission not only needs the efforts of a single enterprise, but also requires the joint efforts of all enterprises in supply chain. Supply chain coordination management, is the key to effective

operation of the entire supply chain system to reduce carbon emission.

The purpose of existence and coordination of low carbon supply chain is to obtain more supply chain surplus. $S_{sc}>0$ is the prerequisite of formation of low carbon supply chain and the prerequisite of low carbon supply chain coordination. Enterprises in low carbon supply chain can get more profit than before they participate low carbon supply chain. Synergetics theory is good to apply to the study of low carbon supply chain coordination mechanism. In Synergetics, supply chain surplus is the order parameter of the whole low carbon supply chain system, it works through low carbon supply chain system evolution and development, gets the most subsystems' response and drives subsystem work. Supply chain surplus determines the low carbon supply chain systems' evolution speed and progress. The interaction of supply chain surplus with specialization, informatization and knowledge management drives the supply chain system evolving to stably transitional supply chain surplus, and then developing to a new supply chain surplus structure.

Supply chain surplus can be achieved by revenue surplus and cost surplus, revenue surplus of supply chain surplus can be achieved by raising the value or creating new customers, cost surplus of supply chain surplus can be achieved by cutting down inventory cost, transaction cost organization cost, and production cost. How to allocate supply chain surplus fairly, reasonably to the enterprises in low carbon supply chain is a critical issue in low carbon supply chain management. Allocation of supply chain surplus in low carbon supply chain is a Pareto improvement issue. The major basis of supply chain surplus allocation is mainly based on degree of information sharing; the size of the risk; loss of control. Supply chain surplus allocation needs a correct and suitable process.

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