Research Article

Revenue Distribution Decision in Low-Carbon Supply Chain with Revenue Sharing Contract: An Analysis of the Third-Party Participation and GAHP

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1. Introduction

Following the Copenhagen Conference in 2010, the low-carbon economy has become a hot topic, and the low-carbon supply chain is the essential approach for enterprises to adopt the low-carbon economy [1]. Despite the fact that low-carbon supply chains were just recently introduced to the academic community, they have gotten many interest conclusions [2, 3]. The majority of academics were convinced that finding ways to implement low-carbon strategies across the whole supply chain is critical [4]. Yet, building and establishing a low-carbon supply chain, on the other hand, is in its early stages because even within the low-carbon supply chain, the partners have weak willingness to cooperate in low-carbon construction [5]. Later, several contracts such as buyback contract, revenue sharing contract, quantity flexibility contract, sales rebate contract, and quantity discount contract are discussed to coordinate the supply chain by Dana et al. [6, 7].

Generally, rational suppliers and retailers make decisions based on the principle of maximizing their own expected revenue in a low-carbon supply chain coordinated by revenue sharing contract [8]. The RSC may effectively coordinate a low-carbon supply chain if market demand is consistent, both parties are risk-averse, and the expected market demand is unrelated to peak sales season. However, in the low-carbon supply chain, motivating the partners to work hard to achieve emission reduction objectives is much more difficult since each of them solely focuses their own interests. As a result, the nonparticipation of the partners...
may reduce the sustainable performance of the overall low-carbon supply chain [9]. Afterward, Cachon put forward revenue sharing contract and many other scholars found that revenue sharing can coordinate a supply chain well [8].

However, several problems the partners would have to face when applying revenue sharing contract in low-carbon supply chain. First, the restricted characteristics of the RSC model make it difficult to carry out the contract. Second, many specifics of the collaboration cannot be included into the contract due to the incompleteness of the revenue sharing contract. Third, owning to the difficulty to monitor the input-output of the partners in low-carbon supply chain, which will arouse other problems in RSC. Finally, most of the revenue sharing contracts are theoretical models and cannot offer a substantial way to achieve profit sharing.

The aforementioned issues indicate that when the RSC coordinates low-carbon supply chain, it is critical to find a way to minimize noncooperative behavior among partners and quantify and clarify the unclear problems [10]. Therefore, from both a theoretical and practical perspective, it is required to develop a new mechanism to coordinate revenue sharing for the low-carbon supply chain. To this end, we will propose a new commercialized method, which would distribute the revenue of low-carbon supply chain with RSC in a fair and reasonable way. Different from the traditional evaluation method, in this paper, we intend to use the third-party participation mechanism and the GAHP method to implement the revenue sharing contract for low-carbon supply chain. Moreover, in our paper, we will divide the revenue sharing parameter of \( \phi \) into [0–0.1), [0.1–0.2), [0.2–0.3), [0.3–0.4), [0.4–0.5), [0.5–0.6), [0.6–0.7), [0.7–0.8), [0.8–0.8), and [0.9–1].

The following are main contributions of the paper: first, the 43 indicators, as well as the analytical hierarchy process (AHP) matrix and extensive explanations for each index, are produced after we surveyed 22 relative experts. In addition, with the help of the Yaahp12.0 software, we will calculate the value of each index and its sensitivity to decision-making. In a word, this research can help low-carbon supply chain decision-makers determine the value of revenue distribution and expand the application of revenue sharing contract. Second, according to three aspects of the literature, there comes more and more literature using RSC to coordinate the supply chain recently. The RSC designed before is still a theoretical contract rather than the implementation view of decision-making. Therefore, we not only consider the problem of revenue sharing contract, but also build a model and propose a set of evaluation index for the decision-making of low-carbon supply chain. The coordination of low-carbon supply chain with the RSC is different from both the supply chain contract itself and the coordination of the low-carbon supply chain. We will only refer to the literature that comes across common parts of the both. Then, we will spare no effort to find out the unique decision-making perspective, mechanism, and method in the low-carbon supply chain coordinated by the RSC. Third, owning to the difficulty to monitor the input-output of the partners in low-carbon supply chain, it will arouse other problems in revenue sharing contract.

The rest of this paper is structured as follows. In Section 2, we will review the literature of low-carbon supply chain, revenue sharing contract, and decision-making method and describe the key problems in low-carbon supply chain with RSC. In Section 3, we will put forward a theoretical model of decision-making. Then, a set of decision index will be established in Section 4. We will devise a kind of decision-making mechanism and calculation method of revenue distribution. In Section 5, a calculation case will be given to verify the preceding findings. The final part of the paper will contain assuming comments.

2. Literature Review

This paper is related to three fields of the literature, namely, low-carbon supply chain, supply chain revenue sharing contract, and supply chain decision-making method. Next, we will review related studies on low-carbon supply chain in Section 2.1. In Section 2.2, we will review studies on supply chain revenue sharing contract. And in Section 2.3, studies on the supply chain decision-making method will be summarized.

2.1. Low-Carbon Supply Chain. According to United-Nation (2010) principles, “low-carbon supply chain is the management of carbon emission reduction and the encouragement of good governance practices throughout the lifecycle of goods and services.” This concept is relevant to “green supply chain” and “sustainable supply chain management” [11]. Cheng et al. studied cooperative pricing strategies of closed-loop supply chain [12]. Jaber et al. studied a supply chain with one manufacturer and one supplier to find how to increase sustainable benefits through carbon emission reduction [13]. Zhao and Wang discussed the revenue optimization model of a 2-level supply chain with the Stackelberg game [14]. Zhang et al. explored the impact of cap regulation on manufacturer’s low-carbon strategy [15]. To investigate the impact of carbon trading on low-carbon supply chain, Xia et al. developed a game model between low-carbon products and ordinary products [16]. Nie et al. studied a new configuration problem in supply chain to optimize carbon emission based on a service guarantee-modeling framework [4].

Based on the natural resource-based view (NRRV), Mao et al. discussed the relationship between internal low-carbon integration and external low-carbon integration and firm performance [17]. Lin et al. investigated the complex dynamics of pricing decision and supply chain carbon reduction strategy [1]. Kang et al. studied the evolutionary behavior of companies in the low-carbon supply chain and the policy challenges associated with low-carbon government policies and the new low-carbon market [18]. Hata et al. developed an input-output model as a quadratic programming model with production and greenhouse gas (GHG) restrictions [19]. Chen and Wang’s study looked at the effectiveness of product mix as a strategy to deliver the low-carbon supply chain under the cap-and-trade policy [9]. Bai et al. created a model for introducing and carrying out
supply chain practices for low-carbon supply chains [11]. Ma et al. established four kinds of differential game models with different low-carbon tourism supply chain (LTSC) network structures and found that horizontal or vertical cooperation are not always conducive to the performance of the whole LTSC network [20]. Peng et al. designed cost-sharing contract in a service supply chain and analyzed the optimal service level, emission reduction, and advertising efforts [21].

The literature on low-carbon supply chain has investigated the issue of carbon emission, low-carbon strategy, and carbon trading. Moreover, profit distribution in low-carbon supply chain is less mentioned. Additionally, the prior research studies have mainly focused on the concept, coordination, and operation of low-carbon supply. To be specific, the prior studies have mainly analyzed from the theoretical perspective without examining the practices of low-carbon supply chains. Moreover, the prior literature has not examined the implementable scheme for carrying out low-carbon supply chain.

2.2. Supply Chain Coordination with Revenue Sharing Contract. Revenue sharing has been known as a coordinating contract based on the classic newsvendor-model. In particular, we summed up three important aspects of literature that may be used to characterize the subject of revenue sharing in supply chain. The first is the precise definition of the revenue sharing contract. The second is about the performance of the revenue sharing contract comparing with the other contracts. And the third is related with the conditions in which the contract is implemented.

Cachon first proposed revenue sharing contract, and it has been widely adopted since 2002. Cachon and Lariviere made a detailed summary of revenue sharing and showed that such contracts can coordinate the supply chain and distribute the supply chain profit with a specific setting on the wholesale price [8]. They pointed out that with price dependent demand, revenue sharing contract would coordinate the supply chain. Particularly, they also concluded that the distribution of profits probably depended on the relative bargaining power of the enterprise. Wang and Hao studied a consignment arrangement with revenue sharing [22]. Van der Veen and Venugopal have shown that revenue sharing contracts could deliver a win-win situation for all the partners of supply chain [23]. Wang et al. constructed a coordination game model of carbon emission reduction and analyzed the carbon emission reduction of the coal-fired power enterprises under the revenue sharing contract [2]. Liu put forward and analyzed four common cost-sharing models, and they utilized revenue sharing contract to coordinate supply chain by the proposed models [3]. Bart et al. provide mathematical formulations of the two RSC structures that are most prevalent in research and in practice [24]. They also summarized six alternative approaches for determining the revenue sharing ratio. Among these research studies, the ratio was set by the downstream party in 37 papers, and it was set by the upstream party in 34 papers. And the ratio in 17 papers was negotiated between the parties in a Nash bargaining game. In addition, Berghuis and Den Butter studied WCRS1 in a two-echelon green supply chain [5]. Peng et al. considered a dual-channel closed-loop supply chain (CLSC) and concluded that government can encourage the manufacturer to adopt desired channel structures by setting appropriate subsidy levels [21].

From the above studies, it indicated that the previous research studies on low-carbon supply chain have mostly focused on the mathematical model, cooperative game or noncooperative game, while there is less focus on analyzing the implementation and application of revenue sharing contract. In our study, a theoretical model and a set of index system will be constructed.

2.3. Supply Chain Decision-Making Method. The Supply Chain Council published 13 supply chain operations reference indexes in 1994 (SCOR). Beamon devised a method of evaluation based on resources, output, and adaptability. Gunasekaran et al. proposed a performance evaluation approach based on a variety of supply chain types [25]. Bolstorff et al. proposed a performance-based decision-making framework for customers and internal operations [26]. The FA-DEA-AHP technique was adopted by Xiangshuo et al. to prioritize the supply chain performance system alternatives [27]. A fuzzy approach for identifying green suppliers was suggested by Guo et al. [28]. It is worth mentioning that numerous academics have analyzed the success of supply chain firms by using the weighted output to weighted input ratio. For example, Mani et al. designed a set of criteria for assessing and selecting candidates [29]. And they devised a set of criteria for assessing and choosing potential suppliers. Rosenbaum put forth an evaluation method from the views of the customers, internal processes, and shareholders. Bhagwat and Sharma built up the evaluation index of performance according to the balanced scorecard [30]. Khan et al. developed an integrated knowledge-based system (KBS) that creates a link between decisions and decision criteria (attributes) and evaluates the overall SC performance [31]. Ghosh et al. designed a two-echelon dual-channel supply chain model and illustrated the critical channel strategies to acquire greater management insights for chain members [32].

Reviewing the literature on the supply chain decision-making method reveals that the prior studies have mainly focused on traditional approaches of SCOR, KBS, and AHP. In addition, the existing literature has ignored the conflict and noncooperative game among supply chain decision-makers. Different from the existing literature, this study proposes the third-party participation (TPP) mechanism and the group analytic hierarchy process (GAHP) decision-making approach based on the premise that “heteronomy is better than self-discipline.”

2.4. Research Gaps. Although there are an increasing number of scholars who have discussed on the issue of supply chain decision-making method, while there are quite a few studies on decision-making in low-carbon supply chain through the view of revenue sharing, the literature
relating with our paper is still scarce. There comes more and more literature of using RSCs to coordinate the supply chain recently. The RSCs designed before are still a theoretical contract rather than implementation and the RSCs cannot offer a substantial way to achieve ratio of profit sharing. Besides, the literature on low-carbon supply chain mainly consists of carbon emission and carbon trading. Moreover, the prior research studies have less consideration of carrying out low-carbon supply chain. Different from the foresaid literature, this article proposes a feasible revenue distribution method of low-carbon supply chain and a reference case is given.

From the aforementioned studies, it is clear that above research on low-carbon supply chains has primarily concentrated on mathematical models, cooperative games, and noncooperative games. In comparison with the previous articles, we conceptualize the parameters of the revenue sharing contract model in this work, and a set of index systems is established. At the same time, we propose a theoretical model in which the parameters of the revenue sharing contract model are conceptualized.

Furthermore, as Zhou argues in their paper, the AHP method is effective when using decision-making in low-carbon supply chain [33]. To be more specific, the AHP method has the advantage when handling complex problem settings with low-carbon supply chain. However, the AHP method cannot reflect the authority and influence of each expert. The research of this paper will provide an effective framework and method to help the partners to achieve profit sharing. Meanwhile, some software is useful when evaluating the low-carbon supply chains with revenue sharing contract. In addition, the third-party participation will be introduced to evaluate these indexes and carry out the RSC in low-carbon supply chain. Finally, we will adapt the GAHP method to calculate the weight of each index.

3. Problem Description and Solving Methodology

3.1. Description of Main Problems

3.1.1. The Limited Parameters of the Revenue Sharing Contract Model. For the sake of the convenience of research, the assumption of model construction is strict in the available literature. Meanwhile, the revenue sharing agreement is based on a simplified mathematical model with only three variables: revenue distribution factor ($\phi$), wholesale price ($w$), and order quantity ($q$). However, there are considerably more aspects to consider in the real decision-making of low-carbon supply chain coordination than these metrics. In addition, a few literature studies consider the cost, retail price, and residual value of unsold products of suppliers and retailers. This makes it harder for low-carbon supply chains to make decisions.

3.1.2. Incompleteness of Revenue Sharing Contract. In general, before engaging in revenue sharing, low-carbon supply chains should execute a very comprehensive contract to try to resolve all issues among partners. The revenue sharing contract partners should theoretically provide specific stipulations on the action taken in every potential case, as well as accurate estimates on every probable occurrence, cost, and profit. And the partners of low-carbon supply chain believe that adhering to the terms of the revenue sharing contract is their best option. However, to achieve and perform a complete contract, the partners must anticipate all possible risks. Moreover, the low-carbon supply chain partners must be able and willing to solve all problems that may arise. Due to the limited rationality, the uncertainty of the environment, opportunism, information asymmetry, and other factors in low-carbon supply chain enterprises, there are always certain inadequacies or missing clauses in the revenue sharing contract [7]. The incompleteness of revenue sharing contract makes the low-carbon supply chain unable to overcome these difficulties [34].

3.1.3. The Challenge of Tracking the Partners’ Input-Output in a Low-Carbon Supply Chain with Revenue Sharing Contracts. In terms of input in low-carbon supply chain, it is impossible to track the time and energy invested by the cooperative enterprises. As a result, some enterprises are less enthusiastic in revenue sharing and are more likely to choose opportunistic behavior [22]. As for the output during the coordination of low-carbon supply chain with revenue sharing contract, like other coordination, alliance members can be provided with both direct and indirect benefits. However, the indirect benefits cannot be calculated clearly, since they are not included in the revenue sharing contract mathematical model [28]. Therefore, in order to analyze performance and the effects of the coordination, it is required to completely monitor and estimate its consequences. At the same time, it is also required to carry out a “cost-benefit” and “risk-benefit” analysis on the “input-output” in the process of coordination.

3.1.4. The Challenge of Implementing the Revenue Sharing Contract Model. The execution of the revenue sharing contract will be simple if all firms in the low-carbon supply chain with revenue sharing contracts have symmetrical information and equal status, valuing the supply chain’s overall interests, and having the equivalent strength [35]. Yet, in practice, it is typically difficult to reaching a revenue distribution agreement between suppliers and retailers. On the one hand, the context and circumstances in which revenue sharing contracts are used are significantly more complicated than the idealized model [23]. Communication and the games between partners, in particular, are not only regarded costly, but also inefficient and dissatisfied due to noncontractual issues.

On the other hand, in contrast to the stated conditions in the revenue sharing contract model, all parties must carefully address the implicit terms in the contract model. All of these issues make it difficult to implement the separate revenue sharing contract model in practice, which requires suppliers and retailers to consider various noncontractual elements while executing the revenue sharing contract to
coordinate low-carbon supply chains. Based on the above aspects, we will propose a feasible and realistic application method of the revenue sharing contract model.

3.2. Problem-Solving Methodology. The aforementioned issues suggest that it is critical to find a way to avoid the noncooperative game among the partners with the greatest possible and quantify and clarify the unclear issues. In our study, we will develop a set of indices for decision-making in low-carbon supply chain. This will involve which decision indexes will be developed. Second, the indices must be visible in order to avoid partners from “loafing on the job,” “hitchhiking,” or “opportunism.” As a result, we need to calculate each index through group decision-making and evaluate the relative weights of each index. The goal is to figure out how much each component weighs in the decision-making index, as well as how much every enterprise contributes to the total revenue distribution. Finally, a practical decision-making approach that is acceptable to all parties is chosen.

In the model of revenue sharing contract of low-carbon supply chain, if two of the three parameters are known, the value of the third parameter can be calculated. Of the three parameters, neither the wholesale price “w” nor the order quantity “q” have a range of value, but the range of “ϕ” is between 0 and 1. Some researchers discussed the relationship between revenue sharing factor “ϕ” and wholesale prices “w” in detail. Giannocaro and Pontrandolfo also calculated out the feasible range of “ϕ” [36]. Therefore, we may first quantify the range of revenue sharing factors “ϕ” before making a decision on a revenue sharing contract for low-carbon supply chain coordination. In this paper, “ϕ” will simply be divided into [0–0.1), [0.1–0.2), [0.2–0.3), [0.3–0.4), [0.4–0.5), [0.5–0.6), [0.6–0.7), [0.7–0.8), [0.8–0.8], and between [0.9–1]. The decision-making index also includes other factors that are not included in the revenue sharing contract model. Then, we will adopt quantitative methods combined with qualitative methods to calculate the value of “ϕ.” Ultimately, we will compare the value of “ϕ” with the model of revenue sharing contract and try to see whether it achieves the Pareto improvement in low-carbon supply chain. If it falls into the feasible range, which shows the decision-making is effective; otherwise, it is considered be invalid. Therefore, the goal of this work is to figure out what decision perspectives to use, what decision indexes to create, and how to create a quantitative decision-making method.

Therefore, the methodology of problem solving in this paper is as follows. The decision-making viewpoint will be adopted. Then, by using the method of literature analysis, the decision-making index will be put forward. The related decision index will be chosen by referring to the available literature and combined with the practice of revenue sharing of low-carbon supply chains. In terms of the evaluation method, firstly, an inductive method is adopted to summarize some concrete (single) indexes into a comprehensive index layer by layer. Then, a deductive method is used to design the index layer by layer.

4. Basic Model and Theoretical Framework

4.1. Decision-Theory Model. According to the decision-making theory of low-carbon supply chain and the revenue sharing contract, we will build the theoretical model from the views of “optimization cost,” “increasing efficiency,” and “improving satisfaction” (shown in Figure 1). The synergism of the three aims to maximize the revenue of the low-carbon supply chain while keeping the businesses running smoothly. In the theoretical model, “optimization cost” is the key foundation of the low-carbon supply chain with the revenue sharing contract. Banterle et al. built a vendor management contract and transaction cost model and analyzed them with game theory [37]. Ji et al. have developed a mathematical model to analyze supply chain inventory cost [38]. Spinler and Huchzermeier have designed an option model to improve the coordination of supply and demand [39].

Some Chinese scholars adopted the activity-based costing method to construct a retailer cost optimization model. Some other scholars set up a multicycle supply chain cost management model from the perspective of setting cost targets, breaking down cost targets, and achieving cost targets. Wei et al. established the relative contribution rate of profit and erected a low-carbon supply chain cost management model [34]. According to the models constructed by the above scholars, we will build the cost module from the perspectives of operation cost, management cost, transaction cost, and relationship cost.

The first submodule of our theoretical model focuses on the revenue sharing contract cost. The latter two submodules analyze the transaction cost of the revenue sharing contract and the coordination cost among the supply chain partners. The first submodule can be simply regard as the basis of the three. The latter submodules are the complement of the first submodule.

The second module in the theoretical model primarily describes the efficiency of low-carbon supply chain, market performance, the execution of the revenue sharing contract, and the performance of low-carbon supply chain operation [40].

The third module focuses on the satisfaction, which is discussed from three perspectives. Since profitability is the main criterion for checking low-carbon supply chain, in our paper, we set profitability as the first evaluating index in this module. Revenue sharing contract requires partners to maintain a cooperative relationship. And profitability is the precondition for the pursuit of overall satisfaction of the low-carbon supply chain. Therefore, we set it as the first evaluating index [41]. Since to satisfy the ultimate customer is the most important goal of low-carbon supply chain with the revenue sharing contract, we put forward it as the third index.

4.2. Decision-Making Index. According to the existing literature, we propose the following five concepts in this study. The first is the decision-making index’s comprehensiveness. Due to the complexity and variety of the partners, numerous elements should be addressed in the revenue sharing
the second factor is the decision-making index’s ductility, which is owing to the market’s complexity. On the one hand, the low-carbon supply chain’s coordination goals with revenue sharing contracts will be changed on a regular basis. On the other hand, because various cooperative firms have distinct core competencies and competitive advantages, the assessment index for suppliers and retailers should be varied as well. This necessitates that the decision index be ductile and flexible and that it dynamically changes to the decision index based on the actual situation. The third factor is the decision-making index’s simplicity. The fourth is the comprehensiveness of the index. Some factors are difficult to quantify to assess the strengths and weaknesses of companies in the low-carbon supply chain. Therefore, a combination of qualitative and quantitative approaches will be required.

5. Decision-Making Mechanism and Calculation Method

5.1. Decision-Making Mechanism. In general, the strengths and weaknesses of a low-carbon supply chain should be assessed and determined independently. However, management practice shows that it is not easy for enterprises to make objective and fair decisions to coordinate the cooperative relationship between alliance enterprises.

First, there is a conflict among the partners in low-carbon supply chain, making it difficult to reach a decision-making policy. Although the low-carbon supply chain with revenue sharing relies on the trust of multipartner, there are both cooperation and conflicts between the enterprises because of their separate benefits [51]. In essence, the suppliers and retailers are either driven by self-esteem or unwilling to take the risk of their own mistakes. Furthermore, some enterprises are simply not willing to acknowledge the mistakes they make in contract implementation. This will make decision-making difficult to carry out.

Second, the status of the partners is unbalanced, which would cause the decision-making plan difficult to implement. If all enterprises in the low-carbon supply chain are in an equal position and focus on the overall interests of the supply chain, and the possession of information is the same, then the coordination of decision-making is easy to operate. It is worth noting that the low-carbon supply chain consists of many enterprises with different competitiveness, so coordination of decision-making is not easy to achieve. And their investment, their roles, their status, their activities, and even their contributions to the low-carbon supply chain are
all distinct. When the core enterprises evaluate the problems likely to be aroused by the weak enterprises, the latter are in a kind of inclining to protect their own interests [52].

On the other hand, if the weak enterprises find that the core enterprises make some terrible mistakes, they have no way to prevent the core enterprises from doing so. Their weak position restricts them to put forward improvement suggestions to the core enterprises. This will make it difficult for all parties to accept and carry out the evaluation results efficiently. Therefore, it is necessary for the low-carbon supply chain to establish a new set of decision-making mechanisms to ensure effective cooperation. In this study, we propose a third-party decision-making process based on the viewpoint that “heteronomy is better than self-discipline.” This mechanism would allow low-carbon supply chain firms to concentrate on their main business while also making decision-making more objective, fair, and efficient. To this end, we will establish a third-party institution to carry out the third-party mechanism.

5.1. Establishment of Third-Party Institution. The third-party institution may be an independent management organization or a group of highly qualified consultants who are familiar with low-carbon supply chain management and the revenue sharing contract. The institution should have professional and practical expertise of the low-carbon supply chain as well as a thorough comprehension of the revenue sharing agreement. It should also have less influence on supply chain partners. Because if the third-party institution has authority over the enterprises of the supply chain, the result is the contradictions of the coordinating decision will transfer to the third institution. Thirdly, maintaining a neutral and balanced relationship with supply chain firms is essential. It should not be subject to intervention to ensure the scientific, fair, and reliable evaluation of decision-making. Finally, the institution should be granted some appropriate authority, but it may not have any supervisory or managerial responsibilities [42].

It should be highlighted that the experts of the third-party institution should also be carefully chosen and have clear responsibility. First, to achieve decision-making scientifically, it is required that the experts must be knowledgeable in low-carbon supply chain management and contract management. In the next place, in order to achieve objectivity, the experts must be independent of all enterprises involved in the low-carbon supply chain. At the same time, they must be familiar with the coordination situation. Finally, in order to guarantee that the assessment is carried out effectively, the experts must be able to interact, coordinate, negotiate, and carry out with both suppliers and retailers.

5.1.2. Responsibilities of the Third-Party Institution. The main responsibilities of the third-party institution consist of three aspects. One is to put forward and determine the decision-making index of the low-carbon supply chain coordination. The next is to analyze and coordinate the conflict between the partners. By the principle of objectivity, fairness, and equity, the third-party institution should establish procedures and scientific methodologies in accordance with the principles of objectivity, fairness, and equity.

5.1.3. Operating Mechanism of the Institution. As previously described, the experts of the third-party institution are not from the low-carbon supply chain enterprises, and their operating finances are not reliant on any single enterprise. Meanwhile, once the third-party institution has been established, it should be empowered certain executive powers to strengthen its authority.

5.2. Decision-Making Process. Some factors are difficult to quantify, and the index weight is not easy to judge. In this paper, we will adopt both group decision-making method and the analytical hierarchy process (AHP). The specific steps are as follows. The first step is to conceptualize the evaluation index. According to Satty’s 1–9 scale method, the mood degree given in this paper is 1, 3, 5, 7, and 9, which, respectively, represent important at the same level, slightly important, relatively important, very important, and extremely important.” 2, 4, 6, and 8 are between them [53]. The reciprocal of each value has the opposite similar meaning. Then, the judgment matrix is constructed. In order to overcome the subjectivity of the experts, the decision-making institution will invite several experts to compare the index. The experts then determine the relative level and establish a judgment matrix according to the judgment scale. The third step is judging matrix with a single hierarchical ranking. The single hierarchical ranking is to calculate the weight of the factors related to the previous judgment matrix. This is the basis for ranking all factors in that hierarchy. The fourth step is judgment matrix correction and consistency checking. The consistency of the individual expert judgment matrix in AHP is checked in this step. A new judgment matrix is built to strike out inconsistency, and then the judgment matrix of correction is put forth. The last step is to build judgment matrix. According to the methods of “addition,” “multiplication,” and “index,” the judgment matrices of the multiple expert can be aggregated. In the case study, the most commonly used method of arithmetic average will be adopted to combine the matrix calculation. By the GAHP method, we set the judgment matrix of the expert k as follows:

\[
A^{(k)} = (a_{ij})_{n \times n} = \begin{bmatrix}
1 & a_{12}^{(k)} & \ldots & a_{1n}^{(k)} \\
 a_{21}^{(k)} & 1 & \ldots & a_{12}^{(k)} \\
 & \ldots & \ldots & \ldots \\
 a_{n1}^{(k)} & a_{n2}^{(k)} & \ldots & 1
\end{bmatrix}.
\]  

(1)

In the above matrix, if \( a_{ij} = (1/a_{ji}) \), \( k = 1, 2, \ldots, m \) and if the order consistency \( A^{(1)}, A^{(2)}, \ldots, A^{(m)} \) is satisfied, then the calculation formula of the judgment matrix aggregation of the arithmetic average method will be as follows:

\[
a_{ij} = \frac{\sum_{k=1}^{n} a_{ij}^{(k)}}{n}.
\]  

(2)
5.3. Analysis of Calculation Examples

5.3.1. Data Selection. Since 2016, to enhance its market share, the enterprise “A” has adopted the market development strategy to increase its market share rapidly. In its price policy, enterprise “A” selected one category of low-carbon products to compete with its competitors. The market researchers of the enterprise “A” initially calculated the amount of the purchasing and sales according to the data of the recent years. Then, they calculated the production costs (including average variable cost and fixed cost), purchase, and sales costs of the retailers. According to the basic model of revenue sharing contract, we simulated the decision-making and the results were as follows. Apart from the previously mentioned factors, the index built up in Section 4.2 was also taken into account while deciding on the selected items. Table 1 shows the cost, satisfaction, and efficiency indices. The enterprise “A” then established a third-party institution and a panel of experts.

5.3.2. Data Calculation. Because of the flaws in the low-carbon alliance itself, GAHP is used in this study to choose a decision-making method. Considering that a single decision-maker does not complete coordination and it is
different to make an objective and fair decision on coordination by the AHP method, the experts unanimously agreed to adopt the GAHP method. Due to the differences of the experts in expertise, experience, and influence, the consulting company assigned a weight of 0.25, 0.15, 0.2, 0.25, and 0.15 for each expert. When setting the target layer, we use the parameter of revenue distribution as Alternative Scheme layer and divide it as follows: Alternative Scheme 1 is (0.4–0.425), Alternative Scheme 2 is (0.425–0.5), Alternative Scheme 3 is (0.5–0.525), and Alternative Scheme 4 is (0.5–0.525).

Since the decision involves many indexes and complicated calculations, we calculate each index with the help of Yaahp12.0 software. Due to the space limitation, we only list the target selection layer, the first-level index layers, and the second-level index. In addition, we only take the expert 1 as an example to build judgment matrix. The weight of the index and the decision-making scheme are shown in Tables 2 and 3.

Table 2: The result of three levels of the index.

<table>
<thead>
<tr>
<th>First-level index Wi</th>
<th>Second-level index Wi</th>
<th>Specific contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost 0.5942</td>
<td>Transaction cost 0.2536</td>
<td>Cost of searching information 0.01231</td>
</tr>
<tr>
<td></td>
<td>Low-carbon cost 0.1281</td>
<td>Negotiating cost 0.0799</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contracting costs 0.0537</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Surveillance cost 0.0506</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Execution cost 0.0468</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personnel cost 0.0422</td>
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<td>The harmony of cooperation 0.0019</td>
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Data sources: calculated according to the revenue sharing contract model by Yaahp12.0 software.
results are in line with previous research. followed by surveillance cost and execution cost. And the level indexes, negotiating cost counts for the largest weight, factors, profitability is the greatest weight. Of the 46 third-ciency is of the utmost importance. As for satisfaction largest weight. Among the efficiency factors, market effi- second layer of the index, transaction cost counts for the highest weight among the cost factors in the first layer when the weights of the middle layer change. In the horizontal analysis of the sensitivity, the perturbation analysis, the decision-makers can calculate the sensitivity and the corresponding weights of the first layer when the weights of the middle layer change. Based on the above data, we will calculate, analyze and get the sensitivity of each alternative scheme. The sensitivity of the weights is shown in Table 4.

Table 4: The sensitivity of the alternative schemes.

<table>
<thead>
<tr>
<th>Alternative scheme</th>
<th>Change of weight</th>
<th>Minimum value</th>
<th>Current value</th>
<th>Maximum value</th>
</tr>
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<tr>
<td>Alternative Scheme 1</td>
<td>Increasing with criterion layer</td>
<td>0.3665</td>
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<td>Alternative Scheme 4</td>
<td>Decreasing with criterion layer</td>
<td>0.1762</td>
<td>0.2155</td>
<td>0.2241</td>
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</table>

Data sources: calculated according to revenue sharing contract model by Yaahp12.0 software.

5.3.3. Discussion of the Calculation Result

(1) Analysis of the Calculation Result. The calculated findings show that the optimal revenue sharing value is 0.425. This result is consistent with the forty-sixty-proportion practice concluded by Pan et al. [54]. In the first layer of the index, cost has the highest weight among the cost factors in the second layer of the index, transaction cost counts for the largest weight. Among the efficiency factors, market efficiency is of the utmost importance. As for satisfaction factors, profitability is the greatest weight. Of the 46 third-level indexes, negotiating cost counts for the largest weight, followed by surveillance cost and execution cost. And the results are in line with previous research.

In the first layer of the index, the weight of cost factor is 0.5942, the weight of efficiency factor is 0.2254, and the weight of satisfaction factor is 0.1804. In comparison, the cost factor is more prominent. The findings are in line with the goal of cutting the cost the low-carbon supply chain with the revenue sharing contract. In the cost factor of the second index layer, negotiating cost has the largest weight, followed by contracting cost and surveillance cost.

(2) Analysis of the Sensitivity. Through the sensitivity analysis, the decision-makers can perceive the impact of the weight of each alternative scheme when the weight of a certain element changes, which would help them to make decisions at a higher level.

With the perturbation analysis, the decision-makers can calculate the sensitivity and the corresponding weights of the first layer when the weights of the middle layer change. Based on the above data, we will calculate, analyze and get the sensitivity of each alternative. The sensitivity of the weights is shown in Table 4.

In the horizontal analysis of the sensitivity, the perturbation method is used. According to the GAHP method, the influence degree on the weight of alternatives is calculated when the weight of each middle layer element changes from 0 to 1. Figure 2 shows the alternatives changing with the weights of the third layer, from which we can see the sensitivity between the weights of the third layer and the alternative schemes.

The sensitivity of the evaluation indexes is divided into four different grades, which is expressed by sensitivity indexes 1, 2, 3, and 4, respectively. Sensitivity 1 represents low sensitivity, and the change of this index has little impact on revenue distribution. Sensitivity 2 represents moderate sensitivity, and the change of this index has a certain impact on revenue distribution. Sensitive 3 is highly sensitive, and its change has a great impact on revenue distribution. Sensitivity 4 represents extreme sensitivity. The change of this index has a great impact on revenue distribution.

In the sensitivity level, cost of searching information, relational construction cost, sales efficiency, circulation efficiency, and contract execution efficiency are extremely sensitive indicators. Negotiation cost, contract achievement efficiency, profit ratio of sales, and the harmony of cooperation are highly sensitive indicators. Market control ability, decision efficiency, coordination efficiency, profit ratio of sales, credit, service level, and ratio of profits to cost are moderately sensitive. And other indicators are low sensitive.

In addition, TPP can formulate a set of evaluation criteria. According to the standard and the sensitivity of the index, the cooperative enterprises are able to analyze the problems and differences in implementing revenue sharing contract. This paper proposes a "five level risk evaluation system," which represents no risk, low risk, medium and low risk, medium risk, medium and high risk, high risk, and extreme risk with five different colors. If the risk value of the evaluated enterprise is within the preset index threshold, which indicates that the revenue sharing contract execution is in a controllable and normal stable state. When the score is near the early risk-warning threshold, the TPP needs promptly notify the cooperation. After entering the alert state, TPP evaluation experts should find out the causes of problems in the revenue distribution according to the evaluation results of each evaluation index. Once the risk is in a serious state, TPP experts shall timely identify the causes of the problems according to the data of the risk early warning management system. At the same time, TPP should gather each expert’s knowledge and experience and formulate corresponding risk resolution-
plans according to the specific situation. When extreme risks occur, TPP shall remind the parties to terminate the cooperation.

The analysis of sensitivity brings particular enlightenment to the practice of management. For instance, it should pay close attention to the impact of extremely sensitive indicators on revenue, because the subtle changes of these indicators will have a great impact on revenue distribution. At the same time, we pay great attention to highly sensitive indicators, because the changes of these indicators will have a heavy impact on revenue distribution. Moreover, we should not ignore the impact of sensitive indicators, because the changes of these indicators will have a certain impact on revenue distribution. From our research results, cost of

![Cost Efficiency Satisfaction](chart.png)

**Figure 2:** The alternative schemes changing with the weight of the third layer (the "X" axis is the weight of the third layer; the "Y" axis is the weight of alternatives).
searching information, relational construction cost, sales efficiency, circulation efficiency, and contract execution efficiency have a great impact on revenue distribution, so we should focus on the observation of this index.

To summarize, the GAHP method takes into account not only enterprise comparisons, indexes of criterion level, and subcriterion level, but also the weights of different experts. This method not only calculates the weight of each index precisely, but also reflects the importance of the expert’s personal authority in AHP analysis. Furthermore, the Yaahp12.0 software provides great convenience for calculating the weights and checking for consistency.

6. Conclusions and Future Research

6.1. Conclusions. Due to the revenue sharing contract’s incompleteness, many details of the partnership cannot be contained in the contract. Finding a method to reduce noncooperative conduct among partners, as well as quantifying and clarifying the ambiguous issues, is crucial. We propose a new commercialized method for distributing low-carbon supply chain revenue through revenue sharing contracts in a fair and reasonable manner. We also provide a solid framework and method for assisting the partners in achieving profit sharing. As a result, a set of indexes is created. In addition, third-party participation is introduced in the low-carbon supply chain to analyze these indices and carry out revenue sharing contracts. Finally, we will use the GAHP method to calculate each index’s weight. Furthermore, the Yaahp12.0 software is used to calculate the weights and checking the correctness of each index.

Based on the above research, we come to the following findings. The first is to find out the limits of the revenue sharing contract model and discovers that a simple revenue sharing contract cannot coordinate low-carbon supply chain effectively. The second is to build a set of decision-making index according to the revenue sharing contract and the low-carbon supply chain. By analyzing the previous literature of low-carbon supply chain and contract coordination and integrating the challenges encountered in the implementation of revenue sharing contracts, in this paper, we have put forward cost, efficiency, and satisfaction from the perspectives of various field scholars. Based on the three decision-making perspectives, in this paper, we build a theoretical model of low-carbon supply chain decision-making with revenue sharing contract. We draw a conclusion that this model not only lays solid theoretical foundation on the low-carbon supply chain decision-making with the revenue sharing, but also sets the groundwork for the establishment of the index. Finally, in terms of decision-making mechanism, according to the principle of “heteronomy is better than self-discipline,” this paper opts for the third-party participation mechanism and the GAHP method. From the case calculation, we conclude that the cost factor has the highest weight. Among the efficiency factors, market efficiency is of the utmost importance. Profitability is the greatest weight in the satisfaction factors. And we find these findings are fundamentally consistent with previous research.

To sum up, in this paper, a feasible application method of revenue sharing contract is proposed in low-carbon supply chain. The third-party participation and group decision-making are used to realize low-carbon supply chain decision with revenue sharing contract. From the case and sensitivity analysis, it is proved that this method can effectively realize management decision for both sides of the low-carbon supply chain. And our findings demonstrate that cost reduction is the most important in low-carbon supply chain with revenue sharing contract. At the same time, managers should do all possible to keep transaction costs under control, increase profit margins, and respond swiftly to market changes. The research of this paper presents an effective analytical framework and implementation method for revenue sharing contract decision-making and provides experience for the implementation of supply chain decision-management in different industries.

6.2. Limitations and Future Research. As for the limitation of this research paper, though we put forward an effective analysis framework and implementation method for enterprise revenue sharing contract decision-making, we lack the effort to promote more low-carbon supply chains to adopt this method. Because it is a relatively new topic and we are still inexperienced to practice our method in many other low-carbon supply chains. Besides, some of the latest data were not available at the time of writing this research paper.

In future research, we will build distinct indexes for different industries and low-carbon products due to the difference between industries and products. If a growing number of low-carbon supply chains are willing to make use of revenue-sharing contracts to coordinate their operations, much more revenue distribution index should be established. We will establish a special third-party evaluation platform and will build more precise and feasible revenue distribution mechanism with the application of the methods and theories in this paper. More specialists would be invited to participate in GAHP evaluations, and more precise assessment methodologies would be developed for the platform.

Data Availability

The data of this paper come from the expert score and the Yaahp12.0 software calculation.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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