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Research Article

Analysis of Coordinated Pricing Model of Closed-Loop Supplying Chain Based on Game Theory in E-Commerce Environment

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Although the research of closed-loop supply chains has attracted great attention and some research results have appeared, it has not formed a complete theoretical system. People have studied many pricing and coordination models by modeling the closed-loop supply chain system, but most of these models are based on the research under the conditions of market demand determination and information symmetry, which is far from the practice of the operation of the closed-loop supply chain system, so it is difficult for these studies to improve its theoretical guidance ability. Starting from reality, this paper fully considers various situations closer to reality, such as multichannel recycling, a conflict between sales channels and recycling channels, and double trust in a complex practical environment. This paper constructs the corresponding pricing decision-making model for analysis and research and further discusses the coordination and incentive mechanism of each node enterprise in the closed-loop supply chain system, so as to realize the overall optimization of the closed-loop supply chain. In this paper, the pricing strategy of the closed-loop supply chain and the coordination of interests among participants are studied by using game theory under the practical e-commerce model. Firstly, the traditional sales channel is considered, and the different situations of centralized decision-making and decentralized decision-making are compared. In short, cooperation can increase profits and achieve win-win results. Finally, this paper puts forward some methods of construction coordination of closed-loop supply chain to guide the closed-loop supply chain to reduce costs, improve competitive advantage, and make the development of closed-loop supply chain more practical significance.

1. Introduction

With the improvement of economic level and people's quality of life, economic globalization, rapid changes in science and technology, and the gradual enhancement of environmental protection awareness, the traditional manufacturing model and logistics mode will no longer meet the requirements of sustainable development and green economy. The reverse logistics theory for the purpose of recycling and remanufacturing waste products has attracted academic attention. The American scholar stock first put forward the concept of reverse logistics: reverse logistics includes product recycling, replacement, waste disposal, repair, treatment, and reprocessing; He expounded the close relationship between reverse logistics and commercial activities and social development. From then on, the concept of reverse logistics came into people's vision. Up to now, the theoretical circles have different expressions on the concept of reverse logistics. At present, it is a more accurate, professional, and generally accepted concept: the process of planning, management, and control in the whole product life cycle for the purpose of value recovery or reasonable disposal as opposed to forward logistics [1–6].

When manufacturing enterprises face many requirements such as product quality, product type, delivery date, and service level, they will combine suppliers and retailers to form a supply chain running through upstream and downstream enterprises. Its advantage is to reduce costs, optimize allocation, save resources, and improve efficiency.

However, it cannot be ignored that with the overcapacity and the increase of waste products, enterprises have an insufficient understanding of product recycling. It is only a one-way and forwards flow linear structure, which is far from meeting the requirements of sustainable development. Reverse logistics theory promotes the development of supply chain theory. The supply chain integrating reverse logistics is gradually valued by business and academic circles [7–13].

The research on closed-loop supply chain coordination is a necessary supplement and improvement to traditional supply chain management. The closed-loop supply chain is not a simple addition of a forward supply chain and a reverse supply chain. Not only are its breadth and depth greatly beyond the traditional supply chain, but also its complexity is far from being achieved by the traditional supply chain. The problem of supply chain coordination is common in all links of supply chain management and the whole supply chain. Closed-loop supply chain coordination management will become an important part of the future strategy. In reality, it also faces a large number of coordination problems: how to distribute the interests of the supply chain and how to solve a few unconnected phenomena from time to time. There is an urgent need to strengthen mutual communication and benefits coordination among enterprises in the supply chain. This concept is not only conducive to the sustainable development of enterprises but also enhances the "green" image of enterprises. In terms of supply chain performance, the advantage of collaborative operation far exceeds that of each doing its own thing.

It carries out the recovery, reprocessing, and resale of products, forming a circular process of "resources manufacturing sales use recycling renewable resources." The closed-loop supply chain comprehensively considers economic development and environmental factors and is based on scientific methods and management technology. Its purpose is to reasonably plan and manage the product life cycle, reduce the negative impact on the environment, and improve the efficiency of resource use.

The members participating in the closed-loop supply chain are customers and relevant government departments. First, in the closed-loop supply chain, enterprises (including suppliers, manufacturers, and retailers) can be summarized as follows: first, create social wealth; second, provide employment opportunities; third, scientific development. However, for a long time, enterprises have ignored the last point in the development process, and extensive economic development has caused environmental problems and waste of resources. Therefore, enterprises should pay more attention to product recycling when participating in the closed-loop supply chain remanufacturing process. Waste products are supplied by customers. In addition, the third-party recycler is important. Enterprises reduce logistics costs with the help of the specialization and scale of third-party logistics. Although the current third-party logistics lacks clear technical and policy guidance, the third-party logistics is closer to customers and demand market and has the advantages of cost and information. Although the government does not directly participate. The government needs to invest a lot of funds and manpower to assist the closed-loop supply chain to improve economic welfare and the social environment [14].

Abdelmohsen et al. [15] study further assessed the role of material pricing in reducing carbon emissions, achieving energy efficiency, and expanding world per capita income over the next 10 years. This will help to formulate resource protection policies on a global scale. The results show that material pricing increases carbon emissions, reduces energy efficiency, and has a negative impact on world income, while ore and metal exports achieve energy efficiency by reducing global carbon emissions. Anser et al. [16] propose an intelligent logistics design scheme, which combines technical indicators with logistics performance indicators (LPIs) to minimize carbon damage in 102 countries. The study used patent and trademark applications to analyze technological progress. Haroon ur et al. [17] control the domestic consumption of coal and lignite and the production of refined oil; the impact of increasing the share of wind and solar power generation on reducing carbon intensity is studied in a world comprehensive data panel. The data of the past three decades have been used for the analysis of the ARDL boundary test method. Awan [18] discusses the regulatory effect of internal environmental investment (IEI) on the relationship between social supply chain management practice and social sustainability performance. Taking 272 manufacturing enterprises as samples, this paper makes an empirical test on the proposed conceptual model. The results show that the social sustainability performance at the enterprise level depends on the wider social supply chain practice.

In terms of theory, we integrate the strategic ideas of scientific development and sustainable development and transform from a single and extensive pursuit of economic profits to an overall and balanced consideration of economic benefits, ecological environment, and social welfare. From the technical level, there are a series of reverse logistics links and related network paths. In terms of structural system, the closed-loop supply chain changes the one-way and wasteful flow mode of the original traditional supply chain, makes resources circulate in the closed-loop system, realizes the integration of the reverse supply chain and the traditional positive supply chain, reduces the negative impact on the external environment, reduces resource consumption, and reduces enterprise costs. It is a green supply chain to meet the economic development in the new period [19, 20].

In recent years, due to the impact of the global financial crisis, China's export pressure has increased sharply, and domestic demand is weak. All industries are in urgent need of industrial structure adjustment and continue to find new market breakthroughs. The progress of supply chain technology and the rise of e-commerce make many enterprises see hope. Government departments at all levels also attach great importance to and actively promote e-commerce and have issued relevant development plans and supporting policies. More and more manufacturing enterprises and sales enterprises begin to implement OTO and other e-commerce modes and simultaneously carry out online and offline supply chain operations. Although online direct selling can reduce the sales cost of enterprises, it is also inevitable to compete with offline stores. How to complement the convenience, product variety, and 7×24-hour uninterrupted shopping experience of online channels with the risk control, physical experience, and many features of traditional offline channels and reduce channel conflicts has become a problem that most enterprises implementing dual-channel supply chain strategy must solve. How to solve channel conflict has become a top priority for many supply chain leaders. Supply chain coordination points out the direction to solve this problem and increases the overall benefits of the supply chain through supply chain coordination. Product sales volume is an important indicator of supply chain system operation. In order to increase their market share, each member of the supply chain implemented a variety of promotion methods, such as discount and low-price sales and installment payments without interest. At present, the biggest application range in the market and the fastest efficient and the highest heat promotion means is advertising. In recent years, the total amount of advertising market has grown rapidly, and the advertising cost generated by various industries and fields has become higher and higher. Ads according to their influence can be divided into national advertising, brand advertising, and local advertising; national advertising promotes the brand image; brand advertising influences and has better consumer cognitive psychology; the effect of local advertising is better to get consumers to make a purchase intention, increase the number of consumers, focus on products, and eventually increase the effect of the product's market share. Both can increase the overall benefit of the supply chain. At the beginning of the research on the basic theory of closed-loop supply chain, stock discussed the close relationship between closed-loop supply chain and enterprise potential benefits and ecological environment protection, so as to provide a theoretical basis for government supervision and organization. Thierry's research shows that the purpose of recycling and remanufacturing products is to obtain economic benefits and reduce waste discharge to protect the environment through recycling and remanufacturing of waste products. Van der LAN proposed that in order to achieve coordination between inventory cost and economies of scale, it is necessary to design a closed-loop supply chain for implementation and study the remanufacturing inventory schemes corresponding to different types of products. For an efficient and stable closed-loop supply chain system, Fleischmann et al. proposed that the closed-loop supply chain network planning should focus on the following three contents: participants, including original forward logistics suppliers, manufacturers, and sellers, as well as third-party logistics service providers, governments, and customers. Product processing link design is as follows: implementation methods of collection, classification, detection, disassembly, and reuse; how to integrate forward and reverse logistics; and the relationship between upstream and downstream enterprises. Krikke studies the true meaning of implementing a closed-loop supply chain. In its links involving enterprise strategy, information, capital, and logistics, Trikke optimizes forward and reverse logistics through a closed-loop supply chain to provide customers with high-quality products, reduce waste, and save resources. Fleischmann analyzes two different logistics network structures from the perspective of waste product recycling network and classified processing remanufacturing. Jayaraman constructs the logistics network structure of electronic equipment enterprises and uses mixed integer programming to determine the number and distribution of electronic device remanufacturing plants. Wassenhove believes that a closed-loop supply chain is a kind of "manufacturing use remanufacturing." Wang Yuyan discusses the relationship between economic benefits and environmental conditions from a more comprehensive perspective and emphasizes that the essence of closed-loop supply chain management is to realize the comprehensive maximization of economic and environmental benefits [21–30].

There are a certain number of studies on the game of closed-loop supply chain members at home and abroad, but because most of the studies are in the extension of positive logistics research, a perfect theoretical system has not been formed. Luo Dingti et al. discussed, from the perspective of product manufacturers, how to use the game incentive mechanism to solve the problem of profit distribution in the supply chain of a product manufacturer and multiple retailers. Margarete applies the Nash equilibrium theory to study the recycling of waste products, puts forward the marketing means of remanufactured products, analyzes the competitive game between original manufacturers and remanufacturers, and puts forward a solution based on life cycle theory. Wang Yuyan and others used the Steinberg game to study the pricing strategy of the reverse supply chain. Qiu Ruozhen and Huang Xiaoyuan study the closed-loop supply chain with stochastic demand through the Steinberg game, consider the recycling channels of manufacturers and retailers, respectively, and solve the pricing problem. Wang Wenbin and Da Qingli designed a reward and punishment mechanism based on game theory to study the recycling and remanufacturing of electronic products. Aiming at the remanufacturing cost advantage, Wang Wenbin constructs three game optimal decision models. Yijiong assumes that the game model about sales price is analyzed by Brownian motion and profit-seeking game, and the pricing problem of waste products for remanufacturing is considered. Guan Qiliang and others discussed the impact of parameter changes on the recovery rate and the profits of supply chain members under different game modes according to government subsidies and considering the recovery rate. Yi Yuyin discusses the maximum benefit of the model led by manufacturers and retailers and the equilibrium game model of manufacturers and retailers. In view of the analysis of the connotation and characteristics of the closed-loop supply chain, the closed-loop characteristics of the closed-loop supply chain are mainly reflected in the return of the used products by customers and the relevant processing of the products to the node enterprises in the supply chain in Figure 1.

From the existing literature at home and abroad, the research on the closed-loop supply chain is still in the initial stage, and the relevant theories and literature are very limited: there is a lack of systematic and in-depth discussion

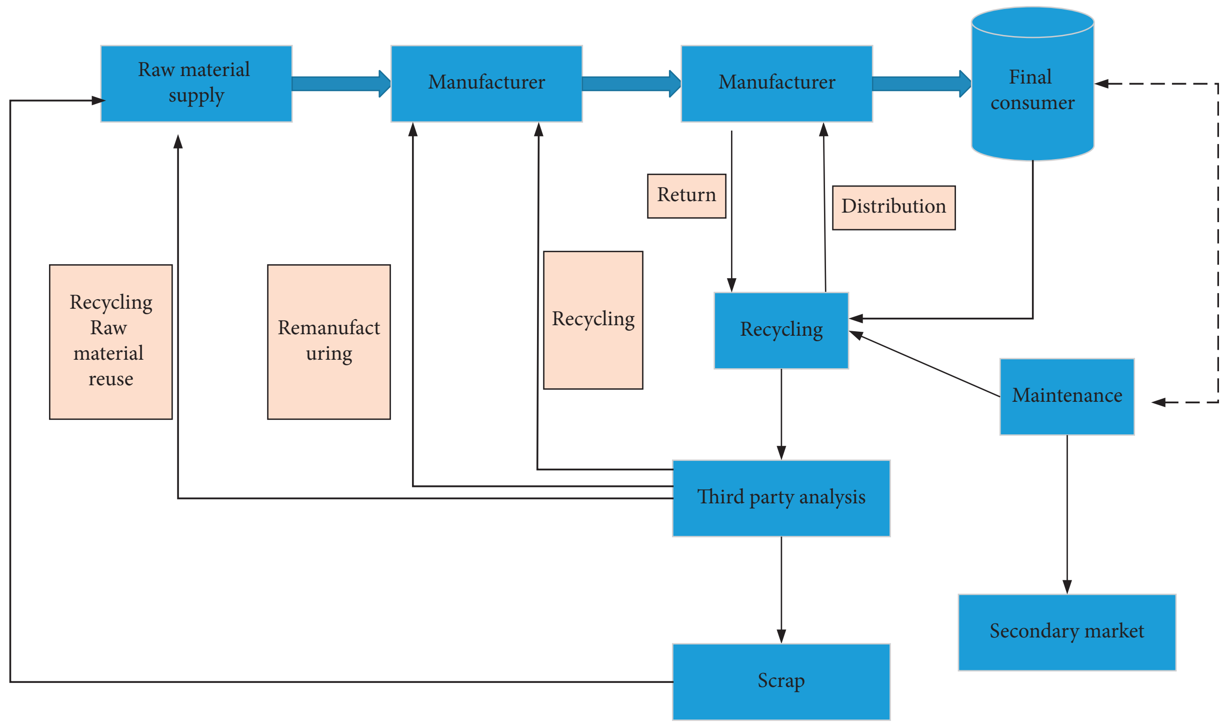

Figure 1: Basic structure of closed-loop supply chain.

and definition, which is embodied in the following points. (1) Most of the existing studies focus on the research of product reengineering network design and inventory system control. However, the research on the benefit distribution of the supply chain is rarely involved. (2) There is a lack of research on the benefit distribution of closed-loop supply chain under the mixed mode of e-commerce manufacturer's e-direct sales mode and traditional retail channels. At present, most studies only optimize the benefits of coordination of closed-loop supply chain under the traditional retailer marketing channel, and there is little research on the combination of the two. (3) The existing research rarely involves the complex market structure of multiple manufacturers or multiple retailers, but most of them only consider the market structure of a single manufacturer and retailer. (4) When considering the e-commerce model, most of them regard it as a one-sided sales model of retailers. However, more and more e-commerce operators participate in the operation of the supply chain as a separate link in the supply chain. Therefore, this paper deeply analyzes the difference between closed-loop supply chains and other supply chains, the difference between the traditional sales models and e-commerce models, and the difference between centralized decision-making and decentralized decision-making under the condition of e-commerce. Finally, this paper puts forward a reasonable supply chain coordination method, so as to expand the theoretical and practical application space of supply chain management.

In this paper, the pricing strategy of the closed-loop supply chain and the interest coordination among the participants are studied by using the game theory under the actual e-commerce mode. In the case of traditional sales channels, through the comparison of different cases of centralized decision and decentralized decision, several different recovery modes are analyzed, and it is found that the overall profit of the system is higher than that of decentralized decision, and the efficiency of the system is also improved. However, the model does not consider the relationship between the recovery price and the amount of recycling and takes the recovery effort port as the intermediate link to analyze.

2. Game Theory

Manufacturer network marketing mode will not be considered; we only consider "suppliers, retailers, and collector" (including recovery and recovery at retailers, professional third-party recycling) of the recycling model of the supply chain: manufacturers recycling model (M), retailers recycling model (R) (TP), and third-party recycling model. In this paper, CLSC coordination methods under different recycling modes are discussed, corresponding pricing models are established for each recycling mode, and then, the coordination methods between decision-makers are constructed by comparing and analyzing the differences of different models. Product reengineering costs should be less than new product manufacturing costs, manufacturers recycling the remanufacturing cost and recycling price should be no more than the sum of the new product manufacturing costs, the manufacturer at the time of the remanufacturing cost and recycling price should be no more than the sum of the new product manufacturing costs, and manufacturers recycling prices should be no more than recycling agencies from recycled consumer prices and should be less than the cost price. This hypothesis ensures that recycling and remanufacturing are meaningful to both the manufacturer and the recycling organization and are the direct economic motivation for manufacturers to implement a closed-loop supply chain. The closed-loop supply chain is composed of processing of raw materials, production of products, sales of finished products, recycling of waste products, and processing of waste products. Material circulates in the whole closed-loop supply chain, forming a closed-loop system of logistics, capital flow, and information flow, so as to reduce the discharge of waste, reduce the impact of economic activities on the natural environment as little as possible, and maximize the total value of the closed-loop supply chain.

Game theory is a subject that studies decision-making when the decision-making subject's behavior interacts directly and there is an equilibrium of this decision-making. Its research was initiated in the publication of game theory and economics in 1944, which was cooperated by Von Neumann-Morganstern. By the 1950s, a cooperative game developed to its peak, and noncooperative game theory also began to be established. The giants of modern noncooperative game theory are Nash and tucker. The former published two important articles on noncooperative games, respectively, and the latter defined the prisoner's dilemma. After the 1960s, some important figures appeared, such as Selten and Harsanyi. Their main contributions are as follows: first, they put forward the concept of refined Nash equilibrium; second, incomplete information is introduced into the research of game theory. Generally, since the 1980s, game theory has become the basis of microeconomics. Game theory is widely used to solve practical problems in the fields of economics, politics, and criminology. The main representatives of this period are keeps, Fudenberg, Tirole, and Wilson. The traditional supply chain, namely, the forward supply chain, is the flow direction of logistics and information flow from manufacturers to consumers. The closed-loop supply chain is not only a chain of information and capital connecting suppliers to consumers but also a value-added chain. Its management is a series of planning, coordination, command, and control activities centering on logistics, capital flow, and information flow of forward and reverse supply chains.

This assumption ensures that recycling and remanufacturing are meaningful to both manufacturers and recycling institutions and are the direct economic motivation for manufacturers to implement a closed-loop supply chain. The average cost of manufacturing (including new manufacturing and remanufacturing) can be expressed as follows [31–37]:

$$C = C_m(1-\tau) + C_r\tau + (C_m - C_r)\tau. \tag{1}$$

Manufacturer revenue function:

$$\Pi_m^M = [w - (C_m - \Delta\tau)]D(p) - \frac{1}{2}C_L\alpha^2 - r\tau D(p). \tag{2}$$

Retailer revenue function:

$$\Pi_m^R = D(p)(P - w), \tag{3}$$

where $\tau D(p)$ represents the number of collections, C_m represents marginal manufacturing cost, C_r is the marginal remanufacturing cost, w is the wholesale price of goods, P is the retail price of goods, and r is the cost recovery.

In the model, retailer R is not only responsible for sales. In this model, manufacturer M is responsible for manufacturing products and buying back all recycled waste products by paying a compensation price of 6 to retailers. Retailer R can not only affect the product demand in the positive market through retail price P but also affect the average manufacturing cost of the manufacturer's products through its recovery price R. The goal of the closed-loop supply chain is to transform the linear system of the traditional supply chain into a closed system with circulating material resources through the integration of reverse logistics, so as to form a circular economy. Obviously, the closed-loop supply chain is an important carrier to realize circular economy, and circular economy is a powerful drive to promote the closed-loop supply chain. Their common research goal is to achieve the coordinated development of economic benefits and environmental protection, which has been unified in the concept of sustainable development. Closed-loop Supply Chain (CLSC) contains not only the traditional forward supply chain but also the reverse supply chain for recycling waste products. The most important thing is that the logistics on the two chains are not independent of each other but are closed from source to sink and then from sink to source.

Manufacturer revenue function:

$$\pi_r^M = [w - C_m + \tau\Delta]D(p) - b\tau D(p). \tag{4}$$

Retailer revenue function:

$$\pi_r^R = (p - w)(\beta_1 - \beta_2 p) = (b - r)\tau^*(\beta_1 - \beta_2 p) - \frac{1}{2}C_L\alpha^2. \tag{5}$$

MDCTM (TP mode for short) model, the third-party logistics service provider, appears in the model, which undertakes the recycling work.

Manufacturer revenue function:

$$\pi_{\text{tp}}^M = [w - C_m + \Delta(\alpha + \theta)]D(p). \tag{6}$$

Retailer revenue function:

$$\pi_{\text{tp}}^R = (p - w)D(p). \tag{7}$$

Third-party revenue function:

$$\pi_{tp}^{3p} = (b - r)(\alpha + \theta)D(p) - \frac{1}{2}C_L\alpha^2. \tag{8}$$

The decision model is

$$\frac{\partial \Pi_m^R}{\partial p} = \frac{\partial D(p)}{\partial p} = \frac{\partial(\beta_1 - \beta_2 p)(P - w)}{\partial p} = \beta_1 - 2\beta_2 p + \beta_2 w. \tag{9}$$

The utility function of the manufacturer's maximum revenue is as follows:

$$\max \Pi_m^M = [w - C_m + (\Delta - r)a]D(p) - \frac{1}{2}C_L\alpha^2 - r\tau D(p),$$
$$w^* = \frac{\beta_1 + \beta_2 C_m}{2\beta_2} = \frac{(\beta_1 - \beta_2 C_m)(\Delta - r)^2}{2\left[4C_L - \beta_2(\Delta - r)^2\right]}, \tag{10}$$
$$\alpha^* = \frac{(\beta_1 - \beta_2 C_m)(\Delta - r)}{4C_L - \beta_2(\Delta - r)^2}.$$

β_1 is the market demand, β_2 is the demand price elasticity coefficient, α is the series of effort functions paid by recycling institutions for waste product recovery, τ is the product recovery rate, and ∂p represents absolute risk aversion measures.

There are three basic assumptions in general game theory: (1) rational players have all the knowledge about the game; that is, rational players can obtain all the information they need; (2) rational players can know exactly the entire decision scope space; (3) rational players have strong logical thinking ability. A game consists of four basic elements. ① Player refers to an individual or an organization that is relatively independent in the game and has the ability to make decisions and bear results independently and can choose actions to maximize its own utility. ② Strategy Space. It indicates that a player can know the range of alternative behaviors or strategies of himself and other participants, as well as the possible results of various behaviors and strategies. (3) Time order of game refers to the relevant agreements reached by the players in the game that are carried out simultaneously or in sequence during decision-making. (4) Pay (o line) function: when each game is over, there are results of the game to indicate the outcome of the game, how much profit. The outcome of this game is called payout. Compared with a simple forward supply chain or reverse supply chain, the process of the closed-loop supply chain is more complicated. It not only has all the characteristics of forwarding supply chain and reverse supply chain but also has unique features that neither of them has. Specific performance is target diversity and operation complexity. There is a high degree of uncertainty. There is an innate imbalance between supply and demand. In the supply chain of forward and reverse logistics, there are cost composition and pricing inconsistencies.

3. Model Analysis

In order to better reflect the scale of the direct marketing channel market and the influence of designed contract parameters on the supply chain system in the mixed channel sales and recovery supply chain and verify the effectiveness of the price discount contract coordination mechanism, the following analysis is carried out through an example.

Manufacturers can through advertising promote the recycling work; recyclers, as an agent, are directly involved in recycling; the manufacturers can, through the propaganda, increase recycling and use other ways to increase the recycling, manufacturers, and recyclers' efforts; when the effort cannot be observed on both sides, both sides may appear moral hazard; this is the so-called bilateral moral hazard problem. In this case, how should the manufacturer design an incentive mechanism?

As can be seen in Figure 2, with the expansion of the direct channel market, policymakers will improve the sale price of the direct channel, in order to gain more profit, but policymakers will reduce the retail price of traditional retail channels, to further enhance their own competitiveness. which shows the necessity of system coordination As can be seen in Figure 3, under decentralized decision-making, as the direct channel market share continues to increase, the manufacturer's profit is also increasing and increases faster and faster, and the retailer's profits will be reduced, and, of course, the amplitude is relatively small, because the manufacturer's profit increased to reduce the amount as the amount is more than retailers.

As can be seen from Figure 4, both manufacturers' direct selling price and retailers' selling price increase with the increase of marketing channel competition coefficient 7 in centralized or decentralized decision-making. As a rule, the more competition there is, the more the market price should go down. As can be seen in Figure 5, retailers' profits increased with the increase of the coefficient of marketing channel competition; this is mainly because the market competition between manufacturers and retailers in the market demand increases, which makes their profits increase.

As can be seen in Figure 6, under decentralized decision-making, competition and conflict between recycling channels become more intense as the competition coefficient of recycling channels increases. As the direct beneficiary of recycling waste products, the recycling price is set by the retailer in order to obtain more waste products. Through comparison, it is found that under the centralized decision, the transfer price paid by manufacturers to retailers is higher than that under the decentralized decision, and the price paid by retailers to consumers is also increased. This is more conducive to the utility of consumers and improves their awareness of environmental protection. Retailers' profits continue to decrease, while the increase in the recycling amount of waste products makes manufacturers' manufacturing costs continue to decrease, leading to the improvement of manufacturers' profits. After the corresponding coordination mechanism is adopted, both manufacturers and retailers raise the corresponding recovery price, but retailers gain more benefits from it and manufacturers suffer certain losses. Therefore, a certain transfer mechanism is still needed for further coordination.

As can be seen from Figures 7 and 8, under the three recovery modes of decentralized decision-making, with the increase of price difference sensitivity of recycling, the retailer's profit decreases in the two modes of recycling and remains unchanged in the mixed recycling mode of the manufacturer and third party. The profit of the third party is

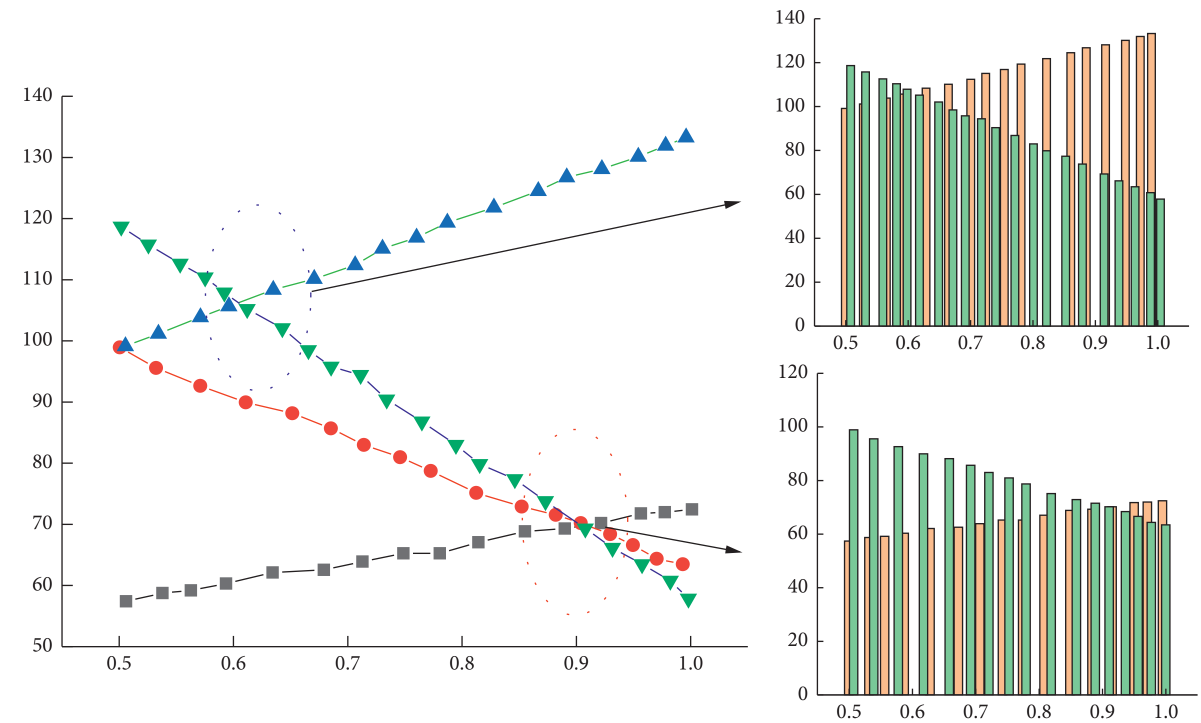

Figure 2: Influence of direct selling on optimal price.

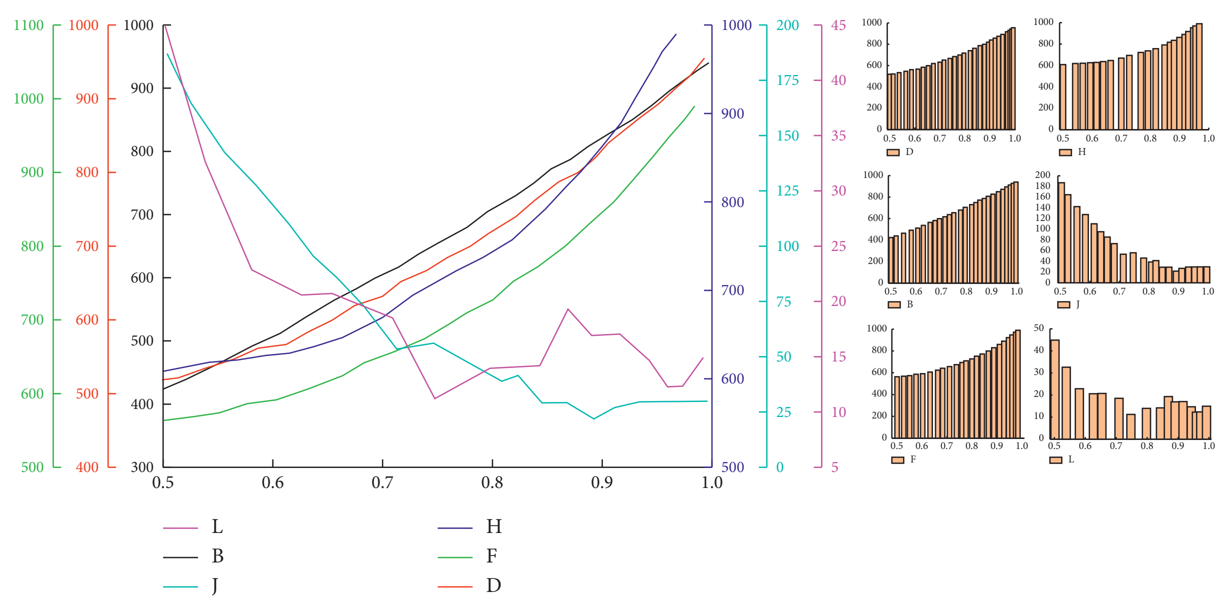

Figure 3: Influence of direct selling on optimal profit.

reduced under the two modes of recycling. This shows that the increase of consumers' sensitivity to price differences is beneficial to manufacturers and the whole closed-loop supply chain system. Therefore, it is not the bigger the better.

4. Benefit Coordination and Distribution Method

In Figure 9, we can see the following. (1) Build a closed-loop supply chain information sharing and transmission platform. The construction of an information platform is an important part of closed-loop supply chain coordination. Information sharing is the first step of coordination to ensure the consistency of information transmission among members of the closed-loop supply chain. By observing more variables such as demand, inventory, production plan, and recycling, we can improve the transparency of the process and reduce the bullwhip effect risk, closely linking customer needs with an efficient response. These information network systems are conducive to promoting

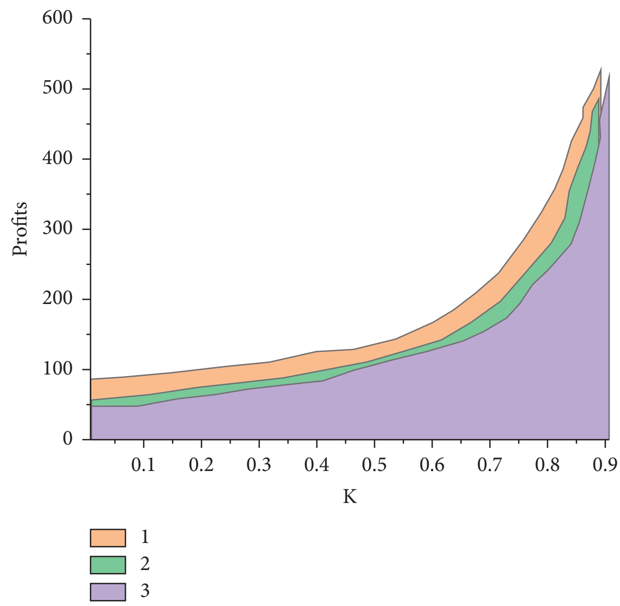

Figure 4: Influence of competition coefficient on optimal price.

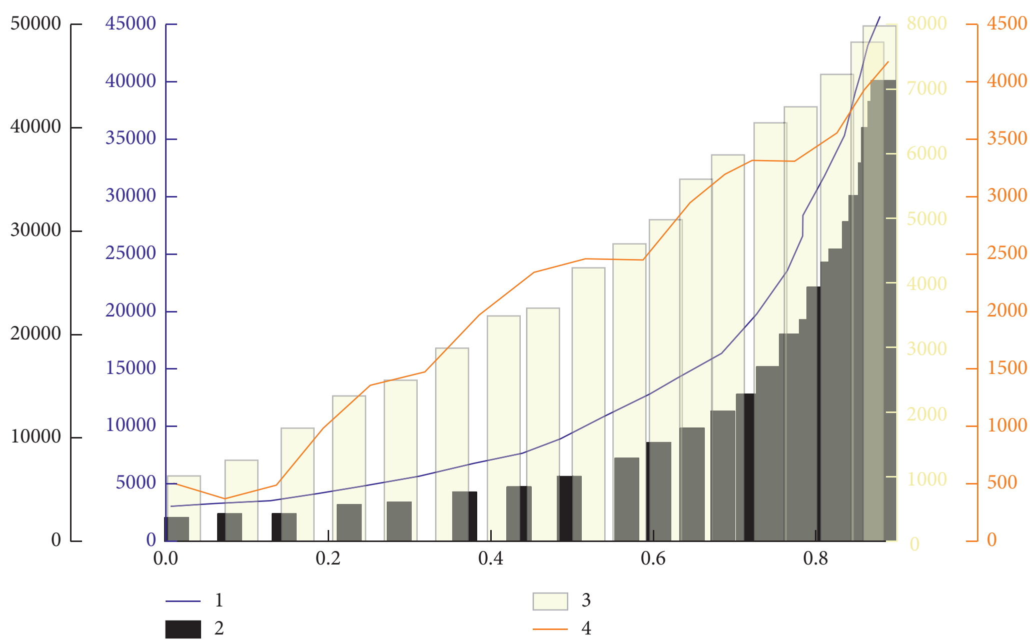

Figure 5: Influence of competition coefficient on optimal profit.

information exchange among enterprises and strengthening the close relationship between supply chain node enterprises. (2) Build a reasonable profit distribution, incentive method, and performance evaluation method. The profit distribution, incentive method, and performance evaluation among enterprises and the difference of their objectives often lead to the loss of benefits of the decision-making. Such a local optimal decision deviates from the global optimization goal of the system. Therefore, the overall system efficiency is reduced. For the competitiveness of the closed-loop supply chain, we must prevent the node enterprises from unilaterally pursuing the maximization of their own interests and ensure that the overall income obtained by the closed-loop supply chain cooperation is greater than the sum of the income of each enterprise when it is dispersed. In addition, core enterprises must establish effective performance evaluation and income distribution methods to ensure the fair distribution of income as far as possible. The trust in the closed-loop supply chain mainly comes from two aspects: one is the trust of core enterprises to other enterprises, mainly a kind of loyalty trust. This trust can be realized by signing corresponding contracts; the second is the trust of other node enterprises in the core enterprises, which is mainly a kind of ability trust, that is, whether the core

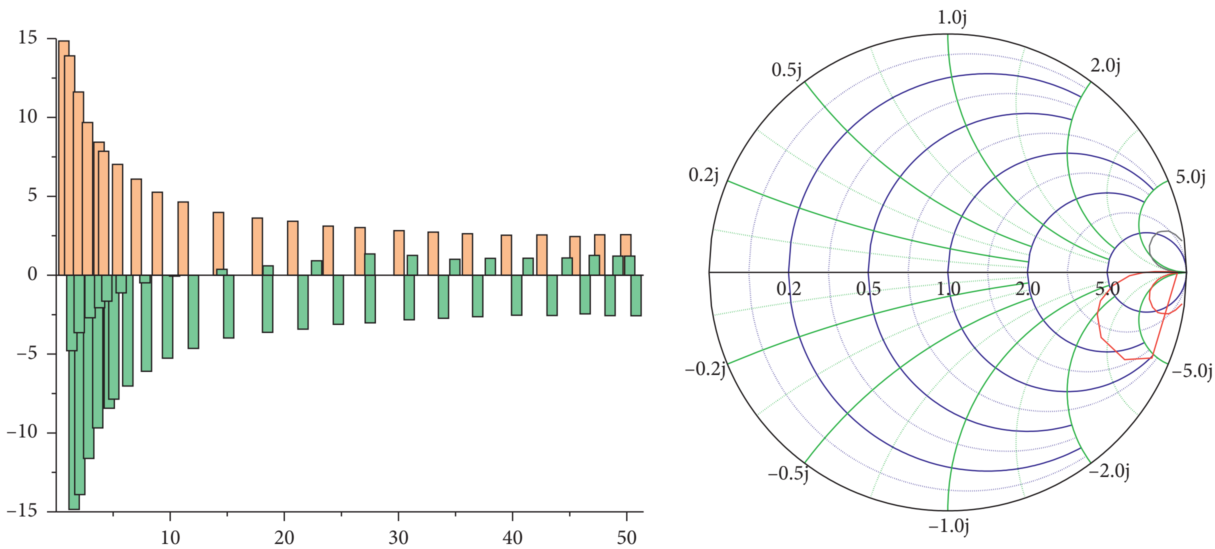

Figure 6: Influence of competition coefficient on recycling.

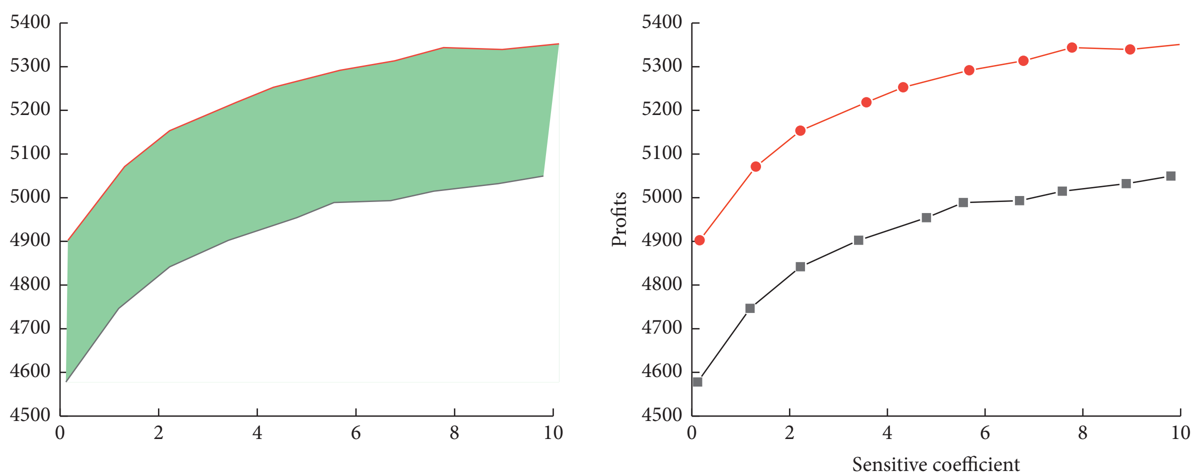

Figure 7: Influence of sensitivity coefficient on profit.

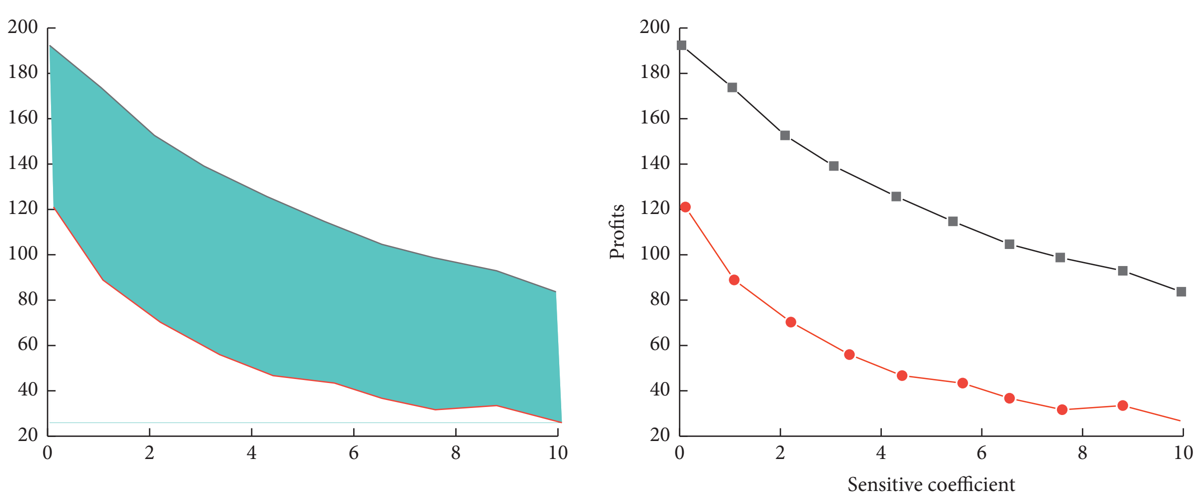

Figure 8: Influence of sensitivity coefficient on third-party profit.

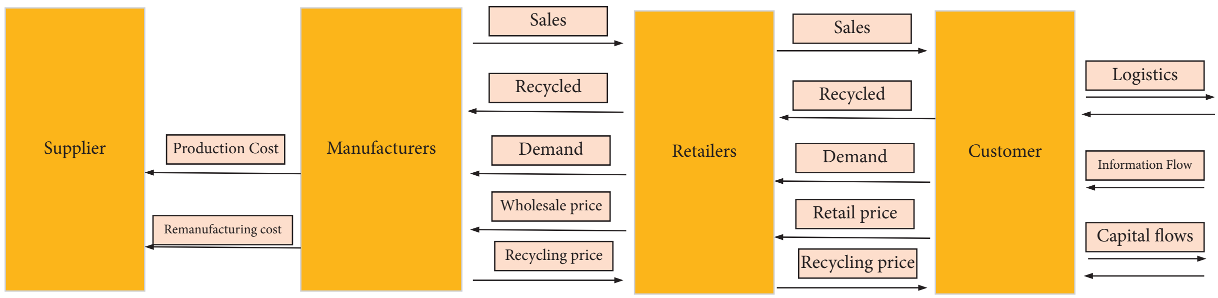

Figure 9: Two-stage closed-loop supply structure diagram.

enterprises have the ability to obtain a larger market share for the whole supply chain in the highly competitive market environment and let each node enterprise share the benefits.

The above schemes are a gradual process. Only when they are implemented in the front can they be guaranteed in the back. Of course, the construction of coordination methods among enterprises must be based on different degrees of competition and cooperation between enterprises. The degree of cooperation between enterprises determines the construction of coordination methods. A correct, reasonable, and efficient coordination method is an effective guarantee for the coordination The node enterprises in the supply chain can adopt their own solutions according to the actual situation and pertinence, so as to solve the problem of closed-loop supply chain coordination, quickly adapt to the changing market environment, and occupy a place in the highly competitive market environment.

Our government should take various measures to encourage and support enterprises to break the traditional marketing model, try new marketing methods, and open up new channel sales models. On the one hand, the addition of this new sales channel can promote benign competition and promote the development of enterprises; on the other hand, consumers can also get a lot of benefits. The development of e-commerce has become the general trend. The state should actively introduce corresponding laws, policies, and measures to protect and promote the innovation of enterprises, so as to cope with the network economy era of global competition and improve the overall competitive advantage of enterprises. (2) Secondly, on the one hand, the Chinese government should strengthen the mandatory role of the legal level and improve the EPR system of enterprises from the perspective of legislation, so as to solve the contradiction between resource shortage and sustainable economic development faced by the Chinese enterprises and promote the connotative development of China's economy. On the other hand, the country should learn from the practices of Japan, Taiwan, the European Union, and other countries (regions), take government subsidies or punishment measures to stimulate the recycling enthusiasm of recyclers, or introduce an independent third-party recycling mechanism to realize the professional operation of recycling and reduce the repeated investment of recycling parties. In addition, it should increase the publicity force, actively guide consumers, improve consumers' awareness of environmental protection, and actively participate in the work of environmental protection. (3) It should learn from the practices of Japan and other countries and can recycle waste products by itself or entrust retailers, after-sales service agencies, repairers, and operators of waste product recycling. At the same time, it should also participate in the retailer's operation plan, For example, it should take the initiative to help retailers establish recycling bases for waste products and help retailers advertise recycled products, so as to achieve a win-win situation. Secondly, we should collect the relevant information of retailers from multiple channels, angles, and all directions to minimize the adverse impact of lack of information on ourselves. Manufacturers should increase investment and establish corresponding information management systems to better share information with retailers and track and understand retailers' information through certain technical means (such as RFID and EDI).

5. Conclusion

The closed-loop supply chain system is composed of different stakeholders, and each participating member also has different decision-making objectives. Interest conflict is inevitable in the process of cooperation. The lack of effective pricing and coordination mechanism will make the interesting relationship of each node enterprise in the closed-loop supply chain unclear and affect the efficiency of the closed-loop supply chain. Therefore, the research on the pricing strategy and profit coordination of remanufacturing closed-loop supply chain has important theoretical and practical significance. This paper studies the two-level closed-loop supply chain coordination method of manufacturers and retailers under the traditional sales channel and the two-level closed-loop supply chain coordination method of manufacturers, retailers, and e-commerce operators under the e-commerce environment establishes the centralized decision-making and decentralized decision-making pricing strategy models and discusses the profits of supply chain node enterprises and systems under different recycling modes through comparative analysis. Finally, the coordination incentive method of the closed-loop supply chain is given. The impact can be enhanced by the results of work on the development and adoption of cleaner production technologies or the improvement of environmental sustainability and by discussing the global significance of the results.

(1) Based on the relationship between cooperation and competition among stakeholders in the closed-loop supply chain system, this paper fully considers various situations closer to reality, especially in complex practical environments, such as multichannel recycling, the conflict between sales channels and recycling channels, and dual information asymmetry. This paper discusses how to build a game model between node enterprises in the closed-loop supply chain, how to optimally price recycled and remanufactured products, and how to coordinate the interests of various subjects from the perspective of contract, the conditions of information symmetry, and information velocity I symmetry.

(2) Through modeling analysis and solution, it is found that the competition and conflict between recycling channels have no impact on the manufacturer's pricing decision, which is unfavorable to retailers; the competition and conflict between sales channels will improve the profits of manufacturers and retailers and achieve win-win and closed-loop supply. The overall efficiency of the chain system has also been improved. However, whether it is the conflict between recycling channels or the conflict between sales channels, consumers can benefit more from it. By designing the corresponding price discount contract, the coordination of the closed-loop supply chain and the improvement of overall performance under channel conflict and competitive environment are realized.

(3) China's per capita resources are very scarce, and the economic development model is extremely extensive; the situation of energy conservation and emission reduction is very severe, which is a major obstacle to the transformation of China's economic structure at the present stage, the adjustment of development mode, and the urgent problem to be solved in the current economic development process. Due to the increasing pressure of resource limitation and environmental pollution, as well as the promulgation and implementation of government incentive measures, the supply chain behavior of enterprises had to pay more attention to remanufacturing. Reasonable government incentive policies and coordination of pricing mechanism can make the closed-loop supply chain internal and external parties achieve the cooperation, will tend to be more resources to the manufactured goods production and sales, gradually can guarantee the enterprise performance, and is advantageous to the social public welfare, with priority to meet the market demand of remanufacturing product manufacturing preferred mode of operation. This paper focuses on a kind of remanufacturing closed-loop supply chain system, which is dominated by manufacturers and responsible for recycling waste products by distributors. Considering the government's restrictive measures on recycling waste products, the pricing strategy of the closed-loop supply chain is studied by using the game method and by designing a coordinated pricing mechanism based on remanufacturing priority.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known conflicts of financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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