Effect on the Model of Government-Subsidized Dual-Channel Closed-loop Supply Chain: Taking Automobile Tire Recycling as an example

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\textbf{Abstract}—The speed of product updating iteration is getting faster and faster, which leads to more and more serious problems of waste of resources and carbon emissions, and the increasing attention to the sustainable use of resources in all countries of the world, and from the concept of sustainable development, many new ideas have been formed. At present, China's economy is facing severe environmental pollution and resource shortage, and recycling waste resources is the key for enterprises to obtain better development prospects, so the closed-loop supply chain model has become the focus of enterprises. For enterprises, the problem of recycling and manufacturing is also quite cumbersome and complex, the government can intervene to solve the problem, with subsidies to promote the recycling of waste goods. Therefore, this study mainly from the two-channel supply chain, closed-loop supply chain and government intervention three angles, to car tire recovery as the research object, using the relevant theory of the Stackelberg game to study the differences between channels. By constructing the model without government subsidy and the model with government subsidy, this paper studies the role of government subsidies in the recycling process of waste tires, and analyzes the influence of government intervention measures on the game among manufacturers, retailers and consumers. The results show that the government subsidy will improve the overall profit level, increase the total demand for tires in the market, and reduce the environmental impact of used tires. By using the theory of dual-channel closed-loop supply chain and other relevant knowledge, the concrete application of closed-loop supply chain in waste material recovery will be promoted.

\textbf{1. INTRODUCTION}

The development of Internet-based information technology has given birth to a series of new businesses and new economies, and for traditional enterprises, this change needs to be adapted. Combine traditional mode with new channel models, it can increase the productivity of the enterprise. The traditional supply chain is mainly based on the channels of physical stores, and under the impetus of the Internet, the network channels are gradually adopted by enterprises, combined with the channel model of physical stores, forming a dual-channel model combining online and offline, and the development of this model meets the development needs of enterprises. In addition, the traditional supply chain is mainly centered on economic interests, the purpose of which is to reduce production costs and improve the competitiveness of enterprises, the traditional supply chain is only a one-way logistics structure, and this structure can’t adapt to the rapid development of enterprises, and lack of understanding of...
sustainable environmental development. With the progress of science and technology and the development of economic globalization, countries are facing environmental degradation and resource shortage, reverse logistics began to be adopted by enterprises in various countries, two-channel supply chain and closed-loop supply chain began to become the focus of enterprises in various countries.

The rapid economic development has been accompanied by a continuous deterioration of the environment. In 2015, the United Nations Summit on Sustainable Development presented Transforming Our World: Agenda 2030, which made it clear that the traditional model of industrial development must shift to a new model: sustainable development. Especially for our country, our country is a big manufacturing country, the problem of waste of resources and environmental pollution is prominent, especially the harm of some waste products, if the waste can’t be recycled, the problem of environmental pollution will be more serious. But for now, the cost of recycling waste is high, some enterprises are unwilling or because of limited funds and can’t be able to recover, the government has introduced relevant policies to subsidize the loss of enterprises.

Two-channel closed-loop supply chain and government subsidy policy has become the driving force for enterprises to recycle tires, and the development of two-channel closed-loop supply chain has spread to all walks of life in various countries. This study uses automobile tires as an example, uses game theory, operations research and other ideas and research methods to construct mathematical decision-making model, analyzes the specific application of closed-loop supply chain in enterprises, analyzes the impact of subsidies and non-subsidies on manufacturers, retailers and users, and the environment, and analyzes the changes in the amount of decision-making before and after subsidies. The theory of dual-channel closed-loop supply chain and other relevant knowledge are used to promote the specific application of closed-loop supply chain in waste material recovery. The study found that government subsidies increase the overall level of profits, increase the total demand for tires in the market, and reduce the negative impact of tires on the environment.

2. LITERATURE REVIEW

2.1. Closed-loop supply chain theory
Closed-loop supply chain as a closed circulation system, it controls the production process of logistics, information flow and capital flow, so that two-way logistics reasonable operation, can reduce the environmental impact of waste items, reduce the manufacturer's production costs, promote waste recycling, save resources[2]. Ruud H. Teunter [12] first proposed a closed-loop supply chain, proposing that the process of reverse logistics mainly refers to the product manufacturers from the hands of consumers recycling and reuse of a life cycle, the traditional forward logistics and reverse logistics supply together to form a closed-loop supply chain system. Govindan et al. [6] studied the cyclic supplier selection and closed-loop supply chain network design under the condition of uncertainty, and proposed a fuzzy solution method that simultaneously considers the uncertainty and transforms the multi-objective model into the single-objective model. Giri et al. [1] established a closed-loop supply chain model consisting of two suppliers, a manufacturer and a retailer. An example is given to illustrate the model and sensitivity analysis is carried out. It is found that production learning has a significant positive influence on the optimal decision of closed-loop supply chain. Tang et al. [11] studied a closed-loop supply chain with remanufacturing in a competitive market where the supply chain is a price taker. Based on the Stackelberg game framework, it is proven that in a competitive market, by establishing contracts between manufacturer and retailer, a remanufacturing closed-loop supply chain can achieve the same return rate as in a centralized coordination channel.

Closed-loop supply chain is a combination of two-way supply chains [7], precisely because the combination of positive and reverse logistics makes closed-loop supply chains suitable for most enterprises.
2.2. Two-channel supply chain
The dual-channel supply chain is composed of online channels and offline channels, which refer to the commodity trading activities carried out through the network mode and e-commerce mode, and the offline channel refers to the trade activities of face-to-face communication with customers through stores and brick-and-mortar stores. With the development of economy, the role of reverse logistics in economic and environment sustainable development is becoming more and more important. Park and Keh\cite{2} use the single-selling channel and mixed-channel sales model of the most decision-making model, to study the single-selling channel can increase profits, coordination of channel conflicts. Chiang\cite{3} studies the impact of customer perception on dual-channel perceptions and concludes that the profitability of manufacturers and retailers increases as a result of the two-channel model in the direct-selling channel model. Wang et al.\cite{4} studied the pricing strategy of dual-channel green investment and sales efforts to sell green products through direct channels and non-green products through retail channels in the case of uncertain demand. Taking the selling price, selling effort and green level of the two products as decision variables, the manufacturer and retailer can realize their expected profit maximization in the centralized model, decentralized model and cooperative model.

From the research of scholars at home and abroad, it can be concluded that the two-channel closed-loop supply chain is becoming more and more important for the recycling of resources and the sustainable development of the economy.

2.3. The theory of government subsidies
At present, government subsidy measures are becoming more and more important in the development of enterprises, the development of enterprises is inseparable from the government subsidies, but the government subsidies projects are quite lack.

Wang et al.\cite{5} took the closed-loop supply chain of low-carbon e-commerce as the research object and discussed the influence of government subsidies and altruistic preferences of remanufacturers on decision-making. In addition, from the perspective of social value, this paper compares and analyzes the decision of the closed-loop supply chain of low-carbon e-commerce. The results show that the government subsidy improves the overall operating efficiency of the supply chain and the total social surplus. Nielsen et al.\cite{6} compare the results of three government policies in manufacturer-Stackelberg and retailer-Stackelberg, namely (i) direct subsidies to consumers, (ii) subsidies to manufacturers to stimulate second-hand product collection, and (iii) subsidies to manufacturers to improve product quality. The results show that under the retailer-Stackelberg game, the level of urban greening, second-hand product collection and industrial subsidy is always higher, while under the manufacturer-Stackelberg game, the government subsidy rate is always higher. Zhao et al.\cite{7} used the method of game theory to study the differences between the two states under the background of the new substitution policy for home appliances in China. The profit distribution model of non-government subsidy and government subsidy in closed-loop supply chain is analyzed. By comparing the profit distribution of the members in the two models, we find that the government can control the profit distribution mode of the members by adjusting the government subsidy rate. In addition, subsidy average, subsidy rate and subsidy limit have significant influence on the effect of government subsidy policy.

2.4. Stackelberg game
The Stackelberg game was proposed in 1934 by the German economist Heinrich von Stackelberg to reflect the unfair competitive relationship between the market’s dealers. Chen et al.\cite{8} studied how suppliers, retailers, as followers, develop price and replenishment strategies in a one-to-many supply chain inventory game model. Pakseresht et al.\cite{9} proposed the joint configuration of green supply chain and green supply chain by adopting leader-follower Stackelberg game method. A Stackelberg game model of this model is established by using a two-level multi objective linear programming problem. Yifan Chen\cite{10} and others put forward the Stackelberg game method of multi-resource allocation and pricing in mobile edge computing, based on Stackelberg game theory, constructed end-user as follower
and mobile edge cloud as leader, aiming to maximize the benefits of all parties under budget constraints by seeking a balanced solution.

The main purpose of this study is to use Stackelberg game ideas to build a two-channel closed-loop supply chain model of whether car tires have government subsidies, in which the tire manufacturer is the leader in the whole process, the retailer is mainly the follower role, the retailer is based on their own information feedback to determine their own strategy. Using the two-channel supply chain, closed-loop supply chain and government intervention theory to analyze the impact of manufacturers and retailers in the tire production and sales process. Focus on the specific role of government subsidy policy in the two-channel closed-loop supply chain.

3. THE CLOSED-LOOP SUPPLY CHAIN FOR TIRE RECYCLING

3.1. Analysis of the current situation of automobile tire recovery

Analysis of the current situation abroad: Global tire demand continues to grow, with global tire sales generally increasing from 2008 to 2018 and growing at a rate of 3.7%, with Africa, the Middle East and other countries with the highest growth rates of 7.0%, Asia second only to 5.5%, and Europe and North America at 2.4% and 2.2%, respectively.

With the increase of automobile production, the demand for tires around the world is increasing rapidly, countries in the production of tires began to pay attention to the brand value of tires, we can see that China's tire brand share is lower than other countries, the United States accounted for the largest, 19 times China, followed by Japan, Japan's tire brand value has been 3 times China's.

Analysis of the current situation in China: With the progress of science and technology, the number of tires produced in China is increasing, and in 2005 China's tire production exceeded that of the United States by 9.6%, making it the world's largest tire producer. Due to the instability of the automobile market, the impact on tire fluctuations is relatively large, and the downward trend of volatility tends to stabilize, with tire production falling by 16% in 2015 and stabilizing in other years. Compared with other countries, China's tire production is increasing.

With the increase of tire production, the amounts of used tires are also increasing, but the amounts of used tires are difficult to dissolve, and can’t be treated through landfill, incineration, otherwise it will cause environmental pollution. Therefore, the Chinese government has formulated the relevant tire recycling policy, which solves the problem of long-term parking of tires and pollution of the environment. Waste tire pollution to the environment is very serious, since 2013, China has introduced tire recycling related policies, so that waste tires are fully and reasonably used.

With the increase of automobile demand, the demand for tires in China shows a state of growth, but also brings about an increase in tire scrap rate, at present, China's tire scrap rate between 6% and 8%, compared with other countries, relatively high. Through the investigation of tire yield analysis and tire refurbishment analysis in recent years, the following statistical tables are drawn:
Since the introduction of relevant policies, from the tire recovery and renovation statistics can be seen that China's waste tire volume is still increasing, the growth rate is lower than in previous years, tire recycling problems temporarily under control. However, the amount of tire refurbishment is still relatively low, and the technology of tire recovery and refurbishment needs to be improved.

3.2. The model of a closed-loop supply chain for tyre recycling
The manufacturer is responsible for recycling itself: the manufacturer's own recycling is primarily responsible for the recycling of used tyre, including the disposal, removal and refurbishment and remand of used tyres, without the need for a middleman's recycling, and the risks and responsibilities associated with the recycling process are borne by the manufacturer itself. The manufacturer's own recycling responsibility is a direct way of recycling, i.e. the manufacturer recycles waste directly from the user's hands and then processes it.

Entrust manufacturer retailers with recycling: Retailers are responsible for recycling used tyre, which can be carried out from all angles, such as tire performance, environmental impact, etc., reducing the reverse logistics of tyre recovery and allowing manufacturers to focus on new product development. The recycling method has two advantages: the first is closer to the consumer, making it easier to recycle. Retailers are directly customer-oriented and have close connections with customers, so retailers can understand consumer dynamics in the recycling process, master the psychology of consumers, develop effective programs to reduce the difficulty of work; When retailers are responsible for recycling used products, manufacturers can focus on their core production business.

The third party logistics is responsible for recycling: This model is the manufacturer 's contractual handling of recycling issues to a third party, reducing the manufacturer's task of recycling the manufacturing process, focusing on the core business, in which the third party can obtain compensation from the manufacturer accordingly. Third-party recycling model not only avoids the manufacturer's uncertainty in waste management risk, but also the manufacturer can drive waste removal innovation, improve efficiency, and benefit from it. In addition, manufacturers can focus on their core business, a recycling model that strengthens the link between manufacturers and third parties.

3.3. Problems in the recovery of automobile tires
In terms of laws and regulations: After the introduction of the relevant tire policy, China's recycling of used tires has been gradually improved, but with developed countries and developed regions through the establishment of laws and other relevant systems to promote the recycling of used tires, China lacks specific laws and regulations; The recycling of used tires is mainly carried out by small and medium-

Figure 1 Statistics for the recovery and refurbishment of car tyres, 2013-2018.
sized enterprises for renovation, due to the small scale of production and operation of small and medium-sized enterprises, lack of advance technology, hindering the improvement of the quality of refurbished tires. In addition, small and medium-sized enterprises have low self-improvement ability and weak competitiveness, and cannot form new industries; In the aspect of encouragement and compensation: in the process of tire recycling, enterprises do not have corresponding compensation, and China lacks corresponding compensation incentive mechanism.

4. STUDY ON THE MODEL OF DOUBLE CHANNEL CLOSED LOOP SUPPLY CHAIN OF GOVERNMENT SUBSIDIZED AUTOMOBILE TIRE

In this study, the relationship among manufacturers, retailers and consumers was studied to construct a dual-channel closed-loop supply chain model for tire recycling with or without government subsidies, and find the optimal results of the relevant data by comparing the models. Traditional sales channels have no government-subsidized sales relationship and are made up of a single manufacturer, a single retailer, and consumers. There are two ways to sell a product, one is a direct sales method, which is sold directly by the manufacturer to the customer, and the other is an indirect consumption method, which is sold by the manufacturer to the retailer and then resold by the retailer to the customer. Waste is remanded through processes such as manufacturer cleaning and dismantling, and the remand produced is no longer marketed through the same distribution channels as new products, but is sold directly by the manufacturer to consumers. In considering government subsidy intervention, the Government will encourage manufacturers’ participation in the recycling and re-manufacturing process in the form of subsidies to promote the development of recycling and re-manufacturing. With the intervention of the government, the model of the two-channel closed-loop supply chain in tire recycling is as shown in the figure:

![Figure 2: A two-channel closed-loop supply chain model under government subsidies.](image)

4.1. Model assumptions and symbol descriptions

Hypothesis 1: Based on a two-channel closed-loop supply chain model with government subsidies, it is assumed that there is a Stackelberg game between manufacturer and retailer. In a Stackelberg game, the manufacturer is the leader and the retailer the follower. Both of them make decisions based on profit maximization, are at neutral risk, and have completely symmetrical information.

Hypothesis 2: When consumers choose a product, they start from two aspects: first, the performance of the product, generally expressed in \( V \), the consumer based on the performance attributes of the acceptance of there-creation is expressed with \( \delta \), and \( \delta \in [0,1] \). Second is the environmental performance, the environmental performance of the product without any environmental treatment of the environmental pollution as the initial environmental impact, set to \( D \). After the manufacturer’s processing, the environmentally friendly size of new products and re-creations is \( e_\alpha \) and \( e_\beta \), so the
actual impact of new products and re-creations on the environment is the \( k_{\alpha} = D - e_{\alpha} \) and \( k_{\beta} = D - e_{\beta} \) respectively, \( e_{\alpha} \in [0,D] \), \( e_{\beta} \in [0,D] \). Hypothesis 3: Assuming that the \( \theta \) is the consumer's willingness to pay for the unit environment, and that the maximum value is \( d \), the \( \theta \) satisfies the uniform distribution from 0 to \( d \), \( \theta \in [0,d] \). The following are the relevant variables and compliance instructions that should be noted in the model.

Table 1 Description of related variables and symbols.

| Symbol | The symbol description |
|--------|------------------------|
| \( c_{\alpha} \) | A manufacturer's unit cost of manufacturing a new product or manufactured product that meets \( c_{\beta} < c_{\alpha} \) and \( c_{\beta} < c_{\alpha} < V \) |
| \( w_{\alpha} \) | Wholesale prices of new products and remanufactured goods (decided by the manufacturer) |
| \( p_{\alpha}, p_{\beta} \) | New product and remanufactured product selling price per unit (determined by the retailer) |
| \( q_{\alpha}, q_{\beta} \) | Demand for new products and remanufactured goods |
| \( Y \) | Unit recovery and recovery price of waste products (collected and priced by retailers) |

The consumer's utility function can be used to derive the demand for manufactured goods and new products, and from the consumer's utility function, the demand function of two types of products can be derived. From the above basic assumptions and symbol descriptions, it can be inferred that the manufacturer's net utility function for manufacturing new products is \( U_{\alpha} = V + \theta e_{\alpha} - p_{\alpha} \), the net utility function for the manufacturer's re-manufactured goods is \( U_{\beta} = \delta V + \theta e_{\beta} + Y - p_{\beta} \). According to the principle of maximizing consumer utility, when \( U_{\beta} < U_{\alpha} \) and \( U_{\alpha} > 0 \), consumers will choose new products, and vice versa, when \( U_{\beta} > U_{\alpha} \) and \( U_{\alpha} > 0 \), consumers choose re-manufactured goods. From the related quantity relationship and the symbol, we can get the requirement function relationship of the two as:

Demand functions for new products:
\[
q_{\alpha} = \frac{e_{\alpha} p_{\beta} - e_{\alpha} p_{\alpha} + e_{\beta} V - e_{\alpha} \delta V - e_{\alpha} Y}{\delta e_{\alpha} (e_{\beta} - e_{\alpha})} \tag{1}
\]

Demand function for re-creation:
\[
q_{\beta} = 1 + \frac{p_{\alpha} - p_{\beta} - \gamma + \delta V + Y}{\delta (e_{\beta} - e_{\alpha})} \tag{2}
\]

In the study, the two variables "DN" and "DS" were used to indicate that automobile tires were not subsidized by the government in the two-channel closed-loop supply chain, and that there were model studies with government subsidies. Use the "*" to represent the optimal decision-making volume.

4.2. The two-channel closed-loop supply chain model: DN model for automobile tire recovery without government subsidy

In this model, manufacturers and retailers are the main decision makers, i.e. manufacturers are leaders, retailers are followers, both in pursuit of profit maximization, and in the process the government does not intervene in any way, the tire recycling process adopts a two-channel supply chain and closed-loop supply chain model combined, according to the model construction and basic assumptions, the introduction of manufacturers and retailers profit function relationship is: The function relationship of manufacturer's profit:
\[
\Pi_{R}^{DN} (p_{\alpha}) = \left( p_{\alpha} - w_{\alpha} \right) \frac{e_{\alpha} p_{\beta} - e_{\alpha} p_{\alpha} + e_{\beta} V - e_{\alpha} \delta V - e_{\alpha} Y}{\delta e_{\alpha} (e_{\beta} - e_{\alpha})} \tag{3}
\]

The function relationship of retailer's profit:
According to the function relationship between the above manufacturer and the retailer, the guidance of (3) and (4) is obtained, and first to derivative (3) and get:

\[
\frac{\partial^2 \Pi_R^{DN} (p_\alpha)}{\partial p_\alpha^2} = -\frac{2e_\beta}{d(e_\beta - e_\alpha)} < 0
\]

Combined with the theorem of inequality, it can be concluded that the function (3) has a unique optimal solution, and when the first-order conductor is 0, the optimal retail price of the new product can be derived:

\[
p_\alpha^{*} = \frac{3e_\beta \bar{U}_\alpha - e_\alpha \bar{U}_\beta}{4e_\beta} + c_\alpha.
\]

The matrix relationship of the manufacturer can be obtained by asking for a second-order conductor for the (4) type. Because of

\[
A'' = \frac{\partial^2 \Pi_M^{DN} (w_\alpha, p_\beta)}{\partial w_\alpha^2} = \frac{e_\beta}{d(e_\beta - e_\alpha)} < 0,
\]

\[
B'' = \frac{\partial^2 \Pi_M^{DN} (w_\alpha, p_\beta)}{\partial w_\beta^2} = \frac{1}{d(e_\beta - e_\alpha)} < 0,
\]

\[
C'' = \frac{\partial^2 \Pi_M^{DN} (w_\alpha, p_\beta)}{\partial w_\beta^2} = \frac{2e_\beta - e_\alpha}{d(e_\beta - e_\alpha)} < 0.
\]

And \(A'' C'' - B''^2 = \frac{2}{d(e_\beta - e_\alpha)} > 0\), so the function (4) matrix relationship is negative, so the model has a unique optimal solution, when the first derivative is 0, the optimal wholesale price of the new product and the optimal sales price of the remanufactured product can be obtained:

\[
w_{\alpha}^{*} = \bar{w}_\alpha + c_\alpha,
\]

\[
p_{\beta}^{*} = \frac{\bar{p}_\beta}{2} + c_\beta + Y.
\]

Bringing optimal pricing into the demand function (1) (2), the optimal demand function is obtained as follows:

\[
q_{\alpha}^{*} = \frac{e_\beta \bar{U}_\alpha - e_\alpha \bar{U}_\beta}{4d(e_\beta - e_\alpha)},
\]

\[
q_{\beta}^{*} = \frac{\bar{U}_\alpha - \bar{U}_\beta}{4d(e_\beta - e_\alpha)} + \frac{\bar{U}_\beta}{4d e_\beta}.
\]

By taking the optimal pricing and optimal demand into the profit functions of the manufacturer and the retailer in Equations (3) and (4), the optimal profit of the manufacturer and the retailer in the anarchic-subsidized dual-channel closed-loop supply chain model is obtained:

\[
\Pi_M^{*} = \frac{(e_\beta \bar{U}_\alpha - e_\alpha \bar{U}_\beta)^2}{8d e_\alpha e_\beta (e_\beta - e_\alpha)},
\]

\[
\Pi_R^{*} = \frac{(e_\beta \bar{U}_\alpha - e_\alpha \bar{U}_\beta)^2}{16d e_\alpha e_\beta (e_\beta - e_\alpha)}.
\]

Through the above analysis, it can be concluded that from the perspective of automobile tires to study the impact of with or without subsidy on the environment of the two-channel closed-loop supply chain can be expressed as:
By substituting the optimal demand formula for manufactured goods and new products into Equation (5), it can be obtained that under the optimal decision-making condition, the product's impact on the environment is as follows:

$$\Pi^*_{DE} = \frac{D(e_{\beta} U_{\alpha} - e_{\alpha} U_{\beta})}{4de_{\alpha}e_{\beta}} - \frac{U_{\beta}}{2d}$$

From the above conclusions, the optimal decisions for manufacturers of new products and re-manufactured products in closed-loop supply chain models with optimal decision quantity are as follows:

Optimal wholesale price for manufactured goods:
$$W^*_{DN} = \frac{U_{\alpha}}{2} + c_{\alpha}$$

Optimal retail price for new products:
$$P^*_{D\alpha} = \frac{3e_{\beta}U_{\alpha} - e_{\alpha}U_{\beta}}{4e_{\beta}} + c_{\alpha}$$

Optimal retail price for re-products:
$$P^*_{D\beta} = \frac{U_{\beta}}{2} + c_{\beta} + Y$$

Optimal demand for new products:
$$Q^*_{D\alpha} = \frac{e_{\beta} U_{\alpha} - e_{\alpha} U_{\beta}}{4d e_{\alpha} (e_{\beta} - e_{\alpha})}$$

Optimal demand for re-manufactured products:
$$Q^*_{D\beta} = \frac{U_{\alpha} - U_{\beta}}{4d(e_{\beta} - e_{\alpha})} + \frac{U_{\beta}}{2d}$$

The manufacturer's best profit:
$$\Pi^*_{MN} = \frac{(e_{\beta} U_{\alpha} - e_{\alpha} U_{\beta})^2}{8de_{\alpha} e_{\beta} (e_{\beta} - e_{\alpha})}$$

Retailer's Best Profit:
$$\Pi^*_{RN} = \frac{(e_{\beta} U_{\alpha} - e_{\alpha} U_{\beta})^2}{16de_{\alpha} e_{\beta} (e_{\beta} - e_{\alpha})}$$

Impact on the environment under optimal decision-making:
$$\Pi^*_{EN} = \frac{D(e_{\beta} U_{\alpha} - e_{\alpha} U_{\beta})}{4de_{\alpha} e_{\beta}} - \frac{U_{\beta}}{2d}$$

Where, $U_{\alpha} = de_{\alpha} + V - c_{\alpha}$; $U_{\beta} = de_{\beta} + \delta V - c_{\beta}$. These are the optimal results of trading relationships conducted by manufacturers and retailers without government intervention, and the environmental impact of product use under optimal decision-making conditions.

4.3. The two-channel closed-loop supply chain model: DS model with government subsidy for automobile tire

Assuming that in the process of tire recycling and remand, the subsidy coefficient for scrap tyre recovery is Q, and Q is positive, the same as the model of a two-channel closed-loop supply chain for tire sales without government intervention, the profit function relationship between manufacturers and retailers can be expressed as: based on the relevant variable assumptions and quantitative relationships:

$$\Pi^*_{RS}(p_{\alpha}) = (p_{\alpha} - w_{\beta}) \frac{e_{\alpha}p_{\beta} - e_{\beta}p_{\alpha} + e_{\alpha}V - e_{\alpha}Y}{d e_{\alpha} (e_{\beta} - e_{\alpha})}$$

$$\Pi^*_{MN}(w_{\alpha}, p_{\beta}) = (w_{\alpha} - c_{\alpha}) \frac{e_{\alpha}p_{\beta} - e_{\beta}p_{\alpha} + e_{\alpha}V - e_{\alpha}Y}{d e_{\alpha} (e_{\beta} - e_{\alpha})} - (p_{\beta} - c_{\beta} - Y + Q) \left[1 + \frac{p_{\alpha} - e_{\alpha}V + \delta V + Y}{d(e_{\beta} - e_{\alpha})}\right]$$

(6)

Using the above-mentioned method for (6), (7) formula of guidance, you can get (6) formula

$$\frac{\partial^2 \Pi^*_{RS}(p_{\alpha})}{\partial p_{\alpha}^2} = -\frac{2e_{\beta}}{d e_{\alpha} (e_{\beta} - e_{\alpha})} < 0$$

so the function $\Pi^*_{RS}(p_{\alpha})$ has the only optimal solution, when the
first derivative is 0, to obtain the best retail price of the new product is: \( p^{DS*}_\alpha = \frac{3e_\beta \bar{u}_\alpha - e_\alpha (\bar{u}_\beta + Q)}{4e_\beta} + c_\alpha \). When taking the derivative of Equation (6), the principle is the same as that of Equation (4), so the optimal wholesale price can be obtained as \( w^{DS*}_\alpha = \frac{\bar{u}_\alpha}{2} + c_\alpha \) and the optimal selling price for remanufactured goods is \( p^{DS*}_\beta = \frac{\bar{u}_\beta - Q}{2} + c_\beta + Y \).

Bringing the best prices get into the demand functions (1) and (2), we can get the best demand for new products and re-creations:

\[
q^{DS*}_\alpha = \frac{e_\beta \bar{u}_\alpha - e_\alpha (\bar{u}_\beta + Q)}{4d e_\alpha (e_\beta - e_\alpha)},
q^{DS*}_\beta = \frac{\bar{u}_\beta - \bar{u}_\alpha}{4d (e_\beta - e_\alpha)} + \frac{u_\beta}{4d e_\beta} + \frac{2e_\beta - e_\alpha}{4d e_\beta (e_\beta - e_\alpha)}.
\]

The optimal profits for new products and manufactured goods in the two-channel closed-loop supply chain that can be recovered with government subsidies are:

\[
\Pi^{DS}_E = \frac{(e_\beta \bar{u}_\alpha - e_\alpha \bar{u}_\beta)^2}{8d e_\alpha (e_\beta - e_\alpha)} + \frac{e_\alpha e_\beta (\bar{u}_\beta - \bar{u}_\beta)}{4d e_\beta (e_\beta - e_\alpha)} + \frac{2e_\beta - e_\alpha}{8d e_\beta (e_\beta - e_\alpha)}
\]

\[
\Pi^{DS}_E = \frac{(e_\beta \bar{u}_\alpha - e_\alpha \bar{u}_\beta)^2}{16d e_\alpha e_\beta (e_\beta - e_\alpha)} - \frac{e_\alpha Q (e_\beta \bar{u}_\alpha - e_\alpha \bar{u}_\alpha)}{16d e_\beta e_\alpha (e_\beta - e_\alpha)} - e_\alpha^2 Q^2
\]

We can deduce it from the above, the two-channel closed-loop supply chain with government subsidies for tire recycling has a functional relationship to the environment: \( k_\alpha q^{DS}_\alpha + k_\beta q^{DS}_\beta = (D - e_\alpha) q^{DS}_\alpha + (D - e_\beta) q^{DS}_\beta \) (8)

Bringing the optimal demand for new products and manufactured goods into the (8) formula we can get the environmental impact of government subsidies as:

\[
\Pi^{DS*}_E = \frac{D(e_\beta \bar{u}_\alpha + e_\alpha \bar{u}_\beta)}{4d e_\alpha e_\beta} - \left( \frac{\bar{u}_\beta}{2d} + \frac{D - 2e_\beta}{4d e_\beta} \right) Q
\]

In this model, it still satisfies \( q_\alpha > q_\beta \geq 0 \). From the above conclusions, the optimal decision with government intervention is as follows:

Best wholesale price: \( w^{DS*}_\alpha = \frac{\bar{u}_\alpha}{2} + c_\alpha \)

Optimal retail price for new products: \( p^{DS*}_\alpha = \frac{3e_\beta \bar{u}_\alpha - e_\alpha (\bar{u}_\beta + Q)}{4e_\beta} + c_\alpha \)

The optimal retail price for a new product is: \( p^{DS*}_\alpha = \frac{3e_\beta \bar{u}_\alpha - e_\alpha (\bar{u}_\beta + Q)}{4e_\beta} + c_\alpha \)

Optimal demand for new products: \( q^{DS*}_\alpha = \frac{e_\beta \bar{u}_\alpha - e_\alpha (\bar{u}_\beta + Q)}{4d e_\alpha (e_\beta - e_\alpha)} \)

Optimal demand for re-manufactured goods: \( q^{DS*}_\beta = \frac{\bar{u}_\beta - \bar{u}_\alpha}{4d (e_\beta - e_\alpha)} + \frac{\bar{u}_\beta}{4d e_\beta (e_\beta - e_\alpha)} + \frac{2e_\beta - e_\alpha}{4d e_\beta (e_\beta - e_\alpha)} Q \)

The manufacturer’s optimal profit is:
The retailer's best profit is:

$\Pi_d^* = \frac{(e_{\alpha} - e_{\alpha})^2}{8\delta e_\alpha e_\beta (e_{\beta} - e_{\alpha})} Q + \frac{2e_{\beta} - e_{\alpha}}{8\delta e_\beta (e_{\beta} - e_{\alpha})}$

Optimal decision-making on the environmental impact:

$\Pi_f^* = \frac{(e_{\beta} - e_{\alpha})^2}{16\delta e_\alpha e_\beta (e_{\beta} - e_{\alpha})} - \frac{2e_{\alpha} (e_{\beta} - e_{\alpha}) - e_{\alpha}^2 Q^2}{16\delta e_\alpha e_\beta (e_{\beta} - e_{\alpha})}$

The retailer's best profit is:

$\Pi_f^* = \frac{D}{4d e_\alpha e_\beta} \left( \frac{e_{\beta} - e_{\alpha}}{2d} + D - 2e_{\beta} \right) Q$

In this model, there is a subsidy threshold $Q$ for government subsidy $Q$, which is illogical when the amount of government subsidy per unit exceeds this threshold, the government does not grant subsidies and the subsidy threshold is:

$\Pi_g^* = \frac{e_{\beta}^2 + e_{\alpha} e_{\beta}}{3e_\alpha e_\beta - e_{\alpha}} \frac{e_{\beta} - e_{\alpha}}{2} - \frac{e_{\beta}}{2}$

This section mainly describes the role of government subsidies and non-government subsidies and subsidies on dual channels and related model analysis, through the analysis of the model, we can get the optimal decision-making volume, and find out the environmental impact of government subsidies and non-government subsidies.

5. STUDY ON THE MODEL OF DOUBLE CHANNEL CLOSED LOOP SUPPLY CHAIN OF GOVERNMENT SUBSIDIZED AUTOMOBILE TIRE

5.1. A comparative analysis of models of government subsidies and non-government subsidies

In order to better explore the role of government subsidies in the two-channel closed-loop supply chain in tire sales, this section analyzes and compares the optimal decision-making volume of the two models above, summarizes the changes in the decision-making volume before and after the subsidy, and explains the reasons for the change and the final change in the total decision-making volume in the market. By comparison, you get the following table 2:

Government intervention has an impact on decision-making volumes, particularly retail prices and demand for goods, and the impact on the profits and environment of manufacturers and retailers. Through the comparative analysis of the table, the following conclusions can be drawn: Analysis of differences in demand: By analyzing the comparison, it is not difficult to find that the above table meets the following inequality relationships:

$p_{\alpha N^*} - p_{\alpha S^*} = \frac{e_{\alpha}}{4e_{\beta}} Q > 0,$

$p_{\beta N^*} - p_{\beta S^*} = \frac{Q}{2} > 0,$

$q_{\alpha N^*} - q_{\alpha S^*} = \frac{e_{\alpha} Q}{4d e_\alpha (e_{\beta} - e_{\alpha})} > 0,$

$(q_{\alpha N^*} - q_{\beta N^*}) - (q_{\alpha S^*} + q_{\beta S^*}) = \frac{-Q}{4d e_{\beta}} < 0.$

From these inequalities, it can be concluded that the following relationships can be satisfied in the model of non-government intervention and government intervention:

$w_{\alpha N^*} = w_{\alpha S^*},$

$p_{\alpha N^*} + p_{\alpha S^*} = p_{\alpha S^*},$

$p_{\beta N^*} + p_{\beta S^*} = p_{\beta S^*},$

$q_{\alpha N^*} + q_{\alpha S^*} = q_{\alpha S^*}.$
This conclusion shows that the government's intervention policy has no effect on the wholesale price of the product, but will reduce the retail price of tire manufactured goods and new tire products, reduce the market demand for new products and increase the sales volume of re-creations, which may be due to the subsidy policy to make the sales of re-creations gain a greater competitive advantage, in general, the overall sales volume of re-creations is greater than the decline in new products, so the market demand for products is increased.

Analysis of profit relationship changes:
This paper mainly from the manufacturer, retailer's point of view to study the practical application of subsidy measures, from the above table, before and after the subsidy manufacturer and retailer profit relationship changes as follows:

\[\Pi_\alpha^{DN^*} - \Pi_\alpha^{DS^*} = \frac{2e_\alpha U_\alpha - e_\alpha U_\beta - e_\alpha^2 Q^2}{16de_\alpha e_\beta (e_\beta - e_\alpha)} > 0\]

\[\Pi_\mu^{DN^*} - \Pi_\mu^{DS^*} = \frac{-8e_\alpha e_\beta U_\alpha (e_\beta - e_\alpha) + 3e_\alpha - e_\beta}{8de_\alpha e_\beta (e_\beta - e_\alpha)} < 0\]

| Table 2 Tire recovery non-government subsidy model – DN and tire recovery government subsidy model - DS comparative analysis. |
|---------------------------------|---------------------------------|---------------------------------|
| Optimal decision-making | Model DN | Model DS |
| \(\omega_\alpha^*\) | \(\frac{U_\alpha}{2} + c_\alpha\) | \(\frac{U_\alpha}{2} + c_\alpha\) |
| \(p_\alpha^*\) | \(\frac{3e_\beta U_\alpha - e_\alpha U_\beta}{4e_\beta} + c_\alpha\) | \(\frac{3e_\beta U_\alpha - e_\alpha (U_\beta + Q)}{4e_\beta} + c_\alpha\) |
| \(p_\beta^*\) | \(\frac{U_\beta}{2} + c_\beta + Y\) | \(\frac{U_\beta - Q}{2} + e_\beta + Y\) |
| \(q_\alpha^*\) | \(\frac{e_\beta U_\alpha - e_\alpha U_\beta}{4de_\alpha (e_\beta - e_\alpha)}\) | \(\frac{e_\beta U_\alpha - e_\alpha (U_\beta + Q)}{4de_\alpha (e_\beta - e_\alpha)}\) |
| \(q_\beta^*\) | \(\frac{U_\beta - U_\alpha}{4d(e_\beta - e_\alpha)} + \frac{U_\beta}{4d(e_\beta - e_\alpha)}\) | \(\frac{U_\beta - U_\alpha}{4d(e_\beta - e_\alpha)} + \frac{U_\beta}{4d(e_\beta - e_\alpha)} - \frac{2e_\beta - e_\alpha}{Q}\) |
| \(\Pi R^*\) | \(\frac{(e_\beta U_\alpha - e_\alpha U_\beta)^2}{16de_\alpha e_\beta (e_\beta - e_\alpha)}\) | \(\frac{(e_\beta U_\alpha - e_\alpha U_\beta)^2 - 2e_\alpha Q(e_\beta U_\alpha - e_\alpha U_\beta) - e_\alpha^2 Q^2}{16de_\alpha e_\beta (e_\beta - e_\alpha)}\) |
| \(\Pi M^*\) | \(\frac{(e_\beta U_\alpha - e_\alpha U_\beta)^2}{8de_\alpha e_\beta (e_\beta - e_\alpha)}\) | \(\frac{(e_\beta U_\alpha - e_\alpha U_\beta)^2 + e_\beta e_\alpha e_\beta (U_\beta - U_\alpha)}{8de_\alpha e_\beta (e_\beta - e_\alpha)} + \frac{e_\beta U_\alpha - e_\alpha U_\beta}{4de_\alpha e_\beta (e_\beta - e_\alpha)}\) |
| \(\Pi E^*\) | \(\frac{D(e_\beta U_\alpha - e_\alpha U_\beta)}{4de_\alpha e_\beta} - \frac{U_\beta}{2d}\) | \(\frac{D(e_\beta U_\alpha + e_\alpha U_\beta)}{4de_\alpha e_\beta} - \frac{U_\beta}{2d} + \frac{D - 2e_\beta}{4de_\beta} Q\) |
From the above relationships can be analyzed to draw: \( \Pi^{\text{DN}^*}_{R} > \Pi^{\text{DS}^*}_{R} > \Pi^{\text{DN}^*}_{M} > \Pi^{\text{DS}^*}_{M} \). This conclusion shows that in the two-channel closed-loop supply chain for the recovery of automobile tires, government subsidies make manufacturers profit and retailers lose money, but retailers lose less than manufacturers profit, so the overall social welfare is increasing. The results show that the government subsidy policy reduces both the demand for retailers to sell new products and the price of retail sales, and therefore the profits of retailers are also decreasing. It can be inferred from this: Government subsidies must be limited to a certain extent, and make manufacturers and retailers profit balance, otherwise it will disrupt the market order, affecting the smooth and healthy development of the economy.

Environmental variance analysis:
It can be known from above that the environmental impact of government subsidies is two-sided, which depends mainly on the environmental friendliness of new product re-creations.

\[
\frac{D}{2} < e_{\beta} < D, \quad \frac{D - 2e_{\beta}}{4e_{\beta}} s < 0 \Pi^{\text{DS}^*}_E > \Pi^{\text{DN}^*}_E
\]

when \( e_{\alpha} < e_{\beta} < \frac{D}{2} \), \( \frac{D - 2e_{\beta}}{4e_{\beta}} s > 0, \Pi^{\text{DS}^*}_E > \Pi^{\text{DN}^*}_E \)

So the environmental impact of the two models was:
when:
\[
\frac{D}{2} < e_{\beta} < D, \quad \Pi^{\text{DS}^*}_E > \Pi^{\text{DN}^*}_E; \quad \text{when } e_{\alpha} < e_{\beta} < \frac{D}{2},
\]

From the above comparison table analysis, the difference between the environmental impact of the two-channel supply chain with subsidy and non-subsidy policy is \( \Pi^{\text{DS}^*}_E - \Pi^{\text{DN}^*}_E = \frac{D - 2e_{\beta}}{4e_{\beta}} Q \). This shows that under the two-channel closed-loop supply chain, when the manufacturer's technical level of manufacturing re-manufactured goods is high, it has a positive impact on the environment, and when it is in a relatively low state, it has a positive effect on the environment, that is, the environmental friendliness of automobile tires depends on the environmental friendliness of re-creation \( e_{\beta} \). When \( \frac{D}{2} < e_{\beta} < D \), government intervention will reduce the impact of tires on the environment; when \( e_{\alpha} < e_{\beta} < \frac{D}{2} \), government subsidies will only increase the extent of the product's impact on the environment and play a role in inhibiting the impact on the environment. Therefore, from the point of view of protecting the environment, whether government subsidy intervention can play a good role in improving environmental impact depends on the maturity of the manufacturer's re-manufacturing technology.

This part mainly from the degree of consumer demand for tires, has built non-government subsidies and government subsidies of the two-channel closed-loop supply chain model, through game theory to find out the closed-loop supply chain model between the members and related quantitative relations between the optimal decision-making and the optimal decision-making conditions of the environmental impact. "It is concluded from the analysis that the subsidy policy in this model will reduce the price of new and re-created tyres, and that the latter will reduce the volume of retail prices by more than the former, while also reducing the retailer's sales volume, increasing the manufacturer's sales volume, the market demand for re-creations is higher than the demand for new products, and the total demand for tyres will increase. From an economic point of view, government intervention will increase profits throughout the supply chain system, but it will harm the interests of retailers, so government intervention should take into account the overall and individual interests. From the point of view of environmental protection, greater benefits will also bring greater environmental problems, so the relationship between the environment and the economy is inversely proportional."
5.2. Case analysis

This section is based on case analysis to verify the validity and correctness of the above model construction, as well as to demonstrate whether government intervention will increase the profitability of manufacturers and retailers, and whether government intervention will have an impact on product demand and the environment.

First of all, suppose \( D = 2, d = 1 \), then \( e_{\alpha}, e_{\beta} \in [0, 2], \theta \in [0, 1] \), and set to \( e_{\alpha} = 0.3, e_{\beta} = 0.5 \), the unit cost of the new product \( c_{\alpha} \) is 10, and the unit cost of the re-creation \( c_{\beta} \) is 8, the government subsidy value \( Q \) is 4, \( V = 15 \), the unit recovery cost \( Y = 2, \delta = 0.5 \). Bringing the values into the above-mentioned relationship, the changes before and after the subsidy are shown below (Table 3):

Above assumptions and \( Q \), through numerical analysis, it is found that government intervention reduces the selling price of manufactured goods and new products, increases the demand for re-creations reduces the demand for new products, and increases the demand for re-creations is higher than the demand for new products decreases, and the subsidy measures increase the profits of manufacturers and reduce the profits of retailers, which is consistent with the logical reasoning above.” At this point, government intervention has a dampening effect on the environment. Assuming that the government's subsidy value is in a changing process and the subsidy factor \( Q \) is: 1, 2, 3, 4, 5, 6, we can get the following changes in profits between manufacturers and retailers:

![Figure 3](image1.png)

**Figure 3** A diagram of manufacturers' and retailers' profits and changes in demand.

![Figure 4](image2.png)

**Figure 4** A graph of changes in the amount of decision making.

It can be found from the figure above that this assumption is consistent with the view above that subsidies increase the profits of manufacturers and retailers, reduce consumer demand for new
products, increase consumer demand for re-creations, and assume meets that \( \frac{D}{2} < a_\beta < D \). According to the figure, we can get that with the increase of subsidy intensity, the impact of subsidy on the environment showed a gradually decreasing trend, which indicated that the subsidy reduced the impact on the environment and played a promoting role in the improvement of the environment.

The profits of manufacturers and retailers as well as the changes in the demand for new products and remanufactured products are not only dependent on the subsidy coefficient of the government, but also affected by the acceptance degree of consumers. Assuming that the consumer's acceptance of the re-creation is valued at 0.23, 0.34, 0.46, 0.65, 0.78, 0.88, the

### Table 3 Balanced solutions for both models.

| decision content | \( w_\alpha \) | \( p_\alpha \) | \( p_\beta \) | \( q_\alpha \) | \( q_\beta \) | \( M \) | \( R \) | \( E \) |
|------------------|----------------|----------------|----------------|----------------|----------------|--------|--------|--------|
| Before the subsidy. | 15.15 | 10.35 | 11.25 | 18.33 | -8.5 | 80.667 | 40.333 | 8.583 |
| After the subsidy. | 15.15 | 9.75 | 9.25 | 13.33 | -1.5 | 105.667 | 21.333 | 9.083 |

relevant government subsidy value \( Q \) is 1. Consumer acceptance of re-creations directly affects the profits of manufacturers and retailers. Assuming environmental friendliness is based on hypothesis 2. It can be studied and analyzed how much consumer acceptance changes in each decision as follows:

![Figure 5 The impact of consumer acceptance of re-creations on the volume of decision-making](image)

The figure above clearly shows the inverse relationship between consumer acceptance of re-creations and consumer demand for new products, retailers' and manufacturers' profits, and the positive proportionality of re-creations' profits. The more consumers accept re-creations, the less profitable the manufacturer will be. Through the above analysis, the tire recycling process, not only to consider the government's subsidy value but also to consider the acceptance of consumers after the renovation of used tires, combined with the analysis of the two, the manufacturer and retailer's profits for a reasonable distribution, so that the profits of the two tend to balance.

The above conclusions confirm the results of the previous model study, namely: in the Stackelberg game, we should always follow the principle that manufacturers are the leader and retailers are the
followers, and the government should intervene appropriately in order to seek profits and promote economic development.

5.3. Decision-making scheme on tire recovery
1. Establish relevant rules and regulations and supervision system: Strong rules and regulations are the key to the realization of recycling problems, China should gradually improve the rules and regulations, establish a standardized, institutionalized, information-based regulatory system to ensure the sustainable and healthy development of the economy.

2. Give full play to the government's regulatory role: At present, our government's subsidies on recycling are narrow in scope, and only some tire companies are compensated, so we can expand the scope of government subsidies so that more tire companies can enjoy government subsidies. The development of the market can’t be separated from the role of the government, only give full play to the role of the government, especially the role of fiscal policy, can promote the solution of the tire recycling problem. To this end, scrap tyres can be fully utilized by increasing the recovery price of tyres and encouraging retailers and third parties to recycle them.

3. Establish compensation incentive mechanism: When dealing with recycling, the government should set up recovery compensation incentive mechanism, fully mobilize the enthusiasm of manufacturers, retailers and distributors, strengthen the links between members of the closed-loop supply chain, improve the efficiency of tire recovery, and standardize the recycling model.

4. Mobilize consumers to participate in the process of recycling and manufacturing: The government and people from all walks of life should step up publicity efforts to raise consumer awareness of the hazards of used tyres and the seriousness of consumers’ awareness of the shortage of resources and environmental pollution, so that consumers can actively participate in the problem of tyre recycling, improve the efficiency of tyre recycling and reduce the pollution caused to the environment by waste tyres.

5. Enterprises can improve the utilization rate of tire refurbishment by introducing new technologies: lack of advanced technology is another major obstacle to the development of the tire industry, enterprises should actively introduce new technology, reduce the difficulties in the recovery and refurbishment process, speed up tire refurbishment, while ensuring the quality of tire refurbishment.

6. CONCLUSION
The rapid development of information technology has accelerated the use of dual-channel supply chain and closed-loop supply chain in various industries, and through gradually reaching out to various enterprises, increasing the utilization rate of resources, reducing carbon emissions, optimizing the ecological environment, but also put forward more requirements for all aspects of enterprise production.

This paper takes automobile tire recycling as the research object, understands the specific application of the two-channel closed-loop supply chain, assists the government to take corresponding intervention measures, and analyzes the impact of subsidy and non-subsidy measures on manufacturers and retailers by studying the model with or without government intervention. Research shows that government intervention increases the profits of manufacturers and retailers, and appropriate government intervention will make businesses profitable. At present, due to the rapid economic development, manufacturers manufacture more and more products, the production of waste products are also more and more, not only will cause great waste of resources, but also will pose a threat to the ecological environment, therefore, enterprises can take a closed-loop supply chain model to recycle waste, on the one hand, can alleviate the pressure of the shortage of resources, but also for green sustainable development into a sustained power. For the government, in order to realize the green sustainable development of the national economy, we should strengthen the producer responsibility system, let the producer bear the responsibility of tire recycling, at the same time, the government can take some subsidy measures or introduce some policies to benefit enterprises to recycle waste products, improve the enthusiasm of enterprises to recycle waste products, and promote the sustainable and healthy development of the economy.
There are also some shortcomings in this study: (1) The premise of this study is that manufacturers and retailers conform to the Stackelberg game, that is, manufacturers are leaders, retailers are followers, but in reality, there may also be retailers as the lead, and manufacturers as the dominant situation, future research can continue to study in this regard; (2) Our research object is the recycling of automobile tires, but there are also a large number of other entities in the real economic activities, such as automobile recycling problems, so future research can expand the scope of research to study the recycling of waste products within a certain industry or an industrial chain; explore other factors that may affect business recycling in addition to government subsidies.

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