buildings

MDPI

Article

Considering Consumers' Green Preferences and Government Subsidies in the Decision Making of the Construction and Demolition Waste Recycling Supply Chain: A Stackelberg Game Approach

Yating Han †, Haoxuan Zheng †, Yicheng Huang and Xingwei Li *

College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu 611830, China; 201908440@stu.sicau.edu.cn (Y.H.); 201908323@stu.sicau.edu.cn (H.Z.); huangyicheng@stu.sicau.edu.cn (Y.H.)
* Correspondence: xwl@sicau.edu.cn
† These authors contributed equally to this work.

Abstract: Resource utilization of construction and demolition waste (CDW) is regarded to be an important means of achieving the sustainable development of the economy and the environment. However, previous research has not fully considered the green degree of products in the demand function of CDW remanufactured products. This study aimed to clarify how consumers' green preferences and government subsidies affect decision making in the supply chain. First, a CDW resource utilization supply chain model composed of building materials manufacturers and retailers was constructed using consumer behavior theory. Second, the optimal decision making of members under conditions of decentralized and centralized decision making was analyzed using the Stackelberg game solution. Finally, the validity of the model and conclusions were verified by numerical simulation. The main conclusions are as follows. Government subsidies have a different impact on the pricing of new building materials products and CDW remanufactured products. Under decentralized decision making, the optimal profit of the CDW resource utilization supply chain with government subsidies is higher. However, under centralized decision making, the optimal profit is also related to consumers' green preferences. According to consumers' green preferences, choosing different decision-making models can not only improve the total profit of the CDW resource utilization supply chain, but also improve the reuse rate of CDW.

Keywords: consumer green preference; government subsidies; closed-loop supply chain for construction and demolition waste (CDW); Stackelberg game; product green degree

Citation: Han, Y.; Zheng, H.; Huang, Y.; Li, X. Considering Consumers' Green Preferences and Government Subsidies in the Decision Making of the Construction and Demolition Waste Recycling Supply Chain: A Stackelberg Game Approach. *Buildings* **2022**, *12*, 832. https://doi.org/10.3390/buildings12060832

Academic Editor: Audrius Banaitis

Received: 13 May 2022
Accepted: 10 June 2022
Published: 15 June 2022

1. Introduction

As a result of the rapid development of the world economy and the rising living standards of the global population, urbanization and industrialization are accelerating. An increasing amount of construction and demolition waste (CDW) is generated in the demolition, retrofitting, and new construction of buildings and municipal infrastructure projects [1–4]. Statistics show that more than 10 billion tons of CDW are generated every year, of which about 700 million tons are generated in the United States [5], more than 800 million tons are generated in the European Union [6], and about 230 million tons are generated in China [7].

Engineering construction units, as CDW producers, often follow the principle of prioritizing interests, and will accumulate garbage and send it to landfills. If these wastes are not properly disposed of, they will wreak havoc on the environment, adversely affect arable land, and threaten people's physical and mental health. Therefore, determining how to balance economic development and environmental protection is particularly important, and the effective implementation of CDW management has become a priority action item for the global sustainable development goals [8].

In terms of technology, many materials in CDW can be reused as renewable resources after being sorted, shredded, or removed. For example, CDW can be used as an eco-friendly alternative in the production of eco-efficient cement [9]. In terms of management, construction materials are wasted due to a lack of basic technical and labor knowledge, poor material handling, poor material quality, and other reasons. This wastage can be prevented by strict and regular monitoring of workers, accurate estimation of material quantities, and proper storage [10]. In addition, the European Union, Japan, the United States, etc. have promulgated relevant laws and regulations, ordering manufacturers to be responsible for the entire life cycle of products, and requiring them to recycle and dispose of their products. In addition, an increasing number of enterprises have implemented closed-loop supply chain management [11].

Various issues related to CDW management have also attracted extensive attention from the academic community. The "3Rs" principle has long been proposed in Western countries, and studies have shown that "reducing, reusing, and recycling" of CDW is a hierarchical and well-planned planning strategy [12–14]. Several scholars have also reviewed methods that can quantify CDW generation [15,16]. These studies have promoted the development of CDW management and proposed new directions for subsequent topics. At present, in the research on the supply chain of CDW resource utilization, scholars often believe that consumer demand is only related to the product price, and the green degree of the product has not yet been considered. Based on this, the pricing of green new products and green remanufactured products has become a key decision for supply chain enterprises.

The continuous deterioration in the global ecological environment has awakened people's awareness of environmental protection. Due to the enhancement of consumers' awareness of environmental protection, environmentally friendly products are increasingly favored by consumers [17]. In order to better adapt to the needs of consumers, enterprises in the closed-loop supply chain have gradually shifted from the traditional extensive management model to the consumer-centered intensive management model. This intensive management model can meet the needs of green consumers and maximize corporate profits. However, most enterprises believe that, the greener the product, the better the product meets the needs of consumers, and the higher the profit they will receive. However, this will eventually result in the price of green products exceeding consumer expectations, causing manufacturers to use green materials to produce products that will not be able to be sold. This hurts profits of both manufacturers and retailers. In addition, because their product demand is affected by consumers' green preferences, manufacturers have to invest in the research and development of green products to improve their competitiveness [18,19]. However, the implementation of green technology innovation inevitably increases the production cost of enterprises; as a result, some enterprises may be reluctant to develop green technology [20]. Based on this, many scholars have conducted research and found that the government can adjust the subsidy rate and supervision probability, which can control the distribution mode of corporate profits, and thereby affect the decision-making behavior of stakeholders in the supply chain [21–23]. Therefore, major global economies have successively issued a series of laws, regulations, and subsidy policies in order to promote the green production of enterprises and achieve sustainable development. For example, the United States enacted the Solid Waste Disposal Act as early as 1965 [24], becoming the first country to legally determine waste utilization. In 2021, China proposed that, during the "14th Five-Year Plan" period, it will thoroughly implement relevant laws and regulations, vigorously promote waste reduction, resource utilization, and the harmless disposal of bulk solid waste, and promote the comprehensive utilization of the resources industry to achieve new development [25].

Based on the current problems faced by the construction industry, it is important to focus the impact of consumer green preferences and government subsidies on CDW resource utilization supply chain decisions for the development of recycling and remanufacturing. With the aim of solving problems, and by combining real, down-to-earth, and key breakthroughs [26], this study introduced the product's green degree into the consumer demand function, which complements the decision-making research on the CDW resource utilization supply chain. Moreover, the contributions and implications of this paper are as follows: (1) Considering the influence of consumers' green preferences on the pricing of CDW remanufactured products, this paper enriches the theoretical research on consumer behavior in the remanufacturing closed-loop supply chain. (2) At the same time, this paper provides effective management advice for enterprises and governments. In summary, this study focuses on answering the following three questions: First, how will government subsidies affect the behavioral decisions and profits of building materials manufacturers and retailers in the CDW resource utilization supply chain? Second, how will consumers' green preferences affect the behavioral decisions and profits of building materials manufacturers and retailers in the CDW resource utilization supply chain? Third, in order to make the CDW resource utilization supply chain more profitable, should decentralized or centralized decisions be chosen?

Based on consumer behavior theory, this study established a CDW resource utilization supply chain model that considers consumers' green preferences and government subsidies. This paper compares the decisions of building materials manufacturers and retailers under decentralized and centralized decision-making. At the same time, it provides effective management suggestions for enterprises and governments regarding the CDW resource utilization supply chain.

The remainder of this paper is structured as follows. Section 2 provides a relevant literature review; Section 3 presents the problem description and model assumptions; Section 4 considers consumers' green preferences, and presents the construction of four game models of decentralized and centralized decision making between building materials manufacturers and retailers, with or without government subsidies; Section 5 presents model analysis and discusses the impact of relevant parameters on the decision making of building materials manufacturers and retailers; Section 6 presents the numerical simulation, and intuitively obtains the change in the profit of the CDW resource utilization supply chain under different models; finally, Section 7 summarizes the conclusions of this paper.

2. Literature Review

This study aimed to solve the CDW management problem from the perspective of closed-loop supply chain operation, based on consumers' green preferences and government subsidies, to study the relevant decisions of the CDW resource utilization supply chain. Therefore, this paper reviews the relevant literature in terms of three aspects: the CDW closed-loop supply chain, consumer behavior theory, and the closed-loop supply chain under government subsidies, as shown in Table 1.

Table 1. Research related to construction and demolition waste, consumer behavior theory, and the supply chain under government subsidies.

Research Topics	Dimensions	Source Papers
CDW management	The vast majority of CDW can technically be converted into new building materials.	[27]
	The impact of CDW management stakeholders' behavior and economic incentives on CDW management	[28–30]
	Research on CDW management from the perspective of supply chain operation	[31]
	Decision-making behavior of recycling units and CDW remanufacturers under the evolutionary game	[32]
	The decision and profit of the CDW resource utilization supply chain under the Stackelberg model	[33–35]
Consumer behavior theory	On the new theory of consumer behavior	[36]
	Consumer green preferences improve green innovation	[37,38]
	Consumer environmental awareness and coordination in the closed-loop supply chain	[39]
	Dual-channel green supply chain pricing policy considering consumers' green preferences	[40]

Table 1. *Cont.*

Research Topics	Dimensions	Source Papers
Supply chain under government subsidies	The dominance of the government in recycling of CDW	[41]
	Government subsidies stimulate recycling of CDW	[42,43]
	Research on the supply chain of government subsidized green products	[44,45]
	Research on the supply chain of government subsidized remanufactured products	[46–48]
	Research on consumer preferences and government subsidies on decisions and profits of supply chain members	[49,50]

2.1. CDW Management

In order to alleviate the negative impact of CDW on the environment and promote the stable development of the CDW recycling industry, the scientific management and effective utilization of CDW has become the focus of extensive attention of experts and scholars. Regarding CDW recycling research, some scholars noted, from a technical point of view, that the vast majority of CDW can be converted into new building materials through proper recycling treatment, thereby contributing to the sustainability of the construction industry [27]. Using the technical feasibility of CDW recycling as a guarantee, some scholars have found from a management perspective that the attitudes and behaviors of CDW management stakeholders, and economic incentives, have a significant impact on CDW management [28–30]. To promote the better formation and operation of the CDW resource utilization supply chain, there is an urgent need to study CDW management from the perspective of supply chain operation, to clarify the decision-making process of stakeholders in the supply chain [31]. Therefore, some scholars have constructed evolutionary game models and found that business leaders, the government supervision rate, the government cost subsidy rate, and the recycling unit's effort profit coefficient will affect the decision-making behavior of recycling units and CDW remanufacturers [32]. Other scholars have found, by solving the Stackelberg model, that factors such as the learning effect, reference effect, information sharing, and fairness concerns, can affect the decision making and profit of the CDW resource utilization supply chain [33–35].

The above review proves that it is important to closely study CDW management by constructing a game model. The existing research mainly involves the different decision making of supply chain members, such as the government, construction waste recyclers, recyclers, and retailers, but has not fully considered the behavior of consumers in the supply chain. Based on this, from the perspective of consumer behavior, this study examined how consumers' green preferences and government subsidies affect the decisions of manufacturers and retailers in the CDW resource utilization supply chain. In addition, this study examined the decision making of the CDW resource utilization supply chain when both new products and remanufactured products have a green degree.

2.2. Consumer Behavior Theory

Consumer behavior theory shows that consumers' purchasing decisions are not only closely related to the product itself, but are also influenced by consumer preferences [36]. In reality, consumers' purchasing decision behavior is often affected by a variety of factors, and different consumers have different consumption preferences for various factors. Studies have found that, as a result of the increasingly serious problem of environmental pollution, consumers are more willing to buy low-carbon, energy-saving, and environmentally friendly products. This behavior will change the product attributes of producers, prompt manufacturers to enhance their green innovation capabilities to produce green products, and promote the development of green industries [37,38]. Therefore, the green preferences of consumers have attracted great attention from the government and enterprises. Some scholars believe that the profits of retailers and manufacturers in the supply chain are related to consumers' green preferences. For example, Xu et al. [39] found that the product environmental protection level, recycling rate, and corporate profits at each node were positively correlated with consumers' green preferences, but negatively correlated with the green investment coefficient. Abbey et al. [40] empirically found that green consumers, and consumers who perceived remanufactured products as green, generally found remanufactured products to be more attractive.

The above research results suggest that consumers' green preferences have an impact on the pricing decisions of stakeholders in the supply chain and the green degree of products. However, most studies on consumers' green preferences focus on green manufacturers and do not consider the impact on green remanufacturers' decision making. Moreover, consumer green preferences have not been considered in the CDW resource utilization supply chain. Therefore, further research on consumers' preferences for green products based on consumer behavior theory will play an important role in the development of CDW resource utilization supply chain.

2.3. Closed-Loop Supply Chain under Government Subsidies

The government, as a supervisor and regulator, plays a leading role in the process of recycling CDW [41]. Questionnaires have found that government subsidies can effectively stimulate the recycling of CDW [42,43]. In recent years, a large amount of research has examined closed-loop supply chain management under government subsidy policies.

First, research on subsidizing green products has shown that, when the government subsidizes the manufacturer, the increase in the government subsidy will improve the green degree of the product, but the government subsidy is not always beneficial to the green supply chain and the manufacturer [44]. In addition, scholars have studied how governments use consumer subsidies to promote the development of green technologies, and how policy adjustments interact with industrial production decisions over time [45].

Second, the research on subsidized remanufactured products generally shows that government subsidies effectively stimulate the demand for remanufactured products and promote the development of the remanufacturing industry [46,47]. For example, Huang [48] et al. studied the impact of government subsidies on channel members' pricing decisions and recycling mode choices, and found that government subsidies have a positive effect on remanufacturers' and collectors' willingness to remanufacture.

Aware of the importance of consumers' green preferences and government subsidies, some scholars have considered the impact of supply chain members' related decisions and profits under the combined effect of the two. For example, Barman et al. [49] explored pricing strategies, green strategies, and compared optimal decision making for both centralized and decentralized models. Yu et al. [50] found that the improvement in consumers' environmental awareness and good government subsidy policies will motivate manufacturers to produce more green products and generate profits for manufacturers. However, whether these conclusions can be obtained in the construction waste resource utilization supply chain remains to be confirmed.

To summarize, there are still some deficiencies in the research on the supply chain of CDW resource utilization. First, few scholars have integrated the product's green degree into the closed-loop supply chain of CDW. Second, no scholars have considered both government subsidies and consumer green preferences in the construction waste resource utilization supply chain. In view of this, in this study, Stackelberg game theory was used to solve for and compare the optimal pricing and revenue of building materials manufacturers and retailers under decentralized and centralized decision making, taking the product green degree, consumers' green preferences, government subsidies, and other factors into consideration.

3. Problem Description and Associated Assumptions

Consider a closed-loop supply chain model consisting of building materials manufacturers, retailers, and consumers. Among these, building material manufacturers are responsible for the production of new products and recycling construction waste from consumers, and then remanufacturing the recovered construction waste as raw materials.

The retailer is responsible for selling new and remanufactured products to consumers at different prices, and does not take part in the recycling of the products during the process. The government can choose whether to subsidize CDW remanufactured products. The manufacturer's decision problem is to determine the product green degree and wholesale price of the product to maximize its own profit, and the retailer's decision problem is to determine the retail price of green products to maximize its own benefit. The formed game model is shown in Figure 1.

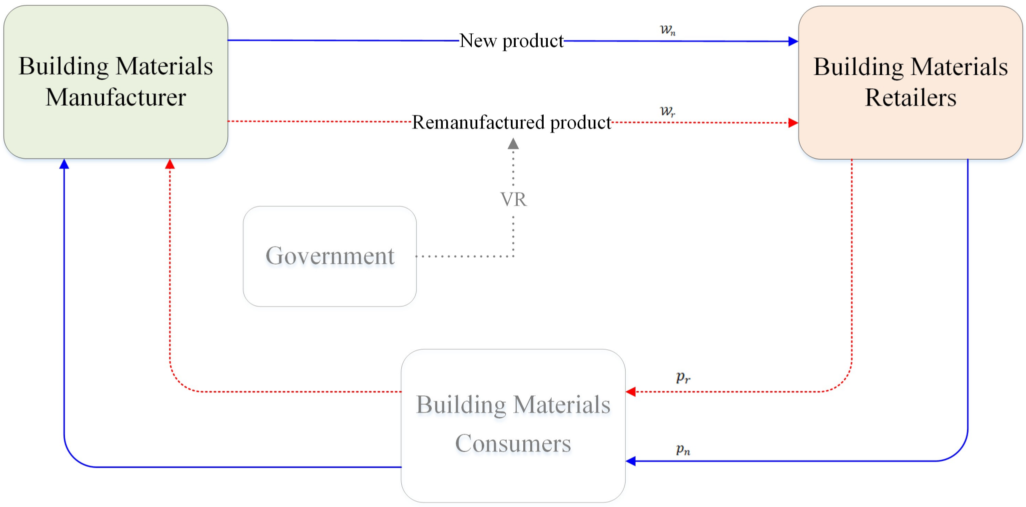

Figure 1. Game model of building materials manufacturer and building materials retailers. Note: VR is the government subsidy for remanufacturing; w_n is the wholesale prices for new products of building materials; w_r is the wholesale price for CDW remanufactured products; p_n is the retail price of new products of building materials; p_r is the retail price of CDW remanufactured products.

The basic definitions of the parameters used in the study are shown in Table 2.

Table 2. Model parameters.

Parameter	Definition
γ	Consumer green preference coefficient. $0 \leq \gamma \leq 1$
v	Unit price subsidy granted by the government for CDW remanufactured products. $v \geq 0$
G	Recycling of CDW.
h	Number of consumers with active recycling awareness. $h > 0$
k	Sensitivity of consumer recycling attitudes to b changes. $k > 0$
η	Research and development effort coefficient of building materials manufacturers. $\eta > 0$
b	Unit CDW recycling costs.
c_n	Manufacturing costs of new products of building materials.
c_r	Manufacturing costs of CDW remanufactured products.
δ	Discount rate of value of remanufactured products relative to new products. $(0 < \delta < 1)$
q_n	Demand for new products of building materials. $q_n \geq 0$
q_r	Demand for CDW remanufactured products. $q_r \geq 0$
Π_X^Y	The profit of X under the Y model. $X = m, r$ represent building materials manufacturers and retailers, respectively; Y = N, VR represent CDW remanufacturing, without and with government subsidies, respectively.
p_n	Retail price of new products of building materials (decision variables).
p_r	Retail price of CDW remanufactured products (decision variables).

Table 2. *Cont.*

Parameter	Definition
$\mathcal{W}_n$	Wholesale price of new products of building materials (decision variables).
$\mathcal{W}_r$	Wholesale price of CDW remanufactured products (decision variables).
g	Product green degree (decision variables).

3.1. Model Assumptions

(1) Manufacturers of building materials produce two products: new products of building materials and remanufactured products of CDW. The unit production cost of new products is c_n, the unit production cost of CDW remanufactured products is c_r, the unit cost of recycling CDW is b, and $c_n > c_r + b > 0$.

(2) Due to the different raw materials used for production, the two products are substitutes for each other and there are differences in quality, which is in line with reality. A retailer of building materials wholesales new products from manufacturers at a unit price $\mathcal{W}_n$ and sells them to consumers at a unit price p_n, and wholesales remanufactured products at a unit price $\mathcal{W}_r$, and sells the remanufactured products at a unit price p_r to consumers. It follows that $\mathcal{W}_n > \mathcal{W}_r > 0$, $p_n > p_r > 0$, and $p_n > \mathcal{W}_n > 0$, $P_r > \mathcal{W}_r > 0$.

(3) In order to stimulate consumer purchases, building materials manufacturers need to invest in green product research and development by purchasing new equipment or technological innovation. It is assumed that there is a quadratic function between the manufacturer's green product development cost and product green degree (g) [51,52]; that is, $\frac{1}{2}\eta g^2$ [53], where $\eta > 0$ is the green product development cost coefficient.

(4) The recycling quantity of CDW is a linearly increasing function of recycling price, namely, $G = h + kb$, where h represents the number of consumers with active recycling awareness in the supply chain, k represents the sensitivity of consumers' recycling attitude to changes in b, and $k > 0, h > 0$ [54,55].

(5) There is a Stackelberg game relationship between building materials manufacturers and retailers, in which the manufacturer is the game leader and the retailer is the game follower. Both the manufacturer and the retailer are risk neutral and information symmetric.

3.2. Demand Function

Referring to the research in [56], it is assumed that market demand is only affected by the product value and green degree. Consumers compare and analyze the utility of the two products to decide which product to buy. a is the value of the new product of building materials considered by consumers, and a obeys a uniform distribution in the interval [0,1]. δa is the value of products remanufactured from construction waste that consumers consider, and δ is the discount rate of remanufactured products relative to new products $(0 < \delta < 1)$. The market demand for green products is negatively correlated with the price, and positively correlated with the green degree of the product. It can be found that the effect functions of consumers on green new products and green remanufactured products are $U_n = a - p_n + \gamma g$ and $U_r = \delta a - p_r + \gamma g$, respectively, where γ represents the green preference coefficient of consumers, and g represents the product green degree.

When $U_n > max\{U_r, 0\}$, that is $\frac{p_n - p_r}{1-\delta} < a < 1$, the demand function of new products of building materials is shown in Equation (1):

$$q_n = \int_{\frac{p_n - p_r}{1-\delta}}^{1} da = 1 - \frac{p_n - p_r}{1 - \delta} \quad (1)$$

Similarly, when $U_r > max\{U_n, 0\}$, that is $\frac{p_r-\gamma g}{\delta} < a < \frac{p_n-p_r}{1-\delta}$, the demand function for CDW remanufactured products is shown in Equation (2):

$$q_r = \int_{\frac{p_r-\gamma g}{\delta}}^{\frac{p_n-p_r}{1-\delta}} da = \frac{p_n - p_r}{1-\delta} - \frac{p_r - \gamma g}{\delta} = \frac{\delta p_n - p_r + \gamma g(1-\delta)}{(1-\delta)\delta} \quad (2)$$

4. Model Building and Solving

4.1. Without Government Subsidies

4.1.1. Decentralized Decision Model (N Model)

Under the decentralized decision-making model (N model), the closed-loop supply chain Stackelberg model composed of building materials manufacturers and retailers is a master–slave game model, in which the manufacturer is the leader and the retailer is the follower. Manufacturers and retailers are independent of each other, and their decision-making goal is to maximize their own profits. The manufacturer first decides the wholesale price of new and remanufactured products ($\mathcal{W}_n$, $\mathcal{W}_r$) and the green degree of the product (g), and then the retailer decides the retail price of new and remanufactured products (p_n, p_r) based on the manufacturer's decision.

Profit function for building materials manufacturers:

$$\max_{(\mathcal{W}_n,\ \mathcal{W}_r)} \Pi_m^N = (\mathcal{W}_n - c_n)q_n + (\mathcal{W}_r - c_r)q_r + (\mu - b)G - \frac{1}{2}\eta g^2 \quad (3)$$

Profit function for building materials retailer:

$$\max_{(p_n, p_r)} \Pi_r^N = (p_n - \mathcal{W}_n)q_n + (p_r - \mathcal{W}_r)q_r \quad (4)$$

Since Π_r^N is a concave function about p_n and p_r, we can obtain:

$$p_n^{N*}(\mathcal{W}_n, \mathcal{W}_r, g) = \frac{1}{2}(1 + g\gamma + \mathcal{W}_n) \quad (5)$$

$$p_r^{N*}(\mathcal{W}_n, \mathcal{W}_r, g) = \frac{1}{2}(g\gamma + \delta + \mathcal{W}_r) \quad (6)$$

We can substitute $p_n^{N*}(\mathcal{W}_n, \mathcal{W}_r, g)$, $p_r^{N*}(\mathcal{W}_n, \mathcal{W}_r, g)$ into the manufacturer's profit function Π_m^N, and find the first-order and second-order derivatives of $\mathcal{W}_n, \mathcal{W}_r$, and g respectively, so as to obtain the Hessian matrix of the manufacturer's profit Π_m^N with respect to $\mathcal{W}_n$, $\mathcal{W}_r$, and g.

$$H = \begin{bmatrix} -\frac{1}{1-\delta} & \frac{1}{1-\delta} & 0 \\ \frac{1}{1-\delta} & -\frac{1}{(1-\delta)\delta} & \frac{\gamma}{2\delta} \\ 0 & \frac{\gamma}{2\delta} & -\eta \end{bmatrix} = \frac{\gamma^2 - 4\delta\eta}{4(1-\delta)\delta^2}$$

Lemma 1. *When $\gamma^2 - 4\delta\eta < 0$, there is $(\mathcal{W}_n, \mathcal{W}_r, g)$ such that Π_m^N achieves the maximum value.*

Prove: The first-order sequential principal subform of the Hessian matrix H is $-\frac{1}{1-\delta} < 0$, the second-order sequence main subform is $\begin{bmatrix} -\frac{1}{1-\delta} & \frac{1}{1-\delta} \\ \frac{1}{1-\delta} & -\frac{1}{(1-\delta)\delta} \end{bmatrix} = \frac{1}{(1-\delta)\delta} > 0$, and the main subform of the third-order sequence is $H = \frac{\gamma^2-4\delta\eta}{4(1-\delta)\delta^2}$; hence, when $\gamma^2 - 4\delta\eta < 0$, the third-order sequential main subform $H < 0$. Therefore, the Hessian matrix H is a negative definite matrix, that is, there is $(\mathcal{W}_n, \mathcal{W}_r, g)$ so that Π_m^N takes the maximum value.

When the condition $\gamma^2 - 4\delta\eta < 0$ is satisfied, Π_m^N is a concave function about $\mathcal{W}_n$, $\mathcal{W}_r$, and g, so the optimal decision of the manufacturer can be obtained:

$$\mathcal{W}_n^{N*} = \frac{\gamma^2 - \gamma^2\delta - 4\delta\eta + (\gamma^2 - 4\delta\eta)c_n + \gamma^2 c_r}{2(\gamma^2 - 4\delta\eta)} \tag{7}$$

$$\mathcal{W}_r^{N*} = \frac{-2\delta^2\eta + (\gamma^2 - 2\delta\eta)c_r}{\gamma^2 - 4\delta\eta} \tag{8}$$

$$g^{N*} = \frac{\gamma(-\delta + c_r)}{\gamma^2 - 4\delta\eta} \tag{9}$$

By substituting $\mathcal{W}_n^{N*}$, $\mathcal{W}_r^{N*}$, g^{N*} into $p_n^{N*}(\mathcal{W}_n, \mathcal{W}_r, g)$, $p_r^{N*}(\mathcal{W}_n, \mathcal{W}_r, g)$, the optimal decision of the retailer can be obtained as:

$$p_n^{N*} = \frac{1}{4}(c_n + \frac{3(\gamma^2 - \gamma^2\delta - 4\delta\eta + \gamma^2 c_r)}{\gamma^2 - 4\delta\eta}) \tag{10}$$

$$p_r^{N*} = \frac{-3\delta^2\eta + (\gamma^2 - \delta\eta)c_r}{\gamma^2 - 4\delta\eta} \tag{11}$$

By substituting the optimal pricing into Equations (3) and (4), Π_m^{N*} and Π_r^{N*} can be obtained, respectively, as shown in Equations (12) and (13):

$$\prod_m^{N*} = \frac{\left\{ \begin{array}{c} (-1+\delta)\left(4\delta\eta(1 - 8bh - 8b^2k + 8h\mu + 8bk\mu) + \gamma^2\left(-1+8b^2k + \delta - 8h\mu + 8b(h - k\mu)\right)\right) \\ +(\gamma^2 - 4\delta\eta)c_n^2 + 2(\gamma^2 - 4\delta\eta)c_n(-1 + \delta - c_r) - 2\gamma^2(-1+\delta)c_r + (\gamma^2 - 4\eta)c_r^2 \end{array} \right\}}{8(-1+\delta)(-\gamma^2 + 4\delta\eta)} \tag{12}$$

$$\prod_r^{N*} = -\frac{\left\{ \begin{array}{c} -((-1+\delta)(-\gamma^4(-1+\delta) + 8\gamma^2(-1+\delta)\delta\eta + 16\delta^2\eta^2)) + (\gamma^2 - 4\delta\eta)^2 c_n^2 + 2(\gamma^2 - 4\delta\eta)^2 \\ c_n(-1 + \delta - c_r) - 2\gamma^2(-1+\delta)(\gamma^2 - 8\delta\eta)c_r + (\gamma^4 - 8\gamma^2\delta\eta + 16\delta\eta^2)c_r^2 \end{array} \right\}}{16(-1+\delta)(\gamma^2 - 4\delta\eta)^2} \tag{13}$$

At this time, the optimal total profit function of the entire CDW resource utilization supply chain is shown in Equation (14):

$$\prod^{DN*} = -\frac{\left\{ \left(\begin{array}{c} -\left((-1+\delta)\left(\begin{array}{c} -\gamma^4(-1+\delta) + 8\gamma^2 \\ (-1+\delta)\delta\eta + 16\delta^2\eta^2 \end{array}\right)\right) + (\gamma^2 - 4\delta\eta)^2 c_n^2 + 2(\gamma^2 - 4\delta\eta)^2 c_n(-1+\delta-c_r) - 2\gamma^2(-1+\delta)(\gamma^2 - 8\delta\eta)c_r + (\gamma^4 - 8\gamma^2\delta\eta + 16\delta\eta^2)c_r^2 + \\ 2(\gamma^2 - 4\delta\eta)\left((-1+\delta)\left(\begin{array}{c} 4\delta\eta(1 - 8bh - 8b^2k + 8h\mu + 8\mathrm{bk}\mu) + \\ \gamma^2(-1 + 8b^2k + \delta - 8h\mu + 8b(h - k\mu)) \end{array}\right) + (\gamma^2 - 4\delta\eta)c_n^2 + 2(\gamma^2 - 4\delta\eta)c_n(-1+\delta-c_r) - 2\gamma^2(-1+\delta)c_r + (\gamma^2 - 4\eta)c_r^2\right) \end{array} \right) \right\}}{16(-1+\delta)(\gamma^2 - 4\delta\eta)^2} \tag{14}$$

4.1.2. Centralized Decision Model

In the centralized decision-making model (N model), building material manufacturers and retailers make joint decisions as a whole, and the goal of decision making is to maximize profits throughout the supply chain. At this point, the total profit function of the supply chain is shown in Equation (15):

$$\max_{(\mathcal{W}_n,\ \mathcal{W}_r)} \Pi^N = (\mathcal{W}_n - c_n)q_n + (\mathcal{W}_r - c_r)q_r + (\mu - b)G - \frac{1}{2}\eta g^2 \tag{15}$$

Among these variables, p_n, p_r, and g are decision variables. Let $\frac{\partial \Pi^N}{\partial p_n} = 0$, $\frac{\partial \Pi^N}{\partial p_r} = 0$, $\frac{\partial \Pi^N}{\partial g} = 0$ to find the maximum values of p_n, p_r, and g, respectively.

$$p_n^* = \frac{\gamma^2 - \gamma^2\delta - 2\delta\eta + (\gamma^2 - 2\delta\eta)c_n + \gamma^2 c_r}{2(\gamma^2 - 2\delta\eta)} \tag{16}$$

$$p_r^* = \frac{-\delta^2\eta + (\gamma^2 - \delta\eta)c_r}{\gamma^2 - 2\delta\eta} \quad (17)$$

$$g^* = \frac{\gamma(-\delta + c_r)}{\gamma^2 - 2\delta\eta} \quad (18)$$

Bringing p_n^*, p_r^*, and g^* into Equation (15), the optimal profit function of the entire supply chain can be obtained as shown in Equation (19):

$$\prod^{N*} = \frac{\left\{ \begin{array}{l} (-1+\delta)\left(2\delta\eta(1 - 4bh - 4b^2k + 4h\mu + 4bk\mu) + \gamma^2\left(-1+4b^2k + \delta - 4h\mu + 4b(h - k\mu)\right)\right) \\ +(\gamma^2 - 2\delta\eta)c_n^2 + 2(\gamma^2 - 2\delta\eta)c_n(-1 + \delta - c_r) - 2\gamma^2(-1+\delta)c_r + (\gamma^2 - 2\eta)c_r^2 \end{array} \right\}}{4(-1+\delta)(-\gamma^2 + 2\delta\eta)} \quad (19)$$

4.2. With Government Subsidies

4.2.1. Decentralized Decision Model (VR Model)

Under the decentralized decision-making model (VR model), the closed-loop supply chain Stackelberg model composed of building material manufacturers and retailers is a master–slave game model, in which the manufacturer is the leader and the retailer is the follower. Manufacturers and retailers are independent of each other, and their decision-making goal is to maximize their own profits. In order to increase the enthusiasm of manufacturers to produce CDW remanufactured products, the government provides remanufacturing subsidies to manufacturers.

Profit function for building materials manufacturers:

$$\max_{(\mathcal{W}_n,\ \mathcal{W}_r)} \Pi_m^{VR} = (\mathcal{W}_n - c_n)q_n + (\mathcal{W}_r - c_r + v)q_r + (\mu - b)G - \frac{1}{2}\eta g^2 \quad (20)$$

Profit function for building materials retailer:

$$\max_{(p_n, p_r)} \Pi_r^{VR} = (p_n - \mathcal{W}_n)q_n + (p_r - \mathcal{W}_r)q_r \quad (21)$$

Since Π_r^{VR} is a concave function about p_n and p_r, we can obtain:

$$p_n^{VR*}(\mathcal{W}_n, \mathcal{W}_r, g) = \frac{1}{2}(1 + g\gamma + \mathcal{W}_n) \quad (22)$$

$$p_r^{VR*}(\mathcal{W}_n, \mathcal{W}_r, g) = \frac{1}{2}(g\gamma + \delta + \mathcal{W}_r) \quad (23)$$

We can substitute $p_n^{VR*}(\mathcal{W}_n, \mathcal{W}_r, g)$, $p_r^{VR*}(\mathcal{W}_n, \mathcal{W}_r, g)$ into the manufacturer's profit function Π_m^{VR}, and find the first-order and second-order derivatives of $\mathcal{W}_n$, $\mathcal{W}_r$, and g, respectively, so as to obtain the Hessian matrix of the manufacturer's profit Π_m^{VR} with respect to $\mathcal{W}_n$, $\mathcal{W}_r$, and g.

$$H = \begin{bmatrix} -\frac{1}{1-\delta} & \frac{1}{1-\delta} & 0 \\ \frac{1}{1-\delta} & -\frac{1}{(1-\delta)\delta} & \frac{\gamma}{2\delta} \\ 0 & \frac{\gamma}{2\delta} & -\eta \end{bmatrix} = \frac{\gamma^2 - 4\delta\eta}{4(1-\delta)\delta^2}$$

As in Lemma 1, when the condition $\gamma^2 - 4\delta\eta < 0$ is satisfied, Π_m^{VR} is a concave function about $\mathcal{W}_n$, $\mathcal{W}_r$, and g, so the optimal decision of the manufacturer can be obtained:

$$\mathcal{W}_n^{VR*} = \frac{\gamma^2 - v\gamma^2 - \gamma^2\delta - 4\delta\eta + (\gamma^2 - 4\delta\eta)c_n + \gamma^2 c_r}{2(\gamma^2 - 4\delta\eta)} \quad (24)$$

$$\mathcal{W}_r^{VR*} = \frac{-v\gamma^2 + 2v\delta\eta - 2\delta^2\eta + (\gamma^2 - 2\delta\eta)c_r}{\gamma^2 - 4\delta\eta} \quad (25)$$

$$g^{VR*} = -\frac{\gamma(v+\delta-c_r)}{\gamma^2-4\delta\eta} \tag{26}$$

Substituting $\mathcal{W}_n^{VR*}$, $\mathcal{W}_r^{VR*}$, and g^{VR*} into $p_n^{VR*}(\mathcal{W}_n,\mathcal{W}_r,g)$, $p_r^{VR*}(\mathcal{W}_n,\mathcal{W}_r,g)$, the optimal decision of the retailer can be obtained as:

$$p_n^{VR*} = \frac{-3\gamma^2(-1+v+\delta)-12\delta\eta+\left(\gamma^2-4\delta\eta\right)c_n+3\gamma^2 c_r}{4\left(\gamma^2-4\delta\eta\right)} \tag{27}$$

$$p_r^{VR*} = \frac{-v\gamma^2+v\delta\eta-3\delta^2\eta+\left(\gamma^2-\delta\eta\right)c_r}{\gamma^2-4\delta\eta} \tag{28}$$

By substituting the optimal pricing into Equations (20) and (21), Π_m^{VR*} and Π_r^{VR*} can be obtained, respectively, as shown in Equations (29) and (30):

$$\prod\nolimits_m^{VR*} = \frac{\left\{\begin{array}{l} \gamma^2-8bh\gamma^2-8b^2k\gamma^2-2v\gamma^2+v^2\gamma^2-2\gamma^2\delta+8bh\gamma^2\delta+8b^2k\gamma^2\delta+2v\gamma^2\delta+\gamma^2\delta^2-4v^2\eta-4\delta\eta+32bh\delta\eta+32b^2k\delta\eta \\ +4\delta^2\eta-32bh\delta^2\eta-32b^2k\delta^2\eta+8h\gamma^2\mu+8bk\gamma^2\mu-8h\gamma^2\delta\mu-8bk\gamma^2\delta\mu-32h\delta\eta\mu-32bk\delta\eta\mu+32h\delta^2\eta\mu+ \\ 32bk\delta^2\eta\mu+\left(\gamma^2-4\delta\eta\right)c_n^2+2\left(\gamma^2-4\delta\eta\right)c_n(-1+v+\delta-c_r)-2\left(\gamma^2(-1+v+\delta)-4v\eta\right)c_r+\left(\gamma^2-4\eta\right)c_r^2 \end{array}\right\}}{8(-1+\delta)\left(-\gamma^2+4\delta\eta\right)} \tag{29}$$

$$\prod\nolimits_r^{VR*} = -\frac{\left\{\begin{array}{l} \gamma^4-2v\gamma^4+v^2\gamma^4-2\gamma^4\delta+2v\gamma^4\delta+\gamma^4\delta^2-8\gamma^2\delta\eta+16v\gamma^2\delta\eta-8v^2\gamma^2\delta\eta+16\gamma^2\delta^2\eta-16v\gamma^2\delta^2\eta \\ -8\gamma^2\delta^3\eta+16v^2\delta\eta^2+16\delta^2\eta^2-16\delta^3\eta^2+\left(\gamma^2-4\delta\eta\right)^2c_n^2+2\left(\gamma^2-4\delta\eta\right)^2c_n(-1+v+\delta-c_r) \\ -2\left(\gamma^4(-1+v+\delta)-8\gamma^2\delta(-1+v+\delta)\eta+16v\delta\eta^2\right)c_r+\left(\gamma^4-8\gamma^2\delta\eta+16\delta\eta^2\right)c_r^2 \end{array}\right\}}{16(-1+\delta)\left(\gamma^2-4\delta\eta\right)^2} \tag{30}$$

At this time, the optimal total profit function of the entire CDW resource utilization supply chain is shown in Equation (31):

$$\prod\nolimits^{DVR*} = -\frac{\left\{\left(\begin{array}{l} \gamma^4-2v\gamma^4+v^2\gamma^4-2\gamma^4\delta+2v\gamma^4\delta+\gamma^4\delta^2-8\gamma^2\delta\eta+16v\gamma^2\delta\eta-8v^2\gamma^2\delta\eta+16\gamma^2\delta^2\eta-16v\gamma^2\delta^2\eta-8\gamma^2\delta^3\eta+16v^2\delta\eta^2+16\delta^2\eta^2- \\ 16\delta^3\eta^2+\left(\gamma^2-4\delta\eta\right)^2c_n^2+2\left(\gamma^2-4\delta\eta\right)^2c_n(-1+v+\delta-c_r)-2\left(\begin{array}{c}\gamma^4(-1+v+\delta)-8\gamma^2\delta \\ (-1+v+\delta)\eta+16v\delta\eta^2\end{array}\right)c_r+\left(\gamma^4-8\gamma^2\delta\eta+16\delta\eta^2\right)c_r^2+2\left(\gamma^2-4\delta\eta\right) \\ \left(\begin{array}{c} \gamma^2-8bh\gamma^2-8b^2k\gamma^2-2v\gamma^2+v^2\gamma^2-2\gamma^2\delta+8bh\gamma^2\delta+8b^2k\gamma^2\delta+2v\gamma^2\delta+\gamma^2\delta^2-4v^2\eta-4\delta\eta+32bh\delta\eta+32b^2k\delta\eta+ \\ 4\delta^2\eta-32bh\delta^2\eta-32b^2k\delta^2\eta+8h\gamma^2\mu+8bk\gamma^2\mu-8h\gamma^2\delta\mu-8bk\gamma^2\delta\mu-32h\delta\eta\mu-32bk\delta\eta\mu+32h\delta^2\eta\mu+32bk\delta^2\eta\mu+ \\ \left(\gamma^2-4\delta\eta\right)c_n^2+2\left(\gamma^2-4\delta\eta\right)c_n(-1+v+\delta-c_r)-2\left(\gamma^2(-1+v+\delta)-4v\eta\right)c_r+\left(\gamma^2-4\eta\right)c_r^2 \end{array}\right) \end{array}\right)\right\}}{16(-1+\delta)\left(\gamma^2-4\delta\eta\right)^2} \tag{31}$$

4.2.2. Centralized Decision Model

In the centralized decision-making model (VR model), the government subsidizes remanufacturing. Building materials manufacturers and retailers make joint decisions as a whole, with the goal of maximizing profits throughout the supply chain. At this point, the total profit function of the supply chain is shown in Equation (32):

$$max\Pi^{VR} = (p_n-c_n)q_n+(p_r-c_r+v)q_r+(\mu-b)G-\frac{1}{2}\eta g^2 \tag{32}$$

Among these variables, p_n, p_r, and g are decision variables. Let $\frac{\partial\Pi^{VR}}{\partial p_n}=0$, $\frac{\partial\Pi^{VR}}{\partial p_r}=0$, $\frac{\partial\Pi^{VR}}{\partial g}=0$ to find the maximum values of p_n, p_r, and g, respectively.

$$p_n^{**} = \frac{\gamma^2-v\gamma^2-\gamma^2\delta-2\delta\eta+\left(\gamma^2-2\delta\eta\right)c_n+\gamma^2 c_r}{2\left(\gamma^2-2\delta\eta\right)} \tag{33}$$

$$p_r^{**} = \frac{-v\gamma^2+v\delta\eta-\delta^2\eta+\left(\gamma^2-\delta\eta\right)c_r}{\gamma^2-2\delta\eta} \tag{34}$$

$$g^{**} = -\frac{\gamma(v + \delta - c_r)}{\gamma^2 - 2\delta\eta} \tag{35}$$

Bringing p_n^{**}, p_r^{**}, and g^{**} into Equation (32), the optimal profit function of the entire supply chain can be obtained as shown in Equation (36):

$$\prod^{VR*} = \frac{\left\{\begin{array}{l} \gamma^2 - 4bh\gamma^2 - 4b^2k\gamma^2 - 2v\gamma^2 + v^2\gamma^2 - 2\gamma^2\delta + 4bh\gamma^2\delta + 4b^2k\gamma^2\delta + 2v\gamma^2\delta + \gamma^2\delta^2 - 2v^2\eta - 2\delta\eta + 8bh\delta\eta + 8b^2k\delta\eta \\ +2\delta^2\eta - 8bh\delta^2\eta - 8b^2k\delta^2\eta + 4h\gamma^2\mu + 4bk\gamma^2\mu - 4h\gamma^2\delta\mu - 4bk\gamma^2\delta\mu - 8h\delta\eta\mu - 8bk\delta\eta\mu + 8h\delta^2\eta\mu + \\ 8bk\delta^2\eta\mu + (\gamma^2 - 2\delta\eta)c_n^2 + 2(\gamma^2 - 2\delta\eta)c_n(-1 + v + \delta - c_r) - 2(\gamma^2(-1 + v + \delta) - 2v\eta)c_r + (\gamma^2 - 2\eta)c_r^2 \end{array}\right\}}{4(-1 + \delta)(-\gamma^2 + 2\delta\eta)} \tag{36}$$

5. Model Analysis

In this section, the following main conclusions were drawn by comparing the optimal solutions of the decentralized decision-making model under two different scenarios with and without government subsidies.

Proposition 1. *Wholesale prices for new and remanufactured products are related as follows:*

(1) $\mathcal{W}_n^{VR*} > \mathcal{W}_n^{N*}$.

(2) *When* $1 > \gamma > \sqrt{2\delta\eta}$, *that is,* $\mathcal{W}_r^{VR*} > \mathcal{W}_r^{N*}$;
When $0 < \gamma < \sqrt{2\delta\eta}$, *that is,* $\mathcal{W}_r^{VR*} < \mathcal{W}_r^{N*}$.

Proof. By comparing the solutions of the two decentralized models, i.e., with and without government subsidies, we obtain:

(1) $\mathcal{W}_n^{VR*} - \mathcal{W}_n^{N*} = \frac{\gamma^2 - v\gamma^2 - \gamma^2\delta - 4\delta\eta + (\gamma^2 - 4\delta\eta)c_n + \gamma^2 c_r}{2(\gamma^2 - 4\delta\eta)} - \frac{\gamma^2 - \gamma^2\delta - 4\delta\eta + (\gamma^2 - 4\delta\eta)c_n + \gamma^2 c_r}{2(\gamma^2 - 4\delta\eta)} = -\frac{v\gamma^2}{2\gamma^2 - 8\delta\eta} > 0$, *that is,* $\mathcal{W}_n^{VR*} > \mathcal{W}_n^{N*}$.

(2) $\mathcal{W}_r^{VR*} - \mathcal{W}_r^{N*} = \frac{-v\gamma^2 + 2v\delta\eta - 2\delta^2\eta + (\gamma^2 - 2\delta\eta)c_r}{\gamma^2 - 4\delta\eta} - \frac{-2\delta^2\eta + (\gamma^2 - 2\delta\eta)c_r}{\gamma^2 - 4\delta\eta} = -\frac{v(\gamma^2 - 2\delta\eta)}{\gamma^2 - 4\delta\eta}$. According to Lemma 1, $\gamma^2 - 4\delta\eta < 0$, $v > 0$; thus, when $1 > \gamma > \sqrt{2\delta\eta}$, $\mathcal{W}_r^{VR*} > \mathcal{W}_r^{N*}$; when $0 < \gamma < \sqrt{2\delta\eta}$, $\mathcal{W}_r^{VR*} < \mathcal{W}_r^{N*}$. □

Proposition 1 shows that the wholesale price of a new product with government subsidies is higher than the price without government subsidies; that is, government subsidies will cause manufacturers to increase the wholesale price of new products, and, the greater the government subsidies, the higher the wholesale price of new products. When consumers' green preferences are greater than $\sqrt{2\delta\eta}$, the wholesale price of remanufactured products with government subsidies is higher than that without government subsidies. Conversely, when consumers' green preferences are less than $\sqrt{2\delta\eta}$, the wholesale price of remanufactured products with government subsidies is lower than that without government subsidies. This suggests that, when consumers' green preferences are smaller, building material manufacturers sell more CDW remanufactured products by lowering wholesale prices in order to realize their own gain. When consumers' green preferences are greater, building material manufacturers will increase the wholesale price of remanufactured products in order to seek greater benefits.

Proposition 2. *The retail prices of new and remanufactured products are related as follows*:

(1) $p_n^{VR*} > p_n^{N*}$.

(2) *When* $1 > \gamma > \sqrt{\delta\eta}$, *that is,* $p_r^{VR*} > p_r^{N*}$;
When $0 < \gamma < \sqrt{\delta\eta}$, *that is,* $p_r^{VR*} < p_r^{N*}$.

Proof. By comparing the solutions of the two decentralized models, i.e., with and without government subsidies, we obtain:

(1) $p_n^{VR*} - p_n^{N*} = \frac{-3\gamma^2(-1+v+\delta)-12\delta\eta+(\gamma^2-4\delta\eta)c_n+3\gamma^2 c_r}{4(\gamma^2-4\delta\eta)} - \frac{1}{4}\left(c_n + \frac{3(\gamma^2-\gamma^2\delta-4\delta\eta+\gamma^2 c_r)}{\gamma^2-4\delta\eta}\right) = -\frac{3v\gamma^2}{4(\gamma^2-4\delta\eta)} > 0$, that is, $p_n^{VR*} > p_n^{N*}$.

(2) $p_r^{VR*} - p_r^{N*} = \frac{-v\gamma^2+v\delta\eta-3\delta^2\eta+(\gamma^2-\delta\eta)c_r}{\gamma^2-4\delta\eta} - \frac{-3\delta^2\eta+(\gamma^2-\delta\eta)c_r}{\gamma^2-4\delta\eta} = \frac{v(-\gamma^2+\delta\eta)}{\gamma^2-4\delta\eta}$. According to Lemma 1, $\gamma^2 - 4\delta\eta < 0$, $v > 0$; thus, when $1 > \gamma > \sqrt{\delta\eta}$, $p_r^{VR*} > p_r^{N*}$; when $0 < \gamma < \sqrt{\delta\eta}$, $p_r^{VR*} < p_r^{N*}$. □

Proposition 2 shows that the retail price of new products with government subsidies is higher than that without government subsidies; that is, government subsidies will lead retailers to increase the retail prices of new products, and, the greater the government subsidies, the higher the retail prices of new products. This shows that retailers resist the increase in wholesale prices of manufacturers by adjusting the retail price of new products. When consumers' green preferences are greater than $\sqrt{\delta\eta}$, the retail price of CDW remanufactured products with government subsidies is higher than that without government subsidies. Conversely, when consumers' green preferences are less than $\sqrt{\delta\eta}$, the retail price of CDW remanufactured products with government subsidies is lower than that without government subsidies. This suggests that, when consumers' green preferences are smaller, retailers sell more CDW remanufactured products by lowering retail prices in order to realize their own interests. When consumers' green preferences are greater, retailers will increase the retail price of CDW remanufactured products in order to seek greater benefits.

Proposition 3. *The relationship between the product green degree of new products and remanufactured products is*: $g^{VR*} > g^{N*}$.

Proof. By comparing the solutions of the two decentralized models, i.e., with and without government subsidies, we obtain:

$g^{VR*} - g^{N*} = -\frac{\gamma(v+\delta-c_r)}{\gamma^2-4\delta\eta} - \frac{\gamma(-\delta+c_r)}{\gamma^2-4\delta\eta} = -\frac{v\gamma}{\gamma^2-4\delta\eta} > 0$, that is, $g^{VR*} > g^{N*}$. □

Proposition 3 shows that the green degree of products is affected by government subsidies, and, with the increase in government subsidies, the green degree of products increases.

Proposition 4. *Using Model N, the effects of*: c_n *and* c_r *on the optimal pricing and product green degree of building material manufacturers and retailers are shown in Table 3.*

Table 3. The influence of the change in each parameter on the optimal decision under the decentralized decision-making model (N model).

N	p_n^{N*}	p_r^{N*}	$\mathcal{W}_n^{N*}$	$\mathcal{W}_r^{N*}$	g^{N*}
c_n	+	/	+	/	/
c_r	−	$0 < \gamma < \sqrt{\delta\eta}, +$ $\sqrt{\delta\eta} < \gamma < 1, -$	−	$0 < \gamma < \sqrt{2\delta\eta}, +$ $\sqrt{2\delta\eta} < \gamma < 1, -$	−

Note:"+" means positive correlation, "−" means negative correlation, "/" means irrelevant.

Proof. From Table 3, it is easy to get the following verification:

(1) $\frac{\partial p_n^{N*}}{\partial c_n} = \frac{1}{4} > 0$. $\frac{\partial p_n^{N*}}{\partial c_r} = \frac{3\gamma^2}{4(\gamma^2-4\delta\eta)} < 0$, then, p_n^{N*} is positively correlated with c_n and negatively correlated with c_r

(2) $\frac{\partial p_r^{N*}}{\partial c_r} = \frac{\gamma^2-\delta\eta}{\gamma^2-4\delta\eta}$. Evidently, $\frac{\gamma^2-\delta\eta}{\gamma^2-4\delta\eta} > 0$ requires $\gamma^2 - \delta\eta < 0$, and $\frac{\gamma^2-\delta\eta}{\gamma^2-4\delta\eta} < 0$ requires $\gamma^2 - \delta\eta > 0$.

(3) $\frac{\partial \mathcal{W}_n^{N*}}{\partial c_n} = \frac{1}{2} > 0$. $\frac{\partial \mathcal{W}_n^{N*}}{\partial c_r} = \frac{\gamma^2}{2(\gamma^2-4\delta\eta)} < 0$, then, $\mathcal{W}_n^{N*}$ is positively correlated with c_n and negatively correlated with c_r.

(4) $\frac{\partial \mathcal{W}_r^{N*}}{\partial c_r} = \frac{\gamma^2 - 2\delta\eta}{\gamma^2 - 4\delta\eta}$. Evidently, $\frac{\gamma^2 - 2\delta\eta}{\gamma^2 - 4\delta\eta} > 0$ requires $\gamma^2 - 2\delta\eta < 0$, and $\frac{\gamma^2 - \delta\eta}{\gamma^2 - 4\delta\eta} < 0$ requires $\gamma^2 - 2\delta\eta > 0$.

(5) $\frac{\partial g^{N*}}{\partial c_r} = \frac{\gamma}{\gamma^2 - 4\delta\eta} < 0$, then, g^{N*} is negatively correlated with c_r. □

Proposition 4 shows that the reduction in the manufacturing cost of new products reduces the wholesale and retail prices of new products, so that more consumers buy new products, and the sales of new products increase, but the sales of CDW remanufactured products decrease. This requires that remanufactured products compete with new products for market share by lowering their own selling prices. In addition, lower manufacturing costs for CDW remanufactured products lead to higher wholesale and retail prices of new products. If consumers' green preferences are low ($0 < 0 < \gamma < \sqrt{2\delta\eta}/0 < \gamma < \sqrt{\delta\eta}$), in order to sell more CDW remanufactured products, the wholesale and retail prices of CDW remanufactured products are also reduced. If consumers have a high degree of green preference ($\sqrt{2\delta\eta} < \gamma < 1/\sqrt{\delta\eta} < \gamma < 1$), in order to maximize profits, the wholesale and retail prices of remanufactured products will increase. At the same time, the cost of remanufacturing is reduced, and manufacturers are more willing to improve the green degree of their products.

Proposition 5. *In Model VR, the effects of c_n, c_r,* and *v on the optimal pricing and product green degree of building materials manufacturers and retailers are shown in Table 4.*

Table 4. The influence of the change in each parameter on the optimal decision under the decentralized decision-making model (VR model).

VR	p_n^{VR*}	p_r^{VR*}	$\mathcal{W}_n^{VR*}$	$\mathcal{W}_r^{VR*}$	g^{VR*}
c_n	+	/	+	/	/
c_r	−	$0 < \gamma < \sqrt{\delta\eta}, +$ $\sqrt{\delta\eta} < \gamma < 1, -$	−	$0 < \gamma < \sqrt{2\delta\eta}, +$ $\sqrt{2\delta\eta} < \gamma < 1, -$	−
v	+	$\sqrt{\delta\eta} < \gamma < 1, +$ $0 < \gamma < \sqrt{\delta\eta}, -$	+	$\sqrt{2\delta\eta} < \gamma < 1, +$ $0 < \gamma < \sqrt{2\delta\eta}, -$	+

Note:"+" means positive correlation, "−" means negative correlation, "/" means irrelevant.

Proof. The proof process is the same as that of Proposition 4. □

Proposition 5 shows that the effects of c_n and c_r on the optimal pricing and product green degree of building material manufacturers and retailers are the same as those in Proposition 4. Increased government subsidies for remanufactured products will lead to higher wholesale and retail prices of new products. The impact of government subsidies on the pricing of remanufactured products is also related to the range of consumer green preferences. When consumers' green preferences are low ($0 < \gamma < \sqrt{2\delta\eta}/0 < \gamma < \sqrt{\delta\eta}$), in order to sell more remanufactured products, the wholesale and retail prices of remanufactured products need to be reduced. If consumers have a high degree of green preference ($\sqrt{2\delta\eta} < \gamma < 1/\sqrt{\delta\eta} < \gamma < 1$), in order to maximize profits, the wholesale price and retail sales of remanufactured products are increased. At the same time, the increase in government subsidies will improve the green degree of the product.

6. Numerical Simulation and Discussion

This section presents the simulation and analysis of the game model using MATLAB2016b in order to provide a more intuitive illustration of the impact of consumer green preferences and government subsidies on the supply chain of construction waste reuse. The initial values of related parameters are shown in Table 5.

Table 5. Simulation parameter assignment.

δ	η	h	k	b	c_n	c_r	μ
0.7	0.6	0.4	0.5	0.2	0.6	0.3	0.25

The basis of these basic parameters was taken from a survey of China's CDW remanufacturing companies and the academic results of related papers [57,58]. Therefore, this paper found that, at the current development stage of China's CDW remanufacturing industry, the cost of remanufactured products is 45–55% of the cost of new products. Overall, we set the unit cost of building materials manufacturers to produce new products at 0.6, the unit cost of CDW remanufactured products at 0.3, $\delta = 0.4$, and $\eta = 0.5$.

Setting $v = 0.02$ and $\gamma \in [0, 1]$ allows us to clarify the impact of consumer green preferences on the profits of building materials manufacturers and retailers under decentralized decision making (as shown in Figure 2).

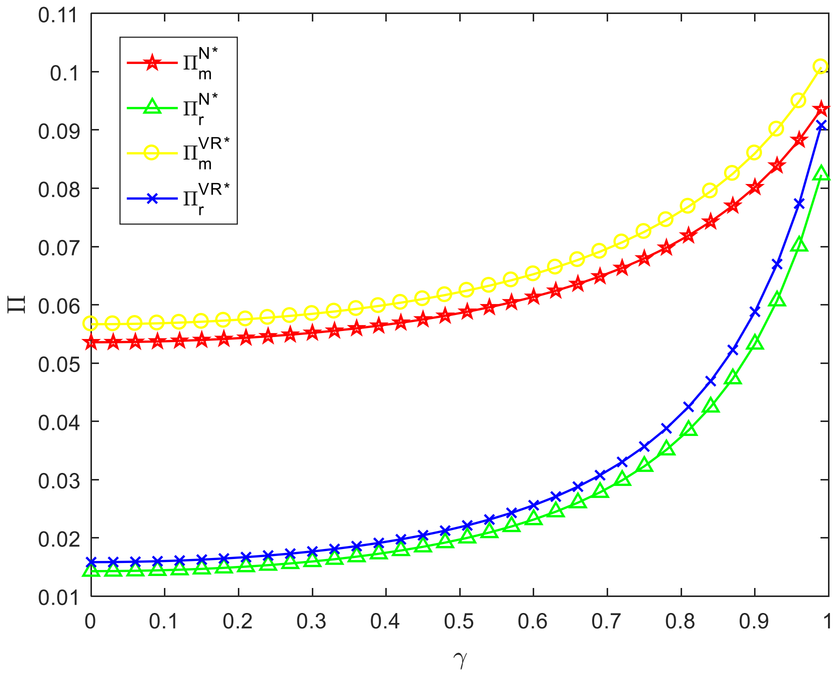

Figure 2. Profits of supply chain members under decentralized decision making.

Figure 2 shows that, under decentralized decision making, when consumers' green preferences increase, the profits of manufacturers and retailers in the CDW resource utilization supply chain also increase. This is because, with the increase in consumers' green preferences, the demand for green products increases, which promotes the increase in the sales revenue of manufacturers and retailers in the supply chain, and ultimately achieves an increase in the total profit of the supply chain. In addition, the change in the profits of building materials manufacturers and retailers increases; that is, the greater the green preferences of consumers, the more obvious the effect of improving profits. At the same time, the profit of the CDW resource utilization supply chain with government subsidies is obviously better than that without government subsidies. This is because government subsidies, to a certain extent, increase the sales of remanufactured products, and thus increase the profits of manufacturers and retailers in the supply chain. In addition, building materials manufacturers have greater profits than retailers, but retailers' profits have grown more than those of manufacturers.

Setting $v = 0.02$ and $\gamma \in [0, 1]$ enables us to clarify the impact of consumers' green preferences on the total profit of the construction waste resource utilization supply chain under centralized decision making (as shown in Figure 3).

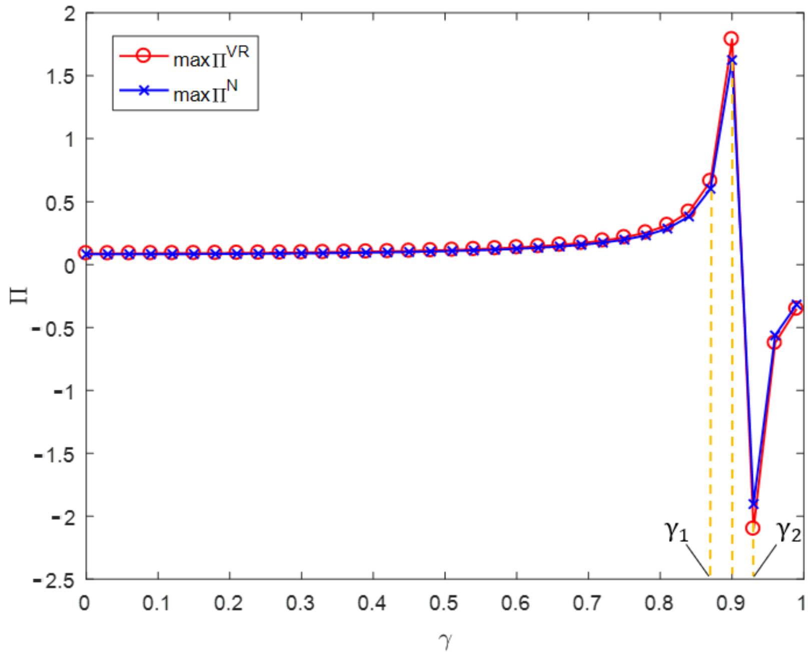

Figure 3. Impact on the total profit of the supply chain under centralized decision making.

Figure 3 shows that, under centralized decision making, when consumers' green preferences are $\gamma \in [0, \gamma_1]$, the total profit of the CDW resource utilization supply chain increases slightly but not significantly. When consumers green preferences are $\gamma \in [\gamma_1, 0.9]$, the total profit of the supply chain surges. When consumers' green preferences are 0.9, the profit reaches the maximum value. Immediately thereafter, the profit drops sharply between $\gamma \in [0.9, \gamma_2]$. Then, the profit starts to increase again between $\gamma \in [\gamma_2, 1]$. At the same time, when consumers' green preferences are between $[0, 0.9]$, the profits of the supply chain with government subsidies are slightly higher than those without government subsidies. However, when consumers' green preferences are between $[\gamma_2, 1]$, the profits of the supply chain without government subsidies are slightly higher than those with government subsidies. In general, with the increase in consumers' green preferences, the total profit of the supply chain first increases and then decreases, and the profit changes from a positive value to a negative value. Thus, the improvement in consumers' green preferences does not always improve the profits of the supply chain. At the same time, government subsidies do not necessarily increase the profits of the supply chain.

This result is slightly different from that of the study by Liu et al. [59]. They believe that, under the two models of decentralized and centralized decision making, the environmental protection level and profit of enterprises are positively correlated with consumers' environmental awareness. This study shows that the green degree of products is positively correlated with consumers' green preferences under both decision models. However, the changes in corporate profits are slightly different; that is, under decentralized decision making, corporate profits are proportional to consumers' green preferences; under centralized decision making, profits first increase and then decrease. This bias may be due to the fact that the manufacturers in this study produce both new and remanufactured products.

Figures 4 and 5 show the influence of consumers' green preferences on the total profit of the CDW resource utilization supply chain under decentralized and centralized decision making, respectively, without and with government subsidies. The total profits of the supply chain under decentralized decision making are Π^{DN*}, Π^{DVR*}; the total profits of the supply chain under centralized decision making are Π^{N*}, Π^{VR*}. Setting $\gamma \in [0, 1]$, $v = 0.02$, enables us to compare the total profit of the CDW resource utilization supply chain under decentralized and centralized decision making without or with government subsidies.

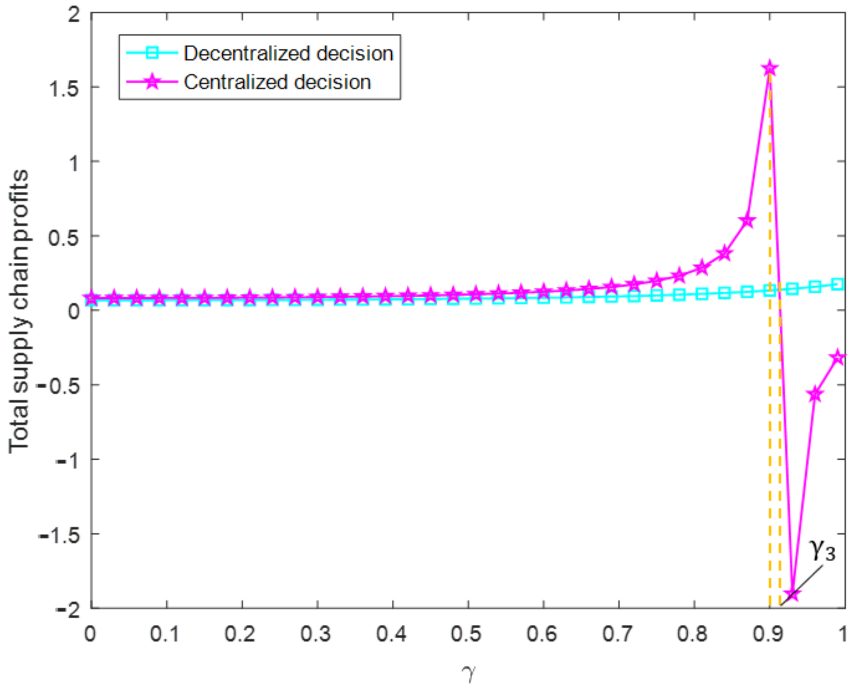

Figure 4. The impact of γ on total CDW supply chain profit without government subsidies.

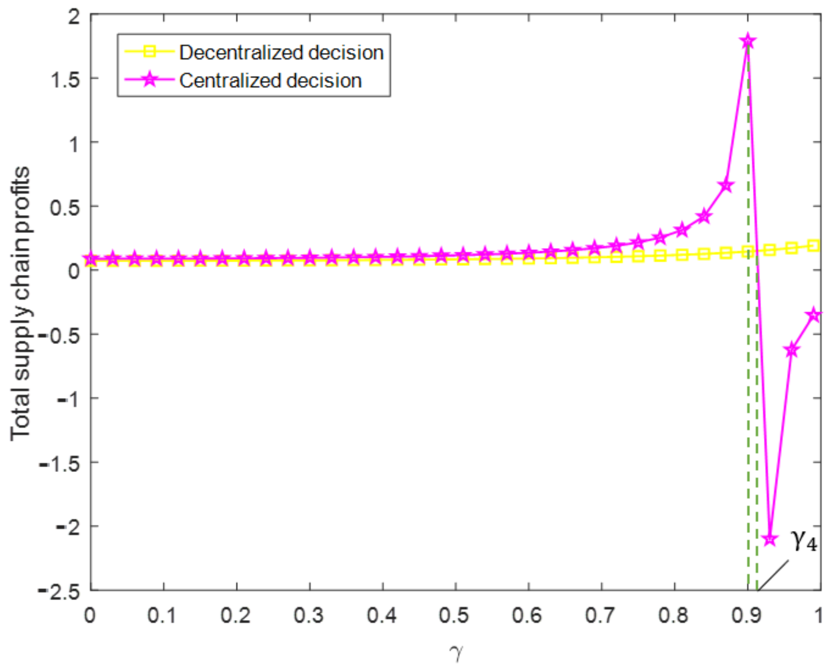

Figure 5. The impact of γ on total CDW supply chain profit with government subsidies.

Figure 4 shows that, when consumers' green preferences are $\gamma \in [0, 0.9]$, the total profit of the construction waste resource utilization supply chain under centralized decision making is higher than that under decentralized decision making. When consumers' green preferences are 0.9, the total profit of the CDW resource utilization supply chain under centralized decision making reaches the maximum value, and then decreases sharply. When consumers' green preferences are γ_3, the total profit of the CDW resource utilization supply chain is equal under centralized and decentralized decision making. Then, when consumers' green preferences are $\gamma \in [\gamma_3, 1]$, the total profit of the CDW resource utilization supply chain under centralized decision making is lower than that under decentralized decision making. In general, with the increase in consumers' green preferences, the total profit of the CDW resource utilization supply chain under centralized decision making is first greater than, and then smaller than, that under decentralized decision making. Therefore, in the case of the absence of government subsidies, the centralized or decentralized decision-making model should be selected according to the degree of consumers' green preferences in order to maximize the total profit of the CDW resource utilization supply chain.

Figure 5 shows that, when consumers' green preferences are $\gamma \in [0, 0.9]$, the total profit of the CDW resource utilization supply chain under centralized decision making is higher than that under decentralized decision making. When consumers' green preferences are 0.9, the total profit of the CDW resource utilization supply chain under centralized decision-making reaches the maximum value, and then decreases sharply. When consumers' green preferences are γ_4, the total profits of the CDW resource utilization supply chain under centralized and decentralized decision making are equal. Then, when consumers' green preferences are $\gamma \in [\gamma_4, 1]$, the total profit of the CDW resource utilization supply chain under centralized decision making is lower than that under decentralized decision making. In general, with the increase in consumers' green preferences, the total profit of the CDW resource utilization supply chain under centralized decision making is first greater than, and then smaller than, that under decentralized decision making. Secondly, the comparison of Figures 4 and 5 shows that, regardless of whether there are government subsidies, the relationship between the total profits of the CDW resource utilization supply chain under two the different decision-making models will change with the increase in consumers' green preferences. Therefore, it is necessary to choose a centralized or decentralized decision-making model according to the degree of consumers' green preferences in order to maximize the total profit of the CDW resource utilization supply chain.

This result is different from that of Zhan et al. [60]. They believe that the overall profit of the supply chain under the centralized decision-making model is always higher than that under the decentralized decision-making model. However, this study shows that the relative size of the two is related to the size of consumers' green preferences. The reason for this bias may be that the previous authors only considered green products and not remanufactured products in the supply chain model. Therefore, the current study better expands the research on remanufactured products in the green supply chain.

7. Conclusions and Implications

7.1. Conclusions

In this study, a Stackelberg game model consisting of building materials manufacturers, retailers, and consumers was constructed and used to investigate the impact of consumers' green preferences and government subsidies on CDW resource utilization supply chain decisions. The following four supply chain models were developed: decentralized decision making without government subsidies, centralized decision making without government subsidies, decentralized decision making with government subsidies, and centralized decision making with government subsidies. The strategies of the members in these four models are discussed in this paper, and are analyzed using numerical simulations. The specific findings of the study can be summarized as follows:

First, government subsidies increase wholesale and retail prices of new products, but do not always lead to lower prices for remanufactured construction waste. Government subsidies are not maximized, depending on the range of consumers' green preferences. When consumer green preferences are low, government subsidies reduce building materials manufacturers' pricing of CDW remanufactured products. When consumers' green preferences are high, under government subsidies, building materials manufacturers will instead increase the price of CDW remanufactured products. Second, government subsidies have an impact on the green degree of products. With the increase in government subsidies, the green degree of products is improved. Moreover, with the increase in consumers' green preferences, the green degree of products also increases.

Second, under decentralized decision making, the optimal profit of the CDW resource utilization supply chain with government subsidies is always greater than that of the CDW resource utilization supply chain without government subsidies. However, under centralized decision making, the optimal profit of the supply chain with government subsidies is not always greater than the optimal profit of the supply chain without government subsidies, and is also related to the degree of consumers' green preferences. When consumers' green preferences are low, the supply chain profit is higher with government subsidies than without government subsidies, whereas, when consumers' green preferences are high, the supply chain profit is higher without government subsidies than with government subsidies.

Third, under decentralized decision making, as consumers' green preferences increase, the optimal profits of building materials manufacturers and retailers also increase gradually. In addition, the greater the green preference of consumers, the more obvious the effect of increasing profits. Furthermore, although the optimal profit of building materials manufacturers is greater than that of retailers, the growth rate of retailers is greater than that of building materials manufacturers.

Fourth, regardless of the implementation of government subsidies, when consumers' green preferences are small, the total profit of the CDW resource utilization supply chain under centralized decision making is higher than that under decentralized decision making. When consumers' green preferences are too high, the total profit of the CDW resource utilization supply chain under decentralized decision making is higher than that under centralized decision making.

7.2. Implications

This study simultaneously considered the two parameters of consumers' green preferences and government subsidies, thereby enriching the research on CDW resource utilization supply chain decision making. The research also provides effective management recommendations for enterprises and governments in the CDW resource utilization supply chain, namely:

(1) For building materials manufacturers and retailers, the degree of consumer green preferences in the CDW resource utilization market should be clarified, so as to choose whether to centralize or decentralize decision making. When choosing centralized decision making, both manufacturers and retailers need to formulate a coordinated plan for common benefits and costs, with the goal of maximizing the benefits of the entire CDW resource utilization supply chain. When choosing decentralized decision making, the goal of both parties should be to maximize their own interests. In conclusion, under different consumer green preferences, choosing different decision-making models is not only beneficial to improving the total profit of the CDW resource utilization supply chain, but also to improving the CDW reuse rate.

(2) For the government, in order to promote the efficient and sustainable development of the CDW resource utilization industry, relevant subsidy policies should be formulated to stimulate the total profit of the supply chain. When consumers' green preferences are low, subsidies for CDW remanufactured products are increased; when consumers' green preferences are high, subsidies for CDW remanufactured products can be appropriately reduced to reduce consumer losses. At the same time, the government can also subsidize consumers who buy CDW remanufactured products to increase the sales of CDW remanufactured products, thereby improving the utilization rate of CDW resources.

Although this study obtained some insights into the impact of consumers' green preferences and government subsidies on CDW resource utilization supply chain decision making, and made effective recommendations for CDW management, some limitations remain.

First, this study examined a CDW resource utilization supply chain that consisted of only one building material manufacturer and one retailer. In the future, researchers can consider multiple building materials manufacturers and retailers to make it more realistic;

for example, both recycling-capable building materials manufacturers and non-recycling-capable building materials manufacturers exist in the supply chain model.

Second, the target of government subsidies in this study was relatively simple, and only the subsidized manufacturers of CDW remanufactured products were considered. In the future, researchers can also consider the situation in which the government subsidizes retailers and consumers, and compare the differences in CDW resource utilization supply chain profits under different government subsidy strategies, so as to provide better subsidy strategies for the government.

Author Contributions: Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing—Original Draft, Writing—Review and Editing, Visualization, Y.H. (Yating Han) and H.Z.; Conceptualization, Methodology, Writing—Original Draft, Supervision, Project administration, X.L.; Writing—Review and Editing, Y.H. (Yicheng Huang). All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by Special Funds of the National Social Science Fund of China (grant number 18VSJ038), the Scientific Research Startup Foundation for Introducing Talents of Sichuan Agricultural University (grant number 2122996022), the Social Science Special Project of Sichuan Agricultural University Disciplinary Construction Dual Support Program (grant number 2021SYYB05).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Banias, G.; Achillas, C.; Vlachokostas, C.; Moussiopoulos, N.; Papaioannou, I. A web-based Decision Support System for the optimal management of construction and demolition waste. *Waste Manag.* **2011**, *31*, 2497–2502. [CrossRef] [PubMed]
2. Chen, M.; Liu, W.; Tao, X. Evolution and assessment on China's urbanization 1960–2010: Under-urbanization or over-urbanization? *Habitat Int.* **2013**, *38*, 25–33. [CrossRef]
3. Duan, H.; Miller, T.R.; Liu, G.; Tam, V.W. Construction debris becomes growing concern of growing cities. *Waste Manag.* **2019**, *83*, 1–5. [CrossRef] [PubMed]
4. Erlandsson, M.; Levin, P. Environmental assessment of rebuilding and possible performance improvements effect on a national scale. *Build. Environ.* **2005**, *40*, 1459–1471. [CrossRef]
5. Jain, P.; Powell, J.; Tolaymat, T. *Methodology to Estimate the Quantity Composition, and Management of Construction and Demolition Debris in the United States*; US Environmental Protection Agency: Washington, DC, USA, 2015.
6. Ajayi, S.O.; Oyedele, L.O.; Akinade, O.O.; Bilal, M.; Owolabi, H.A.; Alaka, H.A.; Kadiri, K.O. Reducing waste to landfill: A need for cultural change in the UK construction industry. *J. Build. Eng.* **2016**, *5*, 185–193. [CrossRef]
7. Zheng, L.; Wu, H.; Zhang, H.; Duan, H.; Wang, J.; Jiang, W.; Dong, B.; Liu, G.; Zuo, J.; Song, Q. Characterizing the generation and flows of construction and demolition waste in China. *Constr. Build. Mater.* **2017**, *136*, 405–413. [CrossRef]
8. Esa, M.R.; Halog, A.; Rigamonti, L. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *J. Mater. Cycles Waste Manag.* **2017**, *19*, 1144–1154. [CrossRef]
9. Oliveira, T.C.; Dezen, B.G.; Possan, E. Use of concrete fine fraction waste as a replacement of Portland cement. *J. Clean. Prod.* **2020**, *273*, 123126. [CrossRef]
10. Widhiawati, I.A.R.; Astana, I.N.Y.; Indrayani, N.L.A. An analysis of building construction waste in Badung, Bali. In Proceedings of the MATEC Web of Conferences, Bali, Indonesia, 24–25 October 2018; EDP Sciences: Les Ulis, France, 2019; Volume 276, p. 02010.
11. Genc, T.S.; De Giovanni, P. Trade-in and save: A two-period closed-loop supply chain game with price and technology dependent returns. *Int. J. Prod. Econ.* **2017**, *183*, 514–527. [CrossRef]
12. Poon, C.S.; Chan, D. The use of recycled aggregate in concrete in Hong Kong. *Resour. Conserv. Recycl.* **2007**, *50*, 293–305. [CrossRef]
13. Ling, Y.Y.; Leo, K.C. Reusing timber formwork: Importance of workmen's efficiency and attitude. *Build. Environ.* **2000**, *35*, 135–143. [CrossRef]
14. Tam, V.W. On the effectiveness in implementing a waste-management-plan method in construction. *Waste Manag.* **2008**, *28*, 1072–1080. [CrossRef] [PubMed]
15. Abanda, F.H.; Tah, J.H.M.; Cheung, F.K.T. Mathematical modelling of embodied energy, greenhouse gases, waste, time–cost parameters of building projects: A review. *Build. Environ.* **2013**, *59*, 23–37. [CrossRef]

16. Wu, Z.; Ann, T.W.; Shen, L.; Liu, G. Quantifying construction and demolition waste: An analytical review. *Waste Manag.* **2014**, *34*, 1683–1692. [CrossRef] [PubMed]
17. Chitra, K. In search of the green consumers: A perceptual study. *J. Serv. Res.* **2007**, *7*, 173–191.
18. Chen, X.; Wang, X.; Zhou, M. Firms' green R&D cooperation behaviour in a supply chain: Technological spillover, power and coordination. *Int. J. Prod. Econ.* **2019**, *218*, 118–134.
19. Modak, N.M.; Ghosh, D.K.; Panda, S.; Sana, S.S. Managing green house gas emission cost and pricing policies in a two-echelon supply chain. *CIRP J. Manuf. Sci. Technol.* **2018**, *20*, 1–11. [CrossRef]
20. Qin, Q.; Jiang, M.; Xie, J.; He, Y. Game analysis of environmental cost allocation in green supply chain under fairness preference. *Energy Rep.* **2021**, *7*, 6014–6022. [CrossRef]
21. Zhao, J.; Sun, N. Government subsidies-based profits distribution pattern analysis in closed-loop supply chain using game theory. *Neural Comput. Appl.* **2020**, *32*, 1715–1724. [CrossRef]
22. Zhang, X.; Li, Q.; Qi, G. Decision-making of a dual-channel closed-loop supply chain in the context government policy: A dynamic game theory. *Discret. Dyn. Nat. Soc.* **2020**, *2020*, 2313698. [CrossRef]
23. Ilyas, S.; Hu, Z.; Wiwattanakornwong, K. Unleashing the role of top management and government support in green supply chain management and sustainable development goals. *Environ. Sci. Pollut. Res.* **2020**, *27*, 8210–8223. [CrossRef] [PubMed]
24. Louis, G.E. A historical context of municipal solid waste management in the United States. *Waste Manag. Res.* **2004**, *22*, 306–322. [CrossRef] [PubMed]
25. Li, L.; Jiang, T.; Chen, B.; Wen, J.; Yang, G. Integrated Utilization of Vanadium-Titanium Magnetite Tailings for Synthesis of Lightweight Foamed Ceramics: Effect of Chemical Composition on the Properties and Phase Evolution. *J. Sustain. Metall.* **2022**, *8*, 646–657. [CrossRef]
26. Brown, S. An interview with Wickham Skinner, emeritus professor at harvard business school. *Int. J. Oper. Prod. Manag.* **2013**, *33*, 104–110. [CrossRef]
27. Nguyen, H.P.; Mueller, A.; Nguyen, C.T. Development and characterization of lightweight aggregate recycled from construction and demolition waste mixed with other industrial by-products. *Constr. Build. Mater.* **2021**, *313*, 125472. [CrossRef]
28. Wu, H.; Zuo, J.; Zillante, G.; Wang, J.; Yuan, H. Status quo and future directions of construction and demolition waste research: A critical review. *J. Clean. Prod.* **2019**, *240*, 118163. [CrossRef]
29. Kabirifar, K.; Mojtahedi, M.; Wang, C.C. A systematic review of construction and demolition waste management in Australia: Current practices and challenges. *Recycling* **2021**, *6*, 34. [CrossRef]
30. Mohammed, M.; Shafiq, N.; Al-Mekhlafi, A.B.A.; Rashed, E.F.; Khalil, M.H.; Zawawi, N.A.; Muhammad, A.; Sadis, A.M. The Mediating Role of Policy-Related Factors in the Relationship between Practice of Waste Generation and Sustainable Construction Waste Minimisation: PLS-SEM. *Sustainability* **2022**, *14*, 656. [CrossRef]
31. Sun, H.; Wan, Y.; Zhang, L.; Zhou, Z. Evolutionary game of the green investment in a two-echelon supply chain under a government subsidy mechanism. *J. Clean. Prod.* **2019**, *235*, 1315–1326. [CrossRef]
32. Li, X.; Huang, R.; Dai, J.; Li, J.; Shen, Q. Research on the evolutionary game of construction and demolition waste (CDW) recycling units' green behavior, considering remanufacturing capability. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9268. [CrossRef]
33. Hu, Q.; Su, P.; Xiong, F. Dynamic game strategies for construction and demolition waste recycling with learning and reference effects. *Environ. Impact Assess. Rev.* **2021**, *89*, 106592. [CrossRef]
34. Zheng, H.; Li, X.; Zhu, X.; Huang, Y.; Liu, Z.; Liu, Y.; Liu, J.; Li, X.; Li, Y.; Li, C. Impact of Recycler Information Sharing on Supply Chain Performance of Construction and Demolition Waste Resource Utilization. *Int. J. Environ. Res. Public Health* **2022**, *19*, 3878. [CrossRef] [PubMed]
35. Li, D.; Peng, Y.; Guo, C.; Tan, R. Pricing strategy of construction and demolition waste considering retailer fairness concerns under a governmental regulation environment. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3896. [CrossRef] [PubMed]
36. Michael, R.T.; Becker, G.S. On the new theory of consumer behavior. *Swed. J. Econ.* **1973**, *75*, 378–396. [CrossRef]
37. Oduro, S.; Maccario, G.; De Nisco, A. Green innovation: A multidomain systematic review. *Eur. J. Innov. Manag.* **2021**, *25*, 567–591. [CrossRef]
38. He, J.; Lei, Y.; Fu, X. Do consumer's green preference and the reference price effect improve green innovation? A theoretical model using the food supply chain as a case. *Int. J. Environ. Res. Public Health* **2019**, *16*, 5007. [CrossRef]
39. Xu, Y.; Xie, H. Consumer environmental awareness and coordination in closed-loop supply chain. *Open J. Bus. Manag.* **2016**, *4*, 427. [CrossRef]
40. Abbey, J.D.; Meloy, M.G.; Guide, V.D.R., Jr.; Atalay, S. Remanufactured products in closed-loop supply chains for consumer goods. *Prod. Oper. Manag.* **2015**, *24*, 488–503. [CrossRef]
41. Alam-Tabriz, A.; Rajabani, N.; Farrokh, M. An integrated fuzzy DEMATEL-ANP-TOPSIS methodology for supplier selection problem. *Glob. J. Manag. Stud. Res.* **2014**, *1*, 85–99.
42. Shooshtarian, S.; Maqsood, T.; Khalfan, M.; Yang, R.J.; Wong, P. Landfill levy imposition on construction and demolition waste: Australian stakeholders' perceptions. *Sustainability* **2020**, *12*, 4496. [CrossRef]
43. Mak, T.M.; Iris, K.M.; Wang, L.; Hsu, S.C.; Tsang, D.C.; Li, C.N.; Yeung, T.L.; Zhang, R.; Poon, C.S. Extended theory of planned behaviour for promoting construction waste recycling in Hong Kong. *Waste Manag.* **2019**, *83*, 161–170. [CrossRef] [PubMed]
44. Yang, D.; Xiao, T. Pricing and green level decisions of a green supply chain with governmental interventions under fuzzy uncertainties. *J. Clean. Prod.* **2017**, *149*, 1174–1187. [CrossRef]

45. Chemama, J.; Cohen, M.C.; Lobel, R.; Perakis, G. Consumer subsidies with a strategic supplier: Commitment vs. flexibility. *Manag. Sci.* **2019**, *65*, 681–713. [CrossRef]
46. Li, Z.; Zhang, J.; Meng, Q.; Zheng, W.; Du, J. Influence of government subsidy on remanufacturing decision under different market models. *Math. Probl. Eng.* **2019**, *2019*, 9460315. [CrossRef]
47. He, P.; He, Y.; Xu, H. Channel structure and pricing in a dual-channel closed-loop supply chain with government subsidy. *Int. J. Prod. Econ.* **2019**, *213*, 108–123. [CrossRef]
48. Huang, Y.; Liang, Y. Exploring the strategies of online and offline recycling channels in closed-loop supply chain under government subsidy. *Environ. Sci. Pollut. Res.* **2022**, *29*, 21591–21602. [CrossRef] [PubMed]
49. Barman, A.; Das, R.; De, P.K.; Sana, S.S. Optimal pricing and greening strategy in a competitive green supply chain: Impact of government subsidy and tax policy. *Sustainability* **2021**, *13*, 9178. [CrossRef]
50. Yu, Y.; Han, X.; Hu, G. Optimal production for manufacturers considering consumer environmental awareness and green subsidies. *Int. J. Prod. Econ.* **2016**, *182*, 397–408. [CrossRef]
51. Ghosh, D.; Shah, J. A comparative analysis of greening policies across supply chain structures. *Int. J. Prod. Econ.* **2012**, *135*, 568–583. [CrossRef]
52. Swami, S.; Shah, J. Channel coordination in green supply chain management. *J. Oper. Res. Soc.* **2013**, *64*, 336–351. [CrossRef]
53. Li, B.; Zhu, M.; Jiang, Y.; Li, Z. Pricing policies of a competitive dual-channel green supply chain. *J. Clean. Prod.* **2016**, *112*, 2029–2042. [CrossRef]
54. Bakal, I.S.; Akcali, E. Effects of random yield in remanufacturing with price-sensitive supply and demand. *Prod. Oper. Manag.* **2006**, *15*, 407–420. [CrossRef]
55. Hong, I.H.; Lee, Y.T.; Chang, P.Y. Socially optimal and fund-balanced advanced recycling fees and subsidies in a competitive forward and reverse supply chain. *Resour. Conserv. Recycl.* **2014**, *82*, 75–85. [CrossRef]
56. Ferrer, G.; Swaminathan, J.M. Managing new and differentiated remanufactured products. *Eur. J. Oper. Res.* **2010**, *203*, 370–379. [CrossRef]
57. Chen, X.; Cao, J.; Kumar, S. Government regulation and enterprise decision in China remanufacturing industry: Evidence from evolutionary game theory. *Energy Ecol. Environ.* **2021**, *6*, 148–159. [CrossRef] [PubMed]
58. Long, X.; Ge, J.; Shu, T.; Liu, Y. Analysis for recycling and remanufacturing strategies in a supply chain considering consumers' heterogeneous WTP. *Resour. Conserv. Recycl.* **2019**, *148*, 80–90. [CrossRef]
59. Liu, Z.L.; Anderson, T.D.; Cruz, J.M. Consumer environmental awareness and competition in two-stage supply chains. *Eur. J. Oper. Res.* **2012**, *218*, 602–613. [CrossRef]
60. Zhan, S.; Shu, Z.; Jiang, H. Research on two-echelon green supply chain decision under government subsidy. *Am. J. Ind. Bus. Manag.* **2018**, *8*, 487–495. [CrossRef]