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Research Article

Incentive Regulation of Construction Waste Resource Recycling: Subsidy and Tax Incentive

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Construction waste destroys the sustainability of environment and economy. In the study of game theory at present, the construction waste resource-based products supply chain only considers that there is only one type of enterprise producing renewable building materials or new building materials in the market, but in the construction market, there is no single type of enterprise. It isvery important for government to protect the environment and promote the resource utilization and development of construction waste. Therefore, this study establishes a game theory model between traditional building materials enterprise and construction waste recycling enterprise, which considers the decision-making behavior of enterprise under no regulation, subsidy incentive regulation, or tax incentive regulation. The findings are listed as follows: (1) both subsidies and tax incentives can effectively improve the economic benefits and production initiative of construction waste recycling enterprise. (2) The impact coefficient of unit new building materials on the environment and the tax rate of unit new building materials are the key factors that affect government decision-making. (3) Resource utilization cost coefficient and builder's preference for renewable building materials have a great impact on the profits of construction waste recycling enterprise. These results will provide reference for the government to formulate incentive regulations and promote the development of construction waste resources.

1. Introduction

With the rapid urbanization of the world, the construction industry generates a large amount of construction waste every year, and the solid waste generated in the renovation and demolition of buildings is the main component [1]. According to relevant research data, the amount of construction waste generated every year in the world is increasing, and the total amount of construction waste has accounted for 30–40% of the total amount of municipal solid waste [2–4]. However, in the construction waste resource recycling industry, due to the high resource recycling cost [5] and the low profit of renewable building materials [6], a large number of construction wastes are transported to urban or rural suburbs without any treatment [7] Take China as an example, China produces more than 2 billion tons of construction waste every year [2], such a large volume of construction waste accumulation brings a huge burden to the environment [3, 8], not only occupies a large amount of land but also causes damage to the surface landscape and groundwater, thus blocking the soil biological chain and causing serious environmental pollution [9]. In addition, the contradiction between the large amount of unrecycled construction waste and the limited landfills is also gradually prominent. Therefore, vigorously developing the resource recovery of construction waste and improving the recovery and utilization rate of construction waste are important means to solve the problem of the low utilization rate of construction waste recovery [10, 11] and are also the focus of research on resource recovery of construction waste [12].

In order to improve the recycling rate of construction waste and prevent and control environmental pollution, many governments of countries and regions have adopted corresponding regulations on the recycling of construction waste. For example, countries with mature resource recycling industries such as the United States, Japan, and Germany require all builders to deal with construction waste generated by themselves, and otherwise, they will be punished [13]. However, in developing countries in Southeast Asia, South America, the Middle East, and other regions, due to the lack of environmental awareness of local people, the acceptance of construction resource-based products is not as high as that of people in Europe and the United States, and the motivation of local enterprises to recycle construction waste is low. Therefore, the government adopts more incentive regulations to encourage construction resource-based enterprises to recycle construction waste and produce renewable building materials products. For example, in recent years, the Chinese government has supported the development of construction waste-related treatment industries by formulating economic incentive regulations for construction waste recycling [14, 15] and encouraging enterprises to recycle construction waste instead of directly burying it in landfill [16]. In2017, the Shenzhen Municipal government issued "Incentive Measures for Emission Reduction and Comprehensive Utilization of Construction Waste in Shenzhen," which pointed out that the comprehensive utilization of construction waste should be guided through tax incentives and subsidies to achieve the purpose of resource conservation.

In recent years, China has implemented tax incentives and subsidy incentive regulations on the construction waste recycling industry, which have achieved corresponding results in Shenzhen, Qingdao, and other coastal cities. In the "14th Five-year Plan of Ecological and Environmental Protection of Shenzhen," it is expected that the comprehensive utilization rate of housing demolition waste will reach more than 95% by 2025. However, in more cities, incentive regulation still exists irrationality because the driving path of incentive regulation is not clear enough. The subsidy regulations adopted in some regions are not effective after implementation. Relevant scholars find that the implementation of subsidy regulations in these regions reduces the recycling enthusiasm of construction waste recycling enterprises [17, 18]. For example, in 2015, Guangzhou Municipal Government issued the Management Measures of Financial Subsidies for Comprehensive Utilization of Construction Waste in Guangzhou. It is required to subsidize the renewable building materials produced by resource-based construction enterprises, but the strict conditions make it difficult or even impossible for enterprises to apply for subsidies, resulting in little implementation effect. In respect of tax incentives, although The Preferential Catalogue of Value-added Tax for Products of Comprehensive Utilization of Resources and Labor formulated by China in 2008 clearly stipulates that construction waste renewable building materials products are subject to preferential taxation, the effect of preferential tax regulation enhances utilization rate is not significant, and the government still need to intensify efforts to perfect the preferential tax regulation [13]. Therefore, it is of great significance to study the driving path of construction waste resource recycling incentive regulation and formulate reasonable incentive regulation for the development of construction waste resource recycling.

It is obvious that the government should protect and guide construction resource-based enterprise to produce renewable building materials products with high resource utilization rate through reasonable incentive regulations: government subsidies and tax incentive regulations for renewable building materials products. However, through a comprehensive literature review, we found that there are two research gaps that have not been mentioned in previous studies. First, in government regulation, there are not enough attention has been paid to the study of tax incentive regulation on construction waste resource recycling. Second, in the construction market, there is no single type of enterprise, and previous studies have not considered different types of enterprises.

The research contribution of this paper is that it can help countries and regions that want to develop resource recycling better understand and explore the mechanism of incentive regulation, so as to promote the development of local construction waste resource recycling, protect the environment, and balance the profit and cost of resource recycling enterprise. Inview of the practical problems of promoting the subsidies and tax incentive regulations, combined with the existing incentive regulation, this paper constructs a supply chain which composed of government, construction waste recycling enterprise, traditional building materials enterprise, and builder. Stackelberg game is used to analyze the model of the paper, to determine, and to compare the incentive regulations of the government. In general, the objectives of the paper are as follows:

(1) The mechanism of subsidy and tax incentive regulation.
(2) What is the optimal decision of the government and enterprise?
(3) The influence of other factors on the utilization and development of construction waste resources.

The rest of the article is organized as follows. Section 2 is a literature review. Section 3 describes the model and basic assumptions. Section 4 studies the decision-making behavior of enterprise under different government policies. Section 5 provides management inspiration for the government to make incentive regulations through comparative analysis. Section 6 analyzes the influence of related factors on the profit and resource utilization rate of construction waste recycling enterprises through numerical simulation. Finally, section 7 draws the main conclusions and points out the shortcomings of this study and prospects for future research directions.

2. Literature Review

2.1. Development of Construction Waste Recycling. Construction waste faces many problems. The extensive waste produced in construction and demolition activities affects the ecological environment, impeding green development in countries worldwide. A large amount of construction waste is generated around the world every year. Shooshtarian et al. [19] thought the increasing rate of construction waste generation indicates low resource efficiency in the architecture, engineering, and construction industry. And in the implementation of new materials, Alhawa et al. [20] found that there are still several barriers facing commercial of cleaner solution in the construction industry. There are also problems with the construction supply chain, such as Zheng et al. [21] found the inefficient supply chain of CDW resource utilization hinders the green development of countries around the world, including China. In terms of policies and regulations, based on stakeholder theory and the grey-DEMA TEL method, Liu et al. [22] identified and quantitatively analyze the critical factors in CDW recycling from the perspective of China and found that the government should prioritize the task of improving specific legislation and regulations, with a focus on a mandatory degree of normative standards. Long et al. [23] thought that the government should standardize the decision-making process of production and recycling units by means of reward and punishment mechanism.

In order to solve the existing problem in construction waste recycling, meanwhile, alleviate the harm caused by construction waste landfill to the environment and promote the development of construction resource utilization. In recent years, scholars have carried out studies on construction waste resource utilization from multiple dimensions. Some scholars carried out research on construction waste resource recover [24], construction waste stock [25], output [26, 27], and reduction [15]. Some scholars also discussed the development of the construction waste resource utilization industry [10], decision-making behaviors of stakeholders [28], and key factors affecting the development of construction waste resource utilization [29, 30]. Among them, the research on regulation mainly focuses on stakeholder behavior decision-making under environmental regulation of construction waste [31, 32] and economic benefit under incentive regulation [13] and so on. However, based on the current situation of construction waste recycling in China, the author finds that the conduction path of incentive regulation effect is not clear enough after the regulation is implemented, especially tax incentive regulation. Therefore, in order to improve the effectiveness of government incentive regulation, it is necessary to further clarify the driving path of incentive regulation.

2.2. Decision-Making Behavior of Stakeholders in Government Incentive Regulations. In the study of incentive regulations for green industries such as building resource recycling, remanufacturing, and new energy, Zhao et al. [33] used evolutionary game and found that the government has an incentive effect on all enterprises in the market no matter whether it adopts direct subsidy or tax preference regulation. Liu et al. [13] established a system dynamics model of the economic benefits of resource-based construction enterprises and found that the government should increase equipment tax incentives to improve the economic benefits of resource-based construction enterprises. Miao et al. [34] applied system dynamics and found that with the increase of the manufacturer's incentive coefficient, the effect of the manufacturer's incentive strategy would be better. In the study of incentive regulation of building resource recycling, some scholars find that under government incentive regulation, decision-making behaviors among stakeholders will have an impact on the effect of regulation. For example, Zhang Hong et al. [35] found that government subsidies can weaken the negative effect of retailers' equity preference on the supply chain. Li et al. [36] analyzed the impact of supply chain members' decisions on environmental performance from an environmental perspective. Yang et al. [32] established a decision-making model including the government, construction waste recycling enterprises, and consumers and optimized the construction waste resource utilization system by adjusting the factors influencing environmental benefits. Han et al. [37] clarified how consumers' green preferences and government subsidies affect decision-making in the supply chain. All the above scholars studied the construction waste problem through the Stackelberg game because the government is in an absolute leader position in the policy formulation of construction waste resource utilization. Stackelberg game can analyze the behavioral decisions of stakeholders in the construction waste industry by considering the strategies of both leaders and followers. It is helpful for the government to formulate reasonable incentive regulations.

However, in the study of game theory at present, the construction waste resource-based products supply chain only considers that there is only one type of enterprise producing renewable building materials or new building materials in the market, but in the actual market, there is no single type of enterprise. Therefore, it is more reasonable to bring traditional building materials enterprises and construction waste recycling enterprises into the interests of the main body to analyze.

In view of this, in order to guarantee the government to protect the environment, with the purpose of maximizing social welfare, this paper uses the Stackelberg game to build a market model which is contracted by the government, a traditional building materials enterprise, a construction waste recycling enterprise, and a builder. Based on the model, this paper analyzes the driving path of incentive regulation and discusses the decision-making behaviors of construction waste recycling enterprise and traditional building materials enterprise under different government incentive regulations and provides reasonable incentive regulations and suggestions for the government.

3. Model Descriptions and Assumptions

3.1. Model Describe. The model established in this paper consists of the government, a construction waste recycling enterprise, a traditional building materials enterprise, and a builder, as shown in Figure 1. In the initial market, only traditional building material enterprise provides the new building material product q_{n1} to builder. In the second cycle, when the market has a consensus on environmental protection, there is a demand for renewable building materials, which means that it enters the green cycle. In this model, some parts of the buildings are demolished, and the quantity of construction waste Q is generated. The construction waste recycling enterprise decides the resource utilization rate τ to provide q_r renewable building materials products, while the traditional building materials enterprise provides q_n new building materials products, and the builder buys all the building materials as shown in Table 1.

In order to promote the development of construction waste recycling, the government designs different regulations to participate in construction activities: (1) the government has no incentive regulations for construction waste recycling enterprise; (2) the government implements subsidy incentive regulations for construction waste recycling enterprise; (3) the government implements tax incentives for construction waste recycling enterprise.

3.2. Symbol Definition. Symbols are defined in the following Table 1.

3.3. Model Assumption

(1) The market is composed of the government, a construction waste recycling enterprise, a traditional building materials enterprise, and a builder. Construction waste recycling enterprise only produces renewable building materials, while traditional building materials enterprise only produces new building materials. Both renewable building materials and new building materials are sold to the same builder.

(2) In this market, buildings with new building materials become construction waste after demolition at the conversion rate of β, which means that the stock of construction waste $Q = q_{n1}\beta$. The construction waste recycling enterprise collects and treats the construction wastes and decides the resource utilization rate τ, which means that the production of renewable building materials $q_r = \tau Q$ and sell all of them to the builder.

(3) Demand is a linear function of price, and the new building materials and renewable building materials interact with each other. The preference of the builder for renewable building materials δ is considered. Therefore, the inverse demand functions of new building materials and renewable building materials are as follows: $p_n = \alpha - q_n - \delta q_r$, $p_r = \delta(\alpha - q_n - \delta q_r)$.

Since there are only new building materials in the initial market, the inverse demand function of the initial market is $p_{n1} = \alpha - q_{n1}$.

(4) In the process of producing renewable building materials, construction waste recycling enterprise needs to collect the construction waste to produce renewable building materials, so the construction waste recycling enterprise needs to invest not only the production cost but also the resource recovery cost which is related to the production of renewable building materials. Therefore, the investment cost is $\varphi q_r^2/2$.

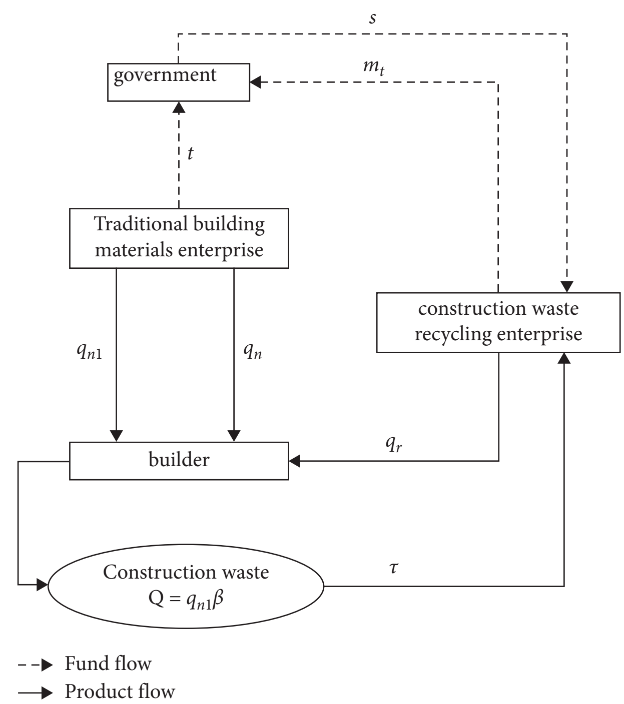

FIGURE 1: Construction waste game theory model based on subsidy and tax preferential regulation.

(5) Traditional building materials enterprise produces new building materials products, and construction waste recycling enterprise produces renewable building materials products, which reduces the impact of construction waste on the environment, so the impact of renewable building materials products on the environment is smaller ($d_r < d_n$).

4. Model Establishment and Solution

In this part, the paper studies the manufacturing decisions of traditional building materials enterprise and construction waste recycling enterprise under different government regulations. Traditional building materials enterprise maximizes their profits by determining the optimal q_n^* and q_{n1}^* Construction waste recycling enterprise maximizes their profits by determining the optimal τ^*. Here, π_n^{i*} and π_r^{i*} represent the maximum profit of the firm. $i \in \{N, S, M\}$, where N, S, and M represent the correlation values in the model of the government under no incentive regulation (N), subsidy incentive regulation (S), and tax incentive regulation (M), respectively.

4.1. Mode N-Decision under the No Incentive Regulation. In mode N, the government taxes construction waste recycling enterprise and traditional building materials enterprise. But does not provide subsidies or tax incentives to construction waste recycling enterprise. Therefore, the decision-making objective functions of building resource utilization enterprise and traditional building materials enterprise are

Table 1: Symbol definition.

Parameter	Description
α	Total market demand for building materials products, $0<\alpha$
β	Building waste conversion ratio, $0<\beta<1$
δ	The preference of builder for renewable building materials products, $0<\delta<1$, the larger δ is, the more inclined builder are to use renewable building materials products
φ	Resource recovery cost coefficient, $\varphi>0$, the larger φ is, the more difficult it is to recycle construction waste
s	Government subsidies for unit renewable building materials, $0<s$
c_r	Cost of unit renewable building materials, $0<c_r$
c_n	Cost of unit new building materials, $0<c_n$
t	Tax rate of unit building materials, $0<t$
t_r	Tax rate of unit renewable building materials and $t_r=mt$
d_r	Environmental impact coefficient of unit renewable building materials, $0<d_r$
d_n	Environmental impact coefficient of unit new building materials, $0<d_r<d_n$
P_r	Sales price of renewable building materials per unit
P_n	Sales price of new building materials per unit
m	Tax adjustment coefficient and $t_r=mt$, $0\le m\le 1$
$1-m$	Proportion of tax incentives. When $1-m=1$, no tax preference When $1-m=0$, renewable building materials are exempted from tax
q_r	Production of renewable building materials, $0<q_r$
τ	Resource utilization rate, $0\le\tau<1$
q_{n1}	Initial market production of new building materials, $0<q_{n1}$
q_n	Production of new building materials, $0<q_n$
π_r	Profit of construction waste recycling enterprise
π_n	Profit of traditional building materials enterprise
π_p	Regulation benefit
U_e	Environmental damage
SW	Social welfare

$$max\pi_r^N=(p_r-c_r-t)q_r-\frac{\varphi q_r^2}{2}, \tag{1}$$

$$max\pi_n^N=[p_{n1}-c_n-t]q_{n1}+[p_n-c_n-t]q_n. \tag{2}$$

Theorem 1. *In mode N, according to backward induction, it can be calculated that when $\beta>\delta^2/(2\delta+\psi)$, the optimal decision of traditional building materials enterprise and construction waste recycling enterprise is as follows:*

$$q_n^{N*}=\frac{\delta(c_r+t-2c_n\beta-2t\beta+2\alpha\beta-\alpha\delta)+(\alpha-c_n-t)\beta\psi}{-\delta^2+\beta(2\delta+\psi)}, \tag{3}$$

$$q_{n1}^{N*}=\frac{1}{2}(\alpha-c_n-t), \tag{4}$$

$$\tau^{N*}=\frac{\alpha\delta-c_r-t/2\beta\delta+\beta\psi+(c_n+t)\delta-cr-t/-\delta^2+\beta(2\delta+\psi)}{\alpha-c_n+t}, \tag{5}$$

$$q_r^{N*}=\frac{\alpha\delta-c_r-t/2\beta\delta+\beta\psi+(c_n+t)\delta-cr-t/-\delta^2+\beta(2\delta+\psi)}{2(\alpha-c_n+t)}(\alpha-c_n-t). \tag{6}$$

Substituting equations (3)–(6) into objective function (1) and (2), it can be obtained:

$$\pi_n^{N*} = \frac{1}{4}\left((c_n + t - \alpha)^2 + \frac{(\delta(c_r + t - 2c_n\beta - 2t\beta + 2\alpha\beta - \alpha\delta) - (c_n + t - \alpha)\beta\psi)^2}{\beta(2\delta + \psi)(-\delta^2 + \beta(2\delta + \psi))} \right), \tag{7}$$

$$\pi_r^{N*} = \frac{(\delta(4(c_r + t)\beta - (c_r + t + 2(c_n + t + \alpha)\beta)\delta + \alpha\delta^2) + \beta(2(c_r + t) - (c_n + t + \alpha)\delta)\psi)^2}{8(2\delta + \psi)(\delta^2 - \beta(2\delta + \psi))^2}. \tag{8}$$

4.2. Mode S-Decision under the Subsidy Incentive Regulation. In model S, the government taxes both construction waste recycling enterprise and traditional building materials enterprise and provides subsidy S for unit renewable building materials products to construction waste recycling enterprise. The decision-making objective functions of building resource utilization enterprise and traditional building materials enterprise are as follows:

$$max\pi_r^S = (p_r - c_r - t + s)q_r - \frac{\varphi q_r^2}{2}, \tag{9}$$

$$max\pi_n^S = [p_{n1} - c_n - t]q_{n1} + [p_n - c_n - t]q_n. \tag{10}$$

Theorem 2. *In mode S, according to backward induction, it can be calculated that when $\beta > \delta^2/(2\delta + \psi)$, the optimal decision of traditional building materials enterprise and construction waste recycling enterprise is as follows:*

$$q_n^{S*} = \frac{\delta(c_r - s + t - \alpha\delta - 2(c_n + t - \alpha)\beta\delta) - (c_n + t - \alpha)\beta\psi}{-\delta^2 + \beta(2\delta + \psi)}, \tag{11}$$

$$q_{n1}^{S*} = \frac{1}{2}(\alpha - c_n - t), \tag{12}$$

$$\tau^{S*} = \frac{\alpha\delta - c_r + s - t/2\beta\delta + \beta\psi + (c_n + t)\delta - c_r + s - t/ - \delta^2 + \beta(2\delta + \psi)}{\alpha - c_n + t}, \tag{13}$$

$$q_r^{N*} = \frac{\alpha\delta - c_r + s - t/2\beta\delta + \beta\psi + (c_n + t)\delta - c_r + s - t/ - \delta^2 + \beta(2\delta + \psi)}{2(\alpha - c_n + t)}(\alpha - c_n - t). \tag{14}$$

Substituting equations (11)–(14) into objective function (9) and (10), it can be obtained:

$$\pi_n^{S^*} = \frac{1}{4}\left((c_n + t - \alpha)^2 + \frac{(\delta(-c_r + s - t + 2c_n\beta + 2t\beta - 2\alpha\beta + \alpha\delta) + (c_n + t - \alpha)\beta\psi)^2}{\beta(2\delta + \psi)(-\delta^2 + \beta(2\delta + \psi))} \right), \tag{15}$$

$$\pi_r^{S^*} = \frac{(\delta(4(c_r - s + t)\beta - (c_r - s + t + 2(c_n + t + \alpha)\beta)\delta + \alpha\delta^2) + \beta(2(c_r - s + t) - (c_n + t + \alpha)\delta)\psi)^2}{8(2\delta + \psi)(\delta^2 - \beta(2\delta + \psi))^2}. \tag{16}$$

4.3. Mode M-Decision under the Tax Incentive Regulation. In mode M, the government imposes taxes on both resource-based construction enterprises and traditional building materials enterprises at the same time but adjusts tax rates in proportion to M for the renewable building materials produced by resource-based construction enterprises to implement preferential tax incentives. Therefore, the decision-making objective functions of building resource utilization enterprises and traditional building materials enterprises are

$$max\pi_r^M = (p_r - c_r - mt)q_r - \frac{\varphi q_r^2}{2}, \tag{17}$$

$$max\pi_n^M = [p_{n1} - c_n - t]q_{n1} + [p_n - c_n - t]q_n. \tag{18}$$

Theorem 3. *In mode M, according to backward induction, it can be calculated that when* $\beta > \delta^2/(2\delta + \psi)$, *the optimal decision of traditional building materials enterprise and construction waste recycling enterprise is as follows:*

$$q_n^{M*} = \frac{\delta(c_r + mt - 2(c_n + t)\beta\delta + \alpha(-1 + 2\beta)\delta) - (c_n + t - \alpha)\beta\psi}{-\delta^2 + \beta(2\delta + \psi)}, \tag{19}$$

$$q_{n1}^{M*} = \frac{1}{2}(\alpha - c_n - t), \tag{20}$$

$$\tau^{M*} = \frac{\alpha\delta - c_r + mt/2\beta\delta + \beta\psi + (c_n + t)\delta - c_r + mt/ - \delta^2 + \beta(2\delta + \psi)}{\alpha - c_n - t}, \tag{21}$$

$$q_r^{M*} = \frac{\alpha\delta - c_r - mt/2\beta\delta + \beta\psi + (c_n + t)\delta - c_r - mt/ - \delta^2 + \beta(2\delta + \psi)}{2(\alpha - c_n - t)}(\alpha - c_n - t). \tag{22}$$

Substituting equations (19)–(22) into objective function (17) and (18), it can be obtained:

$$\pi_n^{M*} = \frac{1}{4}\left((c_n + t - \alpha)^2 + \frac{(\delta(-cr - mt + 2(c_n + t - \alpha)\beta + \alpha\delta) + (c_n + t - \alpha)\beta\psi)^2}{\beta(2\delta + \psi)(-\delta^2 + \beta(2\delta + \psi))}\right), \tag{23}$$

$$\pi_r^{M*} = \frac{\left(\delta\left(4(c_r + mt)\beta - (c_r + mt + 2(c_n + t + \alpha)\beta)\delta + \alpha\delta^2\right) + \beta(2c_r + 2mt - (c_n + t + \alpha)\delta)\psi\right)^2}{8(2\delta + \psi)\left(\delta^2 - \beta(2\delta + \psi)\right)^2}. \tag{24}$$

5. Model Analysis and Comparison

Based on the three cases of nonuse regulation and subsidy or tax incentive regulation, this section studies the driving path of incentive regulation, analyzes the changes in corporate profits, regulation benefit, and social welfare, discusses how the government makes incentive regulation and how enterprise makes decisions, and provides important management enlightenment for the decision-making of the government and enterprise.

5.1. The Driving Path of Incentive Regulation. This part describes the driving path of incentive regulation in three cases. U_e^i is defined as environmental damage caused by building materials products, and $i \in \{N, S, M\}$ represents the environmental damage under the no regulation, subsidy, and tax incentive regulations, respectively, as shown in the following equation:

$$U_e^i = d_n(q_{n1} + q_n) + d_r q_r. \tag{25}$$

Substituting equations (3), (4), (6), (11), (12), (14), (19), (20), and (22) into the objective function (25), we can obtain:

$$U_e^{N*} = d_n\left(q_{n1}^{N*} + q_r^{N*}\right) + d_r q_r^{N*}, \tag{26}$$

$$U_e^{S*} = d_n\left(q_{n1}^{S*} + q_n^{S*}\right) + d_r q_r^{S*}, \tag{27}$$

$$U_e^{M*} = d_n\left(q_{n1}^{M*} + q_n^{M*}\right) + d_r q_r^{M*}. \tag{28}$$

π_p^i is defined as regulation benefit with environmental concern, which is composed of Taxes on building materials products and environmental damage. And $i \in \{N, S, M\}$, respectively, represent regulation benefit under no regulation, subsidy, and tax incentive regulations as shown in the following equation:

$$\begin{cases} \pi_p^N = tq_r + t(q_n + q_{n1}) - U_e^N, \\ \pi_p^S = tq_r + t(q_n + q_{n1}) - sq_r - U_e^S, \\ \pi_p^M = mtq_r + t(q_n + q_{n1}) - U_e^M. \end{cases} \tag{29}$$

Substituting (3), (4), (6), (11), (12), (14), (19), (20), and (22) into corresponding objective function (29), we can obtain:

$$\pi_p^{N*} = tq_r^{N*} + t\left(q_n^{N*} + q_{n1}^{N*}\right) - U_e^{N*}, \tag{30}$$

$$\pi_p^{S*} = tq_r^{S*} + t\left(q_n^{S*} + q_{n1}^{S*}\right) - U_e^{S*}, \tag{31}$$

$$\pi_p^{M*} = tq_r^{M*} + t\left(q_n^{M*} + q_{n1}^{M*}\right) - U_e^{M*}. \tag{32}$$

SW_i is defined as social welfare, which is composed of profit of construction waste recycling enterprise and profit of traditional building materials enterprise regulation benefit. And $i \in \{N, S, M\}$, respectively, represent social welfare under no regulation, subsidy, and tax incentive regulations as shown in the following equation:

$$SW_i = \pi_p^i + \pi_n^i + \pi_r^i. \quad (33)$$

Substituting equations (7), (8), (30), (15), (16), (31), (23), (24), and (32) into corresponding objective function (33), we can obtain:

$$SW_N^* = \pi_p^{N*} + \pi_n^{N*} + \pi_r^{N*}, \quad (34)$$

$$SW_S^* = \pi_p^{S*} + \pi_n^{S*} + \pi_r^{S*}, \quad (35)$$

$$SW_M^* = \pi_p^{M*} + \pi_n^{M*} + \pi_r^{M*}. \quad (36)$$

5.1.1. Subsidy Incentive Regulation Driving Path

Proposition 1

(1) By comparing equations (7), (8), (15), and (16), we can obtain:

$$\pi_n^{N*} > \pi_n^{S*}, \pi_r^{S*} > \pi_r^{N*}. \quad (37)$$

(2) By comparing (31), we can obtain:

$$d_n > \frac{\left[2\beta(2\delta+\psi)-\delta^2\right]d_r}{\delta(2\delta+\psi)}, \text{then } U_e^{N*} > U_e^{S*}, \pi_p^{N*} > \pi_p^{S*}. \quad (38)$$

(3) By comparing (34) and (35), we can obtain: when $dn > d_n^1$, then

$$SW_s^* > SW_N^*. \quad (39)$$

Among them, $d_n^1 = (2d_r + s - 2t)\beta + (\alpha - c_n)\delta/\delta + \delta(-2s + 4t - 4d_r\beta - 3s\beta + 6t\beta + 2c_r(2+\beta) - 2\alpha(2+\beta)\beta)/4\beta(2\beta + \psi) + \beta\delta(2c_r - s + 2t - 2(c_n + t)\delta)/ - 4\delta^2 + 4\beta(2\delta + \psi)$.

(1) According to (37), the profit of traditional building materials enterprises under subsidy incentive regulation π_n^{S*} is lower than that under no regulation π_n^{N*}, while the profit π_r^{S*} of construction waste recycling enterprise under subsidy incentive regulation is higher than that under no regulation π_r^{N*}, which means that after the government implements subsidy incentive regulations, the profits of traditional building materials enterprises will decline, while the profits of construction waste recycling enterprise will rise. This shows that the subsidy incentive regulation has an incentive effect on construction waste recycling enterprise but has a restraining effect on traditional building materials enterprise.

(2) The type (38) shows that when the unit new building materials product's impact on the environment factor d_n is bigger than $[2\beta(2\delta+\psi) - \delta^2]d_r/\delta(2\delta + \psi)$, which means that when the environmental damage of new building materials products production is bigger, then environmental damage under no regulation U_e^{N*} is bigger than the environmental damage under subsidy incentive regulation U_e^{S*}, and the regulation benefit under subsidy incentive regulation π_p^{S*} is lower than that without regulation π_p^{N*}. In other words, the subsidy incentive regulation can effectively reduce the damage of construction waste to the environment, but it is not enough to make up for the subsidy expenditure paid by the government, resulting in the decline of regulation benefits.

(3) According to (39), when the environmental impact coefficient of unit new building materials d_n is greater than d_n^1, which means that when the production of new building materials damages the environment greatly, the subsidy incentive regulation will make the profits of traditional building materials enterprises π_n decline, the profits of construction waste recycling enterprise π_r increase, the regulation benefit π_p decreases, and the social welfare SW increases. The social welfare under subsidy incentive regulation SW_s^* is higher than that without regulation SW_N^*. It can be seen that when the production of new building materials damages the environment greatly, it is necessary for the government to implement subsidy incentive regulations. On the contrary, when the environmental impact coefficient of new building materials is less than d_n^1, which means that the environmental damage of new building materials is relatively small, the social welfare SW is reduced, and there is no need for the government to implement subsidy incentive regulations.

5.1.2. The Driving Path of Tax Incentive Regulation

Proposition 2

(1) By comparing (6) and (7), (20) and (21), we can obtain:

$$\pi_n^{N*} > \pi_n^{M*}, \pi_r^{M*} > \pi_r^{N*}. \quad (40)$$

(2) By comparing (26) and (28), (30) and (32), we can obtain: when $d_n > [2\beta(2\delta+\psi) - \delta^2]d_r/\delta(2\delta+\psi)$, then

$$U_e^{N*} > U_e^{M*}, \pi_p^{N*} > \pi_p^{M*}. \quad (41)$$

(3) By comparing (34) and (36), we can obtain: when $d_n > d_n^2$, then $SW_M^* > SW_N^*$

$$d_n^2 = \frac{2d_r\beta - (1+m)t\beta + (\alpha - c_n)\delta}{\delta} + \frac{\delta(-4d_r\beta + 2c_r(2+\beta) + (1+m)t(2+3\beta) - 2\alpha(2+\beta)\delta)}{4\beta(2\delta+\psi)} + \frac{\beta\delta(2c_r + t + mt - 2(c_n + t)\delta)}{-4\delta^2 + 4\beta(2\delta+\psi)}. \quad (42)$$

(1) *From (40), it can be seen that the profit of traditional building materials enterprise under the regulation of tax incentives $\pi_n^{M^*}$ is lower than that of traditional building materials enterprises without regulation $\pi_n^{S^*}$, while the profits of construction waste recycling enterprise under the regulation of tax incentives $\pi_r^{M^*}$ are higher than that without regulation $\pi_r^{N^*}$, which means that after the government's implementation of tax incentives, the profits of traditional building materials enterprises will decline, and the profits of construction waste recycling enterprise will rise. This shows that the tax incentive regulation also has an incentive effect on the construction waste recycling enterprise but has a restraining effect on the traditional building materials enterprises.*

(2) *By type (41), when the unit new building materials product's impact on the environment factor d_n is bigger than $[2\beta(2\delta+\psi)-\delta^2]d_r/\delta(2\delta+\psi)$, which means that when the environmental damage of new building materials products production is bigger, then the environmental damage under no regulation $U_e^{N^*}$ is bigger than the environmental damage under the tax incentive regulation $U_e^{M^*}$, and the regulation benefit of tax incentives $\pi_p^{M^*}$ is lower than that of no regulation $\pi_p^{N^*}$. In other words, the adoption of tax incentives and regulations can effectively reduce the damage of construction waste to the environment but will lead to a large decrease in the market of new building materials products, and the government's tax revenue from traditional building materials enterprises will decrease accordingly. Olsen et al. [38] also confirmed that government incentive measures were not enough to overcome the weak demand of the transaction market brought by this, which led to the decline of environmental regulation benefits.*

(3) *According to (42), when the environmental impact coefficient of unit new building materials d_n is greater than d_n^2, which means that the environmental damage of new building materials products production is greatly, then the preferential tax incentive regulation can make the profit of traditional building materials enterprise π_n down, regulation benefit π_p fell, but profits of construction waste recycling enterprise and social welfare SW rise. In addition, preferential tax incentive regulation under the social welfare SW_M^* is greater than no regulation under the social welfare SW_N^*. It can be seen that when the new building materials damage the environment greatly, it is necessary for the government to implement tax incentives and regulations. On the contrary, when the environmental impact coefficient of new building materials is less than d_n^2, which means that the environmental damage of new building materials is relatively small, the social welfare SW is reduced, and there is no need for the government to implement tax incentive regulations.*

5.2. Research on Optimal Decision. In view of the description of the driving path of the above three incentive regulations, this section will discuss how the government makes incentive regulations and how enterprise makes decisions.

5.2.1. Optimal Government Decision

Proposition 3. *By comparing (15) and (16), (23) and (24), (27) and (28), (35) and (36), it can be obtained: when $t < s/(1-m)$, then*

$$\begin{aligned}&\pi_r^{S^*} > \pi_r^{M^*}, \pi_n^{S^*} < \pi_n^{M^*}, U_e^{S^*} < U_e^{M^*},\\&SW_s^* > SW_M^*,\end{aligned} \tag{43}$$

when $t > s/(1-m)$, then

$$\begin{aligned}&\pi_r^{M^*} > \pi_r^{S^*},\\&\pi_n^{S^*} > \pi_n^{M^*}, U_e^{S^*} > U_e^{M^*},\\&SW_M^* > SW_s^*.\end{aligned} \tag{44}$$

According to (43), when the tax rate of unit building materials product is less than $s/(1-m)$, the profits of construction waste recycling enterprise and social welfare under subsidy incentive regulation (π_r^{S*} and SW_s^*) are higher than those under tax incentive regulation ($\pi_r^{M^*}$ and SW_M^*). The profit of traditional building materials enterprises under subsidy incentive regulation $\pi_n^{S^*}$ is lower than that under tax incentive regulation π_n^{M*}, tax incentives regulation will bring greater environmental damage ($U_e^{M*} > U_e^{S*}$). In other words, when the tax rate starting point is low, government subsidy incentive regulation can effectively improve the profit of construction waste recycling enterprise, reduce environmental damage, and improve the social welfare, but the profit of traditional building materials enterprise is reduced.

According to (44), when the tax rate of unit building materials product is greater than $s/(1-m)$, the profits of construction waste recycling enterprise and social welfare under the regulation of tax incentive ($\pi_r^{M^*}$ and SW_M^*) are higher than those under the regulation of subsidy incentive ($\pi_r^{S^*}$ and SW_s^*). The profit of traditional building materials enterprises under the regulation of tax incentive $\pi_n^{M^*}$ is lower than that under the regulation of subsidy incentive $\pi_n^{S^*}$. Subsidy incentive regulations will bring greater environmental damage ($U_e^{S*} > U_e^{M*}$). In other words, when the tax rate starting point is high, government tax incentive regulation can effectively improve the profits of construction waste recycling enterprise, reduce environmental damage, and improve the social welfare more than subsidy incentive regulation, but the profits of traditional building materials enterprises will also decrease.

Proposition 4. *As can be seen from Chapter 4, $Q_1 = (\alpha - c_n - t)\delta^2/2(2\delta+\psi)$.*

Make $\partial\pi_r^{S*}/\partial s = 0$, and we can get that if $Q_1 < Q < Q_2$,

$$\text{When } s > (1-\delta)t - (c_n\delta - c_r),\quad \frac{\partial \pi_r^{S^*}}{\partial s} < 0, \tag{45}$$

$$\text{When } s < (1-\delta)t - (c_n\delta - c_r),\quad \frac{\partial \pi_r^{S^*}}{\partial s} > 0, \tag{46}$$

$$\text{so } s^* = (1-\delta)t - (c_n\delta - c_r). \tag{47}$$

When the government adopts subsidy incentive regulation for construction waste recycling enterprises, it can be seen from Equations (45)–(47) that when the construction waste stock Q is in the interval (Q1,Q2), which means that when the construction waste stock is relatively small, there exists the optimal subsidy for unit renewable building materials products $s^* = (1-\delta)t - (c_n\delta - c_r)$. At this time, the profits of construction waste recycling enterprise will reach the peak. The government can calculate the optimal subsidy amount according to Formula (47), so there is no need to blindly add additional subsidy input.

In addition, it can be seen from (47) that s^* is negatively correlated with the preference of the builder for renewable building materials δ. Therefore, the government can strengthen the publicity of environmental protection, improve the recognition of the builder for renewable building materials, and reduce the government's subsidy expenditure.

Proposition 5. *As can be seen from Chapter 4,* $Q_1 = (\alpha - c_n - t)\delta^2/2(2\delta + \psi)$.

Make $\partial\pi_r^{S*}/\partial m = 0$, we can get that $Q_3 = \delta^2(c_r + mt - \alpha\delta)/((c_r + mt - \alpha\delta) + c_r + mt - (c_n + t)\delta)(\alpha - c_n - t)/2(2\delta + \psi)$. If $Q_1 < Q < Q_3$,

$$\begin{gathered}\text{When } m < \frac{(c_n\delta + t\delta) - c_r}{t},\\ \frac{\partial \pi_r^{S^*}}{\partial m} < 0,\end{gathered} \tag{48}$$

$$\text{When } m > \frac{(c_n\delta + t\delta) - c_r}{t},\quad \frac{\partial \pi_r^{S^*}}{\partial m} > 0, \frac{\partial \pi_r^{S^*}}{\partial s} > 0, \tag{49}$$

$$\text{so } m^* = \frac{(c_n\delta + t\delta) - c_r}{t} \tag{50}$$

When the government adopts tax incentive regulation for construction waste recycling enterprises, it can be seen from Equations (48)–(50) that when the construction waste stock Q is in the interval (Q1,Q3), which means that when the construction waste stock is relatively small, there exists the optimal tax adjustment coefficient $m^* = (c_n\delta + t\delta) - c_r/t$, means that the optimal tax preference ratio is $(1 - (c_n\delta + t\delta) - c_r/t)$. At this point, the profits of construction waste recycling enterprise will reach the peak. The government can calculate the optimal proportion of tax incentives according to Equation (50).

In addition, it can be seen from (50) that m^* is positively correlated with builder's preference for renewable building materials δ. Therefore, the government's strengthening of environmental protection publicity and increasing builder's recognition of renewable building materials can reduce tax incentives and increase government tax revenue.

5.2.2. Enterprise Optimal Decision

Proposition 6

(1) By comparing (6) and (11), we can get:

$$q_n^{S*} < q_n^{N*}. \tag{51}$$

The first derivative of (11) with respect to S can be obtained:

$$\frac{\partial q_n^{S*}}{\partial s} < 0. \tag{52}$$

(2) By comparing (6) and (22), we can get:

$$q_n^{M*} < q_n^{N*}. \tag{53}$$

The first derivative of (22) with respect to M can be obtained:

$$\frac{\partial q_n^{M*}}{\partial m} > 0. \tag{54}$$

According to Equations (51)–(54), the production of new building materials under subsidy incentives (tax incentives) q_n^{S*} (q_n^{M*}) is lower than the production of new building materials without regulation q_n^{N*}, and the production of new building materials under subsidy incentive regulation is negatively correlated with subsidy for unit renewable building materials but positively correlated with tax adjustment coefficient for unit renewable building materials. In other words, when the government adopts subsidy incentive or tax incentive regulation, traditional building materials enterprises should reduce the production of new building materials in time to avoid the risk brought by the shrinking market of new building materials. Obviously, the incentive regulation gives construction waste recycling enterprise a cost advantage in production. In order to obtain higher profits, construction waste recycling enterprise should improve the resource utilization rate and produce more renewable building materials.

Proposition 7

(1) By comparing (5),(6),(13), and (14), we can get:

$$q_r^{S*} > q_r^{N*}, \tau^{S*} > \tau^{N*}. \tag{55}$$

The first-order derivative of (13) and (14) with respect to M can be obtained:

$$\frac{\partial q_r^{S*}}{\partial s} > 0, \frac{\partial \tau^{S*}}{\partial s} > 0. \tag{56}$$

(2) By comparing (5),(6),(2122), it can be obtained:

$$q_r^{M*} > q_r^{N*}, \tau^{M*} > \tau^{N*}. \tag{57}$$

The first derivative of (2122) with respect to M can be obtained:

$$\frac{\partial q_r^{M*}}{\partial m} < 0, \frac{\partial \tau^{M*}}{\partial m} < 0. \quad (58)$$

According to Equation (55)–(58), the production of renewable building materials products under subsidy incentives (tax incentives) q_r^{S*} (q_n^{N*}) and the rate of resource utilization under subsidy incentives (tax incentives) τ^{S*} (τ^{M*}) are higher than that without regulation (q_n^{N*} and τ^{N*}). The production of renewable building materials and the rate of resource utilization are positively correlated with subsidy for unit renewable building materials but negatively correlated with the tax adjustment coefficient of renewable building materials. In other words, when the government adopts subsidy incentive or tax incentive regulation, the construction waste recycling enterprise should improve the production of renewable building materials to meet the market demand and improve their profits. The reason is that incentive regulations can make construction waste recycling enterprise has cost advantages in production. In order to obtain higher profits and more preferential benefits from the government, enterprises should improve the resource utilization rate of construction waste and produce more renewable building materials.

6. Numerical Simulation

At the end of 2021, we conducted field research on several building materials production enterprises in southwest China to obtain relevant data. In order to ensure the accuracy of data in the numerical simulation, this paper investigates the building materials market and obtains the data of production, cost, resource utilization rate, and so on. Then, we take the average of these data and substitute them into the model to make the numerical analysis model meaningful and concise. Therefore, the relevant parameters are assumed as follows: $c_r = 0.5c_n, d_r = 0.4d_n, c_r = 0.5, c_n = 1, dr = 0.2, dn = 0.5, \psi = 1, \delta = 0.4, s = 0.25$.

Figures 2 and 3 show that the profit π_r and the resource utilization rate τ of construction waste recycling enterprise increase gradually with the increase of preference δ for renewable building materials. It shows that the government can strengthen the publicity of environmental protection, improve the recognition of construction companies on renewable building materials products, and give priority to the use of renewable building materials products in construction activities, so as to improve the production enthusiasm of construction waste recycling enterprise and promote the development of construction waste resource recycling industry.

Figures 4 and 5 show that with the increase of resource utilization cost coefficient ψ, the profit π_r and resource utilization rate τ of construction waste recycling enterprises decrease gradually. It shows that the key to promote the construction waste recycling industry upgrading is to improve the resource recycling technology of construction waste recycling enterprises, so as to reduce the cost of resource recycling and fundamentally improve the advantages of resource recycling.

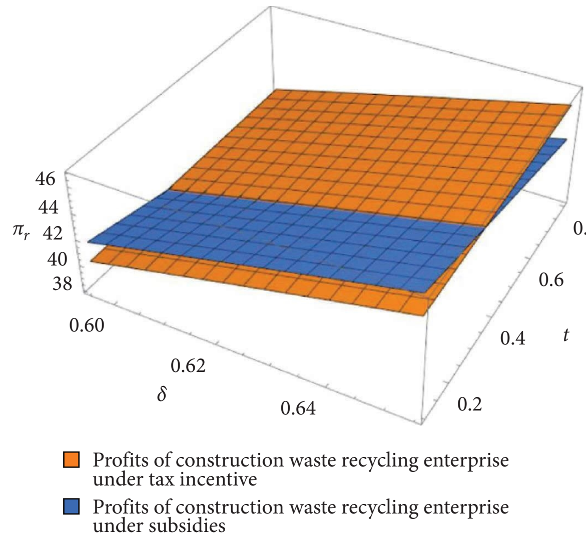

FIGURE 2: The impact of δ and t on the revenue of construction waste recycling enterprise (π_r).

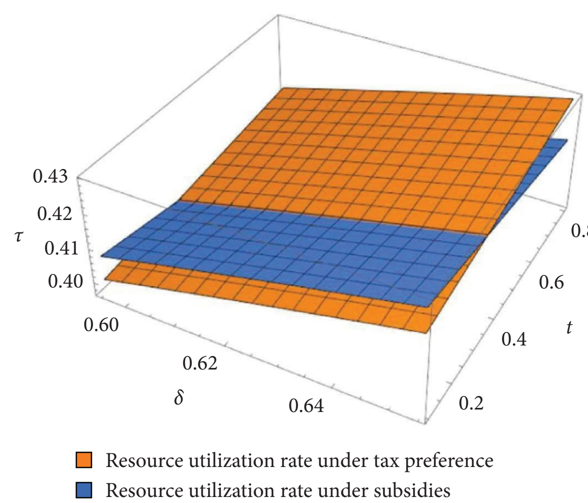

FIGURE 3: The impact of δ and t on the resource utilization rate (τ).

In addition, Figures 2–5 shows that with the increase of the tax rate t of government units of new building materials, the profit $\pi_r^{M^*}$ and the resource utilization rate τ^{M*} of construction waste recycling enterprises under tax incentives will increase, while the profit $\pi_r^{S^*}$ and the resource utilization rate τ^{S*} of construction waste recycling enterprises under subsidy regulations will decrease. Therefore, under the tax incentive regulation, the higher tax rate of unit building materials, the higher discount amount of renewable building materials products will be. Then, the cost advantage of renewable building materials will be greater than that of new building materials. Obviously, construction waste recycling enterprise will improve resource utilization rate τ and recycle construction waste more actively to make more profits.

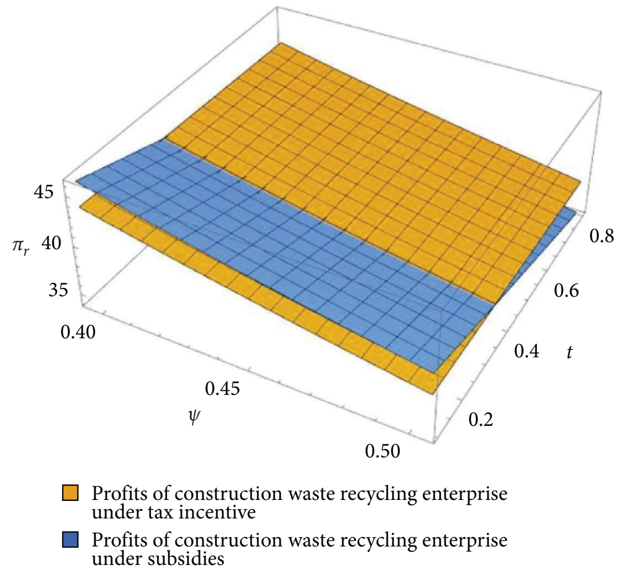

FIGURE 4: The impact of ψ and t on the revenue of construction waste recycling enterprise (π_r).

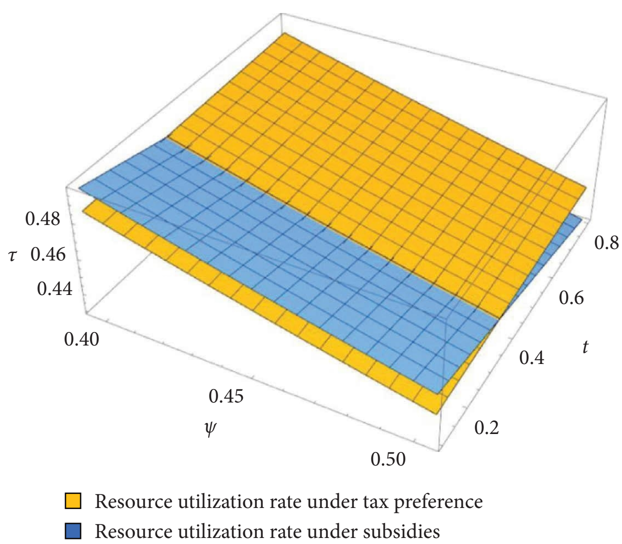

FIGURE 5: The impact of ψ and t on the resource utilization rate (τ).

7. Conclusion and Prospect

The research on resource recovery of construction waste has become an urgent task in global economic development, urban renewal, and construction. The effectiveness of resource utilization policy greatly affects the effect of resource utilization. Therefore, this study analyzes the decision-making behavior between construction waste recycling enterprises and traditional building materials enterprises under different incentive regulations of the government. Therefore, this study establishes a market model which is contracted by government, a traditional building materials enterprise, a construction waste recycling enterprise, and a builder, analyzed the driving path of government subsidies and preferential tax regulation, as well as how the government can develop the upgrade of environmental protection and use incentive regulations, and the specific conclusions and suggestions are as follows:

(1) The government's implementation of incentive regulations can effectively improve the production enthusiasm and profits of construction waste recycling enterprise, reduce environmental damage, and improve the social welfare.

(2) The optimal decision of the government is not to adopt any incentive regulation for the construction waste recycling enterprise when the new building materials are less harmful to the environment. When the tax rate levied per unit of primary building materials is small, the government should adopt subsidy regulations for construction waste recycling enterprise. When the tax rate of unit new building materials is large, the government should adopt preferential tax regulations for construction waste recycling enterprise. In addition, the government needs to step up efforts to promote environmental protection and increase the recognition of renewable building materials products among builders.

(3) Resource recovery cost coefficient and builder's preference for renewable building materials have a great impact on the profit and resource utilization rate of construction resource recovery enterprises. Therefore, construction waste recycling enterprises need to increase investment in resource recycling technology and reduce the cost of resource recycling, so as to fundamentally improve the cost advantage of renewable building materials products and promote the overall development of the construction waste resource recycling industry.

Some aspects of the study need further work: the market model in this paper only considers building materials provided by the builder, which simplifies the influence of materials provided by the construction Company. In the future, the model can be further improved to consider building materials supplied by the builder or materials both supplied by the builder and the construction Company.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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