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Research Article

Exploring the Quantity Change Pattern of Environment-Friendly Products in the Sharing Economy

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In the practice of various Internet-based sharing economies, environmental issues of shared products become more prominent and urgent. By analysing the relationship among government, enterprises, and consumers, this paper develops a system dynamics model based on the evolutionary game theory to explore the quantity change pattern of environment-friendly products in a sharing industry. A discrete dynamic system simulation of the quantity change process takes shared bikes in Beijing as a case study. The simulation results are consistent with the analysis of evolutionary game theory. The results show that government subsidies to both enterprises and consumers can lead to higher quantities of environment-friendly shared products, while consumer subsidy is better than enterprise subsidy. In addition, governments and enterprises need to ensure moderate investments to improve consumer experience and environmental awareness.

1. Introduction

A sharing economy is a form of effective allocation and use of social resources in the Internet era. The advantage of this paradigm is to tap and utilise the idle resources of society and gradually achieve green development [1, 2]. The Chinese government proposed to promote the development of the sharing economy vigorously in 2016 [3]. Since then, a variety of shared products such as shared bikes, shared mobile power, shared cars, and shared umbrellas have flooded into this emerging market. However, as an imperfect business model, the sharing economy model has many problems at the current stage, such as excessive market competition, terrible service experience, and high operating costs [4–6]. Solving those various problems of the existing shared products is a key to ensuring the healthy development of the sharing economy. Since the original purpose of the sharing economy was to save energy and reduce greenhouse gas emissions, the environmental issues of the shared products themselves are often overlooked.

This paper uses the example of bike sharing. Bike sharing in China was promoted in major cities in 2016, which has become the fourth largest mode of travel after cars, buses, and subways. In 2017, the share of bikes in urban transportation increased from 5.5% to 11.6%, reducing short-distance trips by cars by 55% [7]. In the first quarter of 2017 alone, Ofo's users rode a total distance of nearly 600 million kilometres, which reduced the carbon dioxide emissions by 130,956 tons [8], while Mobike's users rode a total distance of more than 2.5 billion kilometres and reduced carbon emissions by 540,000 tons [7].

This calculation of carbon emission reduction does not consider the resource consumption in the bike production, operation, and recycling stages. Chen et al. obtained the energy consumption data of Ofo's shared bikes and found that based on the current number of bikes, Ofo's bikes could reduce carbon emissions after at least 686 days of riding [9]. However, the low cost of Ofo's bike resulted in a lifespan much less than 686 days [10]. This kind of bike itself is an environment-unfriendly product. Therefore, it is necessary for the government to pay attention to the environmental issues of the shared products themselves and promote more environment-friendly shared products in various shared industries. This measure will lay the foundation for the sustainable development of the sharing economy.

The primary purpose of this paper is to explore the quantity change pattern of environment-friendly products in a sharing industry. We analyse the influencing factors that contribute to the change among government, enterprises, and consumers. Several scholars have studied similar issues using methodologies such as evolutionary game theory, innovation diffusion theory, and statistical analysis. These studies provide some theoretical basis for the present paper. However, the complex relationship among stakeholders cannot be fully described by the game theory model alone. The model needs to be combined with the actual case.

In this paper, a system dynamics (SD) model based on evolutionary game theory is developed to explain the change process of the enterprise's strategy choice by analysing the costs and benefits of the enterprise in different strategies. The model effectively describes the influence relationships among the stakeholders and introduces evolutionary game theory to define the rate of change in the quantity of environment-friendly shared products. The model can be divided into three modules: the product quantity change module, the different product benefit module, and the consumer module. The quantity of environment-friendly shared products is determined by enterprises, which make decisions by measuring the effectiveness of their environmental investments, consumer experience and environmental preference, and government legislation and policies. In order to address environmental and energy issues, the government can influence enterprise decisions and consumer preferences by establishing and revising relevant policies. The model studies the relationship between the quantities of environment-friendly and environment-unfriendly products in a sharing industry. Our study provides an important inference for a sharing industry and government to develop appropriate policies for promoting sustainable development.

The paper is structured as follows. In Section 2, the literature review is introduced. In Section 3, the SD model of the quantity change of environment-friendly shared products is developed. In Section 4, the simulation of the model is presented. Finally, the conclusion and limitations are described in Section 5.

2. Literature Review

The sharing economy was introduced by Marcus Felson and Joel Spaeth in 1978 [11]. In this economic model, stakeholders pay different costs and share the economic benefits, and most of this model uses the Internet as a medium [12, 13]. Lin and Jiang subdivided the concept of sharing economy with shared products into two kinds: one kind of shared idle resources is one's own time or services, such as Uber and DiDi, and the other kind of shared resources is tangible assets or products owned by enterprises, such as shared bikes and shared cars [14].

The object of this study is enterprises that share their products. In essence, these enterprises offer an online to offline (O2O) product rental business [15–17]. Therefore, studying the factors that make a sharing industry sustainable had to research the shared product itself. Acquier et al. believed that shared products are a waste of resources if they are put on the market in a disorderly manner [18]. Zhang et al. evaluated the remanufacturability of end-of-life products from technical, economic, and environmental perspectives [19]. Martin took a sustainable design perspective to discover the negative effects of shared bikes on the environment and resources [20]. Yang et al. found that shared bikes' current product life cycle is incomplete and listed the problems in the closed-loop supply chain [21]. Ma et al. explored the key elements of collaborative multiparty governance using the development of shared bikes in Shanghai as an example [22]. Many scholars focused on the government's role in the sharing economy, concluding that proper governance can promote industry's sustainable development [23–26]. The above literature provides ideas for this paper to analyse the impact of government policies.

Several methodologies are used to study the problem of shared products, such as evolutionary game theory and system dynamics. Evolutionary game theory was developed to overcome the disadvantages of traditional game theory when analysing the bounded rationality of players and the dynamic process of game playing [27, 28]. Helbing et al. explored how this general framework can improve people's lives [29]. Based on evolutionary game theory, Yang et al. analysed the conflict between government and enterprises in the bike-sharing system [30]. Similarly, Li and Ma developed an evolutionary game model to study the strategic choices between consumers and enterprises [31]. Huang et al. considered that increasing government subsidies is beneficial to the green development of a sharing industry through the analysis of evolutionary games [32]. From another perspective, Chica et al. concluded that the government should improve the punishment and protection mechanisms in the sharing economy [33]. System dynamics is a practical software simulation approach for analysing feedback behaviour in complex systems and strategy effectiveness [34, 35]. Ranjbari et al. established an SD model to find the influencing factors and their interactions that affect the sustainability of the sharing economy [36]. Sun explored how to extend the lifetime of shared products with the SD model [37]. We identified the interactions among government, enterprises, and consumers, as well as factors related to shared products, with reference to the above studies.

Our model organically integrating system dynamics and evolutionary game theory was influenced by the study of Tian et al. [38], and the model studied competition between environment-friendly and environment-unfriendly products in a sharing industry. This paper is the first to combine multiple approaches to explore the competition issue of shared products. It gives essential management suggestions.

3. System Dynamics Evolutionary Game Model

This paper combines system dynamics and evolutionary game theory to analyse the relationships and behaviours of three stakeholders, such as government, enterprises, and consumers, when enterprises choose to operate environment-friendly or environment-unfriendly shared products. A mathematical model is developed based on the analysis, and simulations are performed based on actual data.

3.1. Model Description and Assumptions. Enterprises are mainly influenced by three driving factors: government policies, consumer perceptions, and competition among industries. In this case, enterprises will have two choices. The first choice is to operate environment-friendly shared products, for which enterprises will have to pay extra costs, such as using environment-friendly materials, developing energy-efficient products, creating recyclable design, improving the consumer experience, and establishing a healthy closed-loop supply chain for the products. The second choice is to operate environment-unfriendly shared products. Compared to the first choice, the product costs less; the consumer experience is less desirable; and the rental price is lower than the rental price of the environment-friendly product. All enterprises in a sharing industry interact with each other due to market competition, and the choices of enterprises may change, resulting in a change in the quantity of both products in the market, as shown in Figure 1. Government policies on subsidies for enterprises and consumers, as well as the products that consumers prefer to rent, may influence the change in the quantity.

The main objective of this paper is to explore how to increase the quantity of environment-friendly shared products in an industry. In our evolutionary game model, enterprises compete in a sharing industry. They have two pure strategies: "operate environment-friendly shared products" and "operate environment-unfriendly shared products", and they play the game by choosing different strategies. To describe the model better, we build a scenario based on evolutionary game theory and make the following assumptions [39].

Assumption 1. The market of the sharing industry is in a saturated state, and the total number of shared products in the market remains unchanged.

Since the rise of bike sharing, market competition within the various sharing industries has been intense, which makes enterprises to aim to maximise their benefits for their survival and growth. Therefore, enterprises prefer to choose the strategy with the greatest expected benefit. When enterprises choose to operate environment-friendly shared products (E), the average expected benefit per environment-friendly shared product is denoted as E_{PAE}. When enterprises choose to operate environment-unfriendly shared products (N), the average expected benefit per environment-unfriendly shared product is denoted as E_{PAN}. In a sharing industry, the actual benefit per shared product is different due to the different size, capacity, and resources of each enterprise. Therefore, we assume that the actual benefits are $E_{\mathrm{PE}} = E_{\mathrm{PAE}} + \alpha_E$ and $E_{\mathrm{PN}} = E_{\mathrm{PAN}} + \alpha_N$, where α_E and α_N are normally distributed random variables.

Assumption 2. The two strategies are mutually exclusive, and enterprises check their benefits and decide whether to change their strategies at each time unit. E_{Pi} and E_{Pj} denote the benefits when enterprises choose different strategies; E and N denote the two strategies of enterprises; then the expected benefit difference D_E between the two strategies can be expressed as follows:

$$D_E = \phi\left(E_{\mathrm{PE}} - E_{\mathrm{PN}}\right) - \phi\left(E_{\mathrm{PN}} - E_{\mathrm{PE}}\right), \quad (1)$$

where the function ϕ is

$$\phi\left(E_{Pi} - E_{Pj}\right) = \begin{cases} 0 & \text{if } E_{Pi} - E_{Pj} < 0 \\ \dfrac{\left(E_{Pi} - E_{Pj}\right)}{E_{Pi}} & \text{if } E_{Pi} - E_{Pj} \geq 0 \end{cases}, \quad (i, j = E, N). \quad (2)$$

Assumption 3. The enterprise's choice of strategy is influenced by its capabilities and resources, and p_C is assumed to be the probability of successfully implementing a new strategy, that is, the probability of successfully changing its product type. The probability of an enterprise choosing the strategy of "operating environment-friendly shared products" is denoted as p_E, and the probability of an enterprise choosing the strategy of "operating environment-unfriendly shared products" is denoted as p_N ($p_N = 1 - p_E$), where both p_E and p_N are functions of time. According to the definition of the replicator dynamics equation [39], the dynamic rate of change of the probability p_E of choosing the strategy of "operating environment-friendly shared products" is as follows:

$$\begin{aligned} \frac{\mathrm{d}p_E}{\mathrm{d}t} &= p_E\left(1 - p_E\right) D_E p_C \\ &= p_E p_N \left[\phi\left(E_{\mathrm{PE}} - E_{\mathrm{PN}}\right) - \phi\left(E_{\mathrm{PN}} - E_{\mathrm{PE}}\right)\right] p_C. \end{aligned} \quad (3)$$

3.2. Model Establishment

3.2.1. Model Framework. In this paper, the three modules in the model are the product quantity change module, the different product benefit module, and the consumer module. The product quantity change and the different product benefit modules are interconnected, and the consumer module has a unidirectional impact on the different product benefit module, as shown in Figure 2. The consumer module does not have a direct impact on the different product benefit module. The probability of enterprises choosing these two pure strategies determines the proportion of the two products in the market.

All business and social systems contain a host of assets, which can be viewed as stock or the accumulation of resources that change according to their physical inflows and

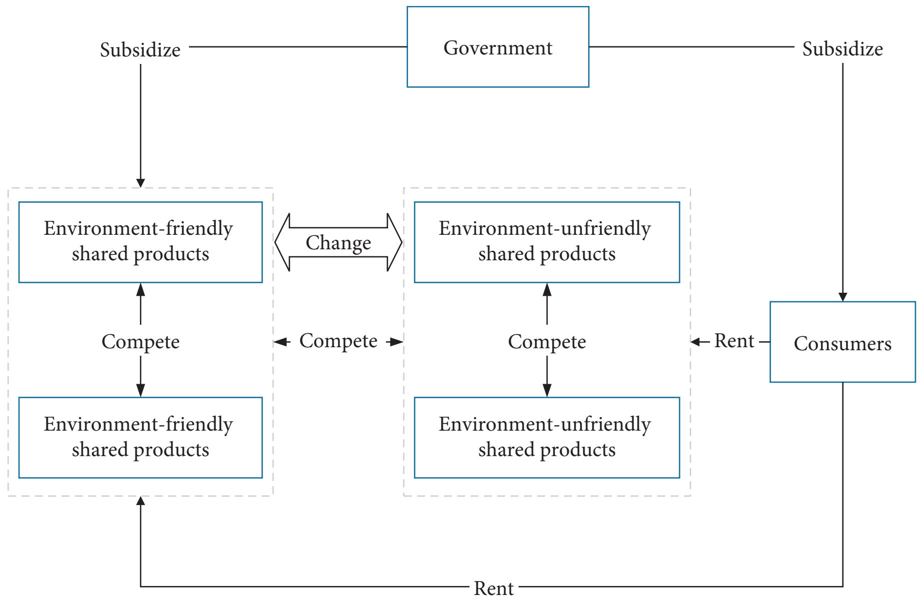

Figure 1: Analytical framework of changes in the quantity of environment-friendly shared products.

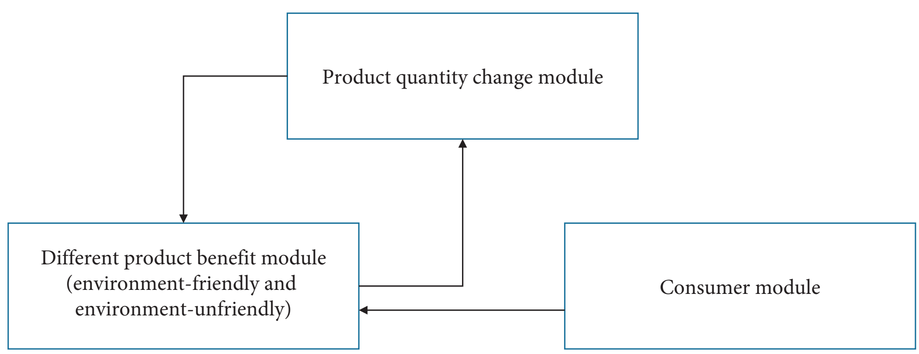

Figure 2: Basic framework of the system dynamics model.

outflows [15]. A system dynamics model in the form of a stock and flow diagram (SFD) can be created by capturing the stock and flow structure of the systems.

3.2.2. Description of Modules and Main Equations

(1) Product Quantity Change Module. The module analyses the change process of the quantity of environment-friendly products in a sharing industry based on the evolutionary game model, as shown in Figure 3. The figure presents the variables used for modelling the module and the causal links among them. The rectangles represent level variables indicating the cumulative results. The valve represents the rate variables indicating the physical flows of items feeding into or depleting. The module contains two level variables and one rate variable. The rate variable, CR, is built based on the replicator dynamics equation, and the two level variables, QE and QN, denote the quantities of environment-friendly and environment-unfriendly shared products, respectively.

In reality, an enterprise usually takes a certain amount of time to implement a new strategy, and the implementation time can be considered as normally distributed due to the different capabilities and resources of each enterprise [40], with a maximum implementation time of two months and an average implementation time of one month. In addition, the success of strategy implementation is constrained by the enterprise's capabilities and resources, and the probability of successfully implementing a new strategy can also be considered as normally distributed [41]. The main equations of this module are as follows:

$$\mathrm{CR} = \mathrm{QT} \times \mathrm{DR}, \tag{4}$$

$$\mathrm{DR} = \text{DELAY FIXED}\,(\mathrm{SR}, \text{RANDOM NORMAL}\,(0, 2, 1, 0.15, 1), \mathrm{SR}), \tag{5}$$

$$\begin{aligned}\mathrm{SR} = \frac{\mathrm{d}p_E}{\mathrm{d}t} &= p_E p_N \left[\phi\left(E_{\mathrm{PE}} - E_{\mathrm{PN}}\right) - \phi\left(E_{\mathrm{PN}} - E_{\mathrm{PE}}\right)\right] p_C \\ &= p_E p_N D_E p_C,\end{aligned} \tag{6}$$

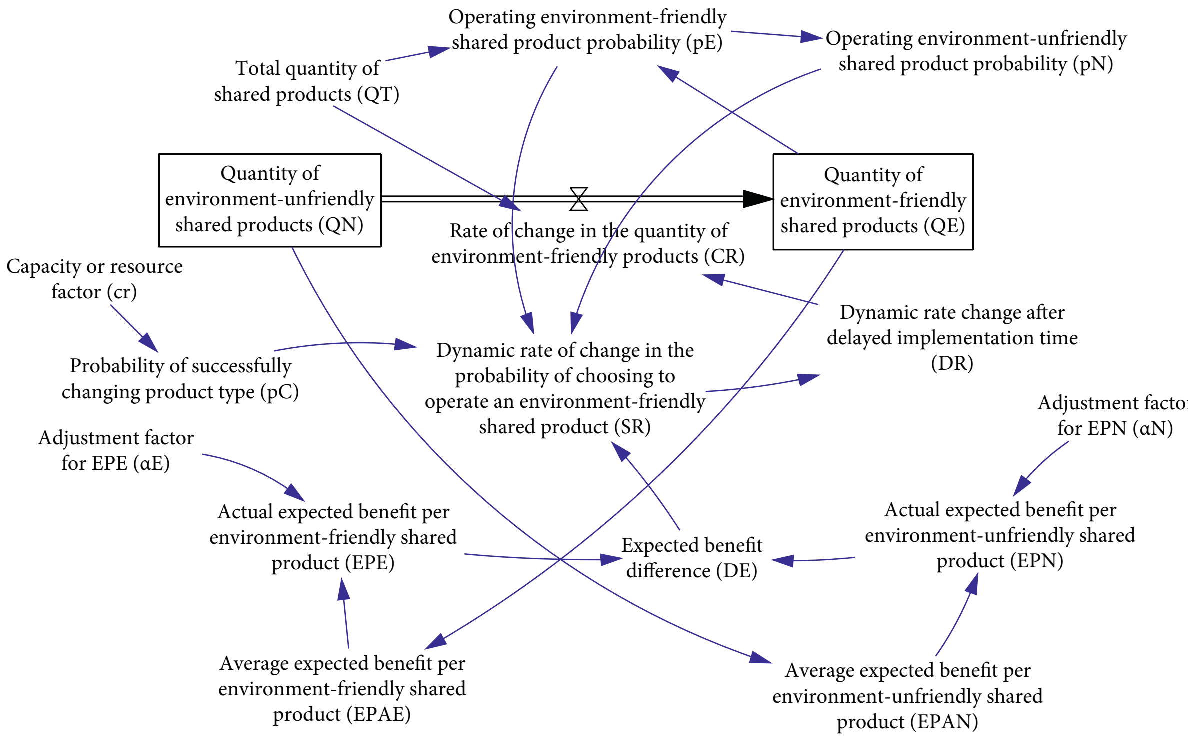

Figure 3: Product quantity change module.

$$D_E = \text{IF THEN ELSE}\left(E_{\text{PE}} - E_{\text{PN}} > 0, \frac{(E_{\text{PE}} - E_{\text{PN}})}{E_{\text{PE}}}, \frac{(E_{\text{PE}} - E_{\text{PN}})}{E_{\text{PN}}}\right), \tag{7}$$

$$p_C = \text{RANDOM NORMAL}\,(0, 1, cr, 0.05, 0.5). \tag{8}$$

Note the following:

DELAY FIXED ({input value}, {delay time}, {initial value})

IF THEN ELSE ({condition}, {ontrue}, {onfalse})

RANDOM NORMAL ({min}, {max}, {mean}, {stdev}, {seed}) where CR denotes the rate of change in the quantity of environment-friendly products, QT denotes the total quantity of products in a shared industry, SR denotes the dynamic rate of change in the probability of choosing to operate environment-friendly shared products, DR denotes the dynamic rate of change after delaying the implementation time required by the enterprise, and cr denotes the capacity and resource factor.

(2) Different Product Benefit Module. The different product benefit module contains E_{PE} and E_{PN} of the two different strategies that enterprises choose to operate environment-friendly shared products (E) and environment-unfriendly shared products (N). The benefit of enterprises is influenced by internal and external factors. Internal factors include the rental price and depreciation cost, the investment and operation cost, and the degree of environmental protection of the product. External factors include government subsidies and the consumer module. The government subsidies to enterprises and consumers are influenced by the subsidy factor and the degree of environmental protection, and reducing operating costs for enterprises operating environment-friendly shared products is influenced by the cost reduction factor and the degree of environmental protection. The benefit modules of both products are similar, and this paper shows the benefit module of environment-friendly shared products, as shown in Figure 4. E_{PAE} is determined by the difference between revenues and costs.

The main equations in the module are as follows:

$$E_{\text{PAE}} = (\text{PEH} - \text{CEP} + \text{SE}) \times \text{QCE} \times \frac{\text{NT}}{\text{QE}} + \text{RE} - \text{IE}, \tag{9}$$

$$\alpha_E = \text{RANDOM NORMAL}\,(-0.1, 0.1, 0, 0.01, 0), \tag{10}$$

$$\text{IE} = i \times e, \tag{11}$$

$$\text{SE} = s \times e, \tag{12}$$

$$\text{RE} = r \times e, \tag{13}$$

where PEH denotes the rental price of environment-friendly shared products; CEP denotes the depreciation cost of environment-friendly shared products; SE denotes government subsidies to enterprises operating environment-friendly shared products; QCE denotes the number of consumers using environment-friendly shared products; NT denotes the average number of rentals per day by consumers; QE denotes the quantity of environment-friendly shared

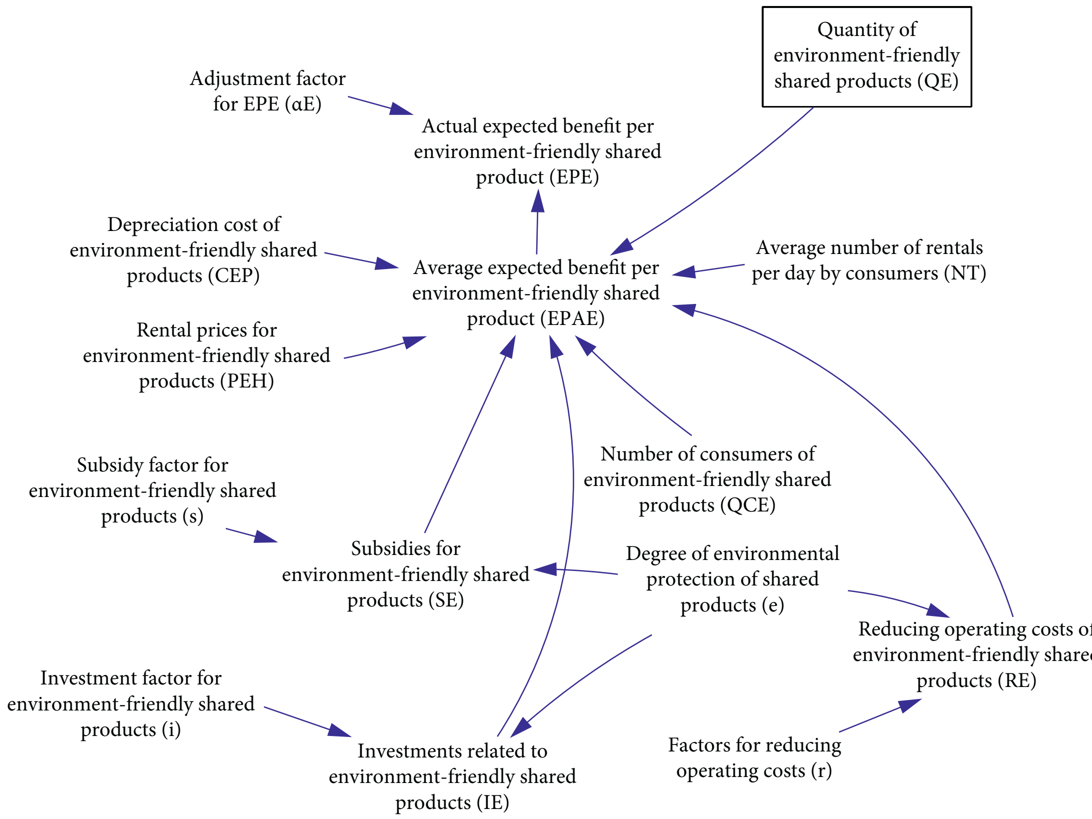

Figure 4: Benefit module of environment-friendly shared products.

products in the market; RE denotes reducing enterprise operating costs for environment-friendly products over environment-unfriendly products; IE denotes the investment in environment-friendly shared products; CEP, SE, RE, and IE are the average amount per product; e denotes the degree of environmental protection of the shared product; and i, s, and r denote the investment factor, subsidy factor, and reducing operating cost factor of the environment-friendly shared product, respectively.

(3) Consumer Module. The consumer module analyses the probability of consumers choosing environment-friendly products in the sharing market, as shown in Figure 5. In practice, the rental price and consumer experience of environment-friendly shared products are generally higher than environment-unfriendly shared products. Whether consumers choose to rent environment-friendly shared products depends on their experience and environmental preference ($\theta \in [0, 1]$), the rental price of environment-friendly shared products (PEH), the rental price of environment-unfriendly shared products (PNH), the payment factor of consumer experience and environmental preference (ep), and government subsidies for consumers to use environment-friendly shared products (CS).

When $\mathrm{PEH} = \mathrm{PNH} + \mathrm{CS} + \mathrm{ep} \times \theta$, consumers have the same utility of using both products [38]. This is a widely used method in utility analysis. The model assumes that consumer experience and environmental preference are uniformly distributed, and then the probability (PCE) of consumers choosing environment-friendly shared products is shown in the following equation:

$$\mathrm{PCE} = \frac{(\theta_{\max} - \theta)}{(\theta_{\max} - \theta_{\min})} = 1 - \frac{(\mathrm{PEH} - \mathrm{PNH} - \mathrm{CS})}{\mathrm{ep}}. \quad (14)$$

The other main equations in the module are as follows:

$$\mathrm{CS} = \mathrm{cs} \times e, \quad (15)$$

$$\mathrm{QCE} = \mathrm{QC} \times \mathrm{PCE}, \quad (16)$$

$$\mathrm{QCN} = \mathrm{QC} - \mathrm{QCE}, \quad (17)$$

where cs denotes the subsidy factor for consumers using environment-friendly shared products, QCE denotes the number of consumers choosing environment-friendly shared products, QCN denotes the number of consumers choosing environment-unfriendly shared products, and QC denotes the total number of consumers of this type of shared products.

3.2.3. System Dynamics Model of Environment-Friendly Shared Product Quantity Change. Based on the above analysis of the three modules, the model of environment-friendly shared product quantity change is shown in Figure 6, containing 2 level variables, 1 rate variable, 16 exogenous variables, and 17 auxiliary variables. Exogenous variables only affect the system and are not affected by it.

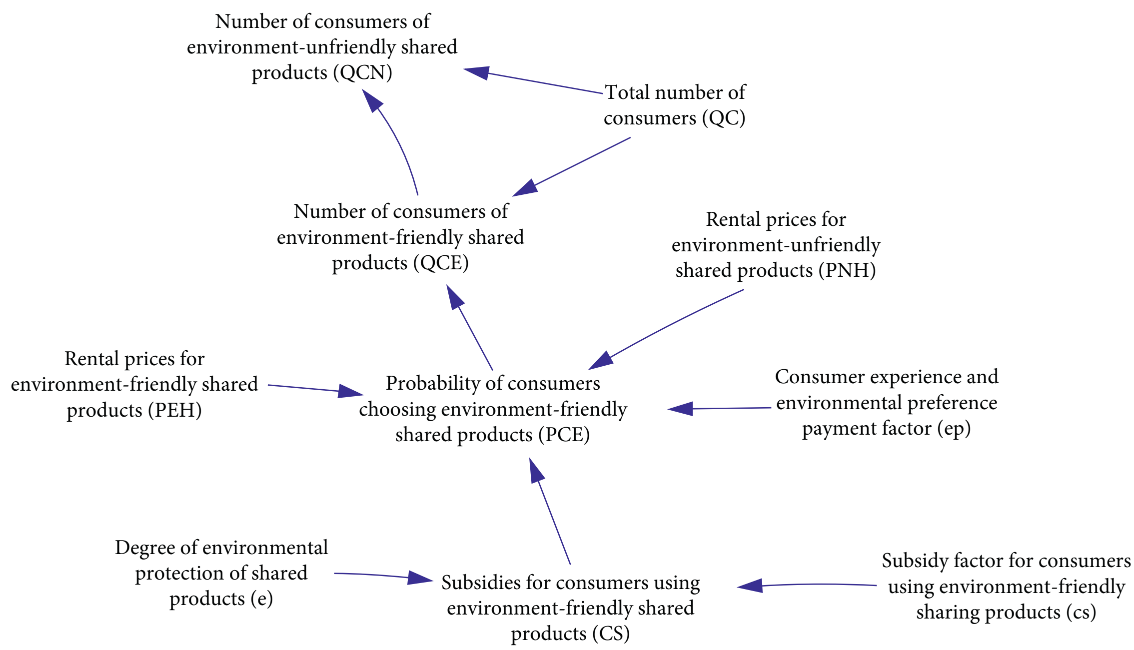

Figure 5: Consumer module.

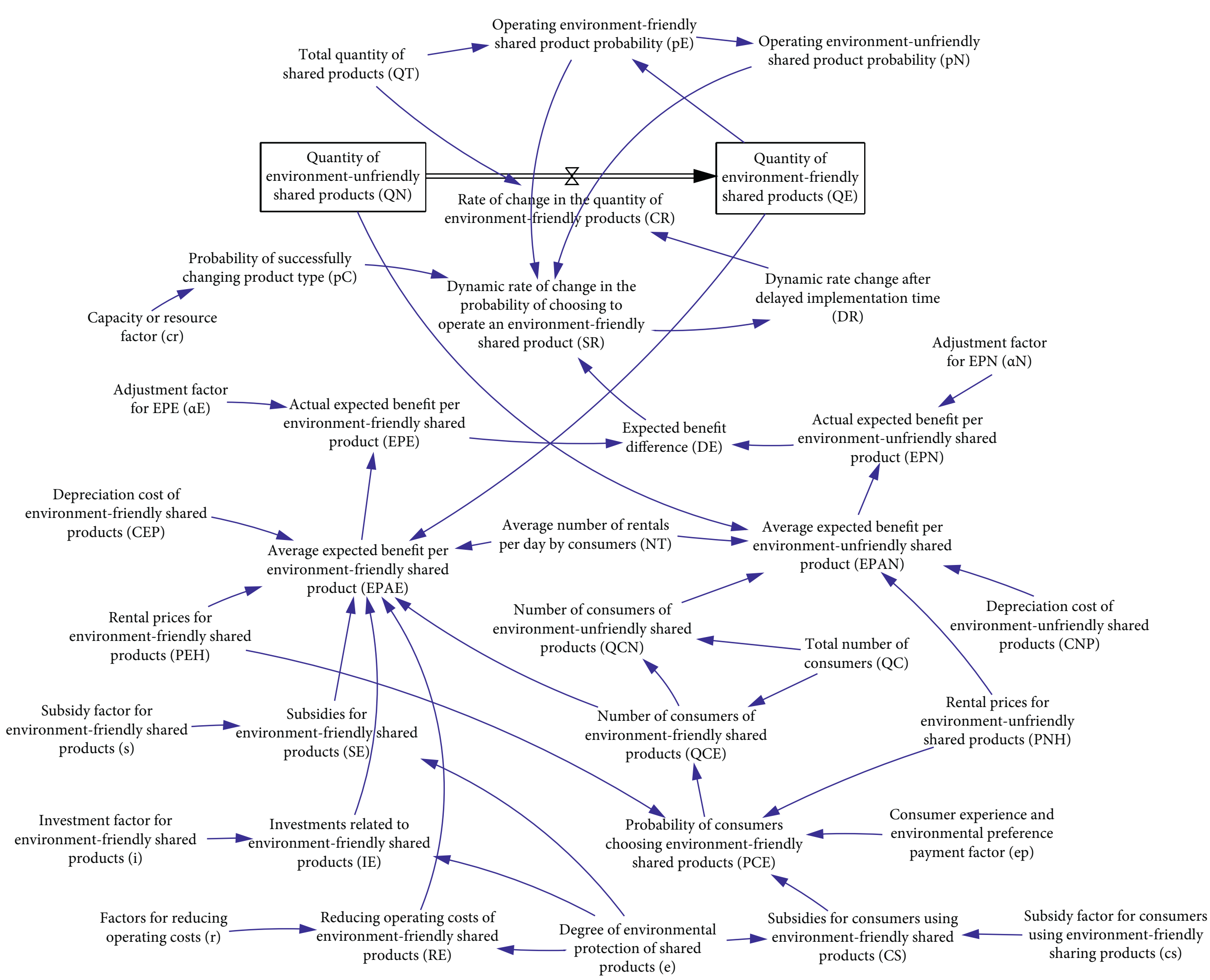

Figure 6: SD model of environment-friendly shared product quantity change.

Auxiliary variables are intermediate variables in the system and are influenced by various related factors.

4. Model Simulation

This paper explores the quantity change pattern of environment-friendly products at the beginning of a sharing industry by simulating the model based on the historical data of bike sharing in Beijing in 2018, which can theoretically be applied in many other sharing industries worldwide.

4.1. Bike-Sharing Industry Development. Since 2016, bike sharing has overgrown based on the mobile Internet because of its borrow-and-return feature. By the end of August 2019, there were 19.5 million shared bikes in China, covering 360 cities, with more than 300 million registered users and 47 million daily orders [15].

The essence of bike sharing is an O2O bike rental business that provides a low-carbon and green lifestyle for people to travel. However, with the rapid development of the bike-sharing industry, some enterprises adopted the standards of low-cost traditional bikes in the manufacturing design process to capture the market, which made a lot of shared bikes inherently environment-unfriendly [42, 43]. In the beginning time of the bike-sharing industry, the recycling price of a bike of Ofo was only a dozen yuan, and a large number of broken bikes could not be recycled in time. Around 39.3% of Ofo's users reported vehicle failure, which led to environmental, economic, and social unsustainability [21, 44]. On the contrary, Mobike focused on the eco-friendly bikes and took the lead in proposing the "Whole Life Cycle Plan", which implemented the 3R (reduce, reuse, and recycle) principles in the whole process of design, procurement, production, operation, and scrapping. All scrapped bikes (100%) were recycled and reused to achieve energy-saving and eco-friendly. The governments of various cities in China issued their policies accordingly to local situations. For example, the Beijing government issued the "Guidance on Encouraging the Standardized Development of Shared Bikes in Beijing" to provide appropriate subsidies for enterprises operating shared environment-friendly bikes [45]. The simulation of government policies is based on the Beijing government's policies and regulations.

4.2. Strategic Choices for Enterprises Operating Shared Products

4.2.1. Model Simulation of Initial Values. We interviewed the relevant personnel of Mobike and Ofo in Beijing and explored publicly available data sources (i.e., literature, institutional reports, and announcements) to set up the initial values with some modifications. In the simulation, some parameters were simplified in this study to make them measurable and calculable. The degree of environmental protection of the shared product is determined by the ratio of the difference in carbon emissions reduced and generated by environment-friendly shared bikes to traditional bikes. A subsidy factor is set for enterprises operating shared environment-friendly bikes in accordance with Beijing's guidance.

In June 2018, the total number of Mobike and Ofo bikes in Beijing was 1,910,000, and these two enterprises put 90% of the shared bikes in Beijing, in which the cost per Mobike bike was ¥1800, and the cost per Ofo bike was only ¥300. Mobike's service life was about three times longer than Ofo's. In terms of the riding experience, Mobike bikes were significantly better than Ofo, but the rental price was also higher than that of Ofo. As the bike-sharing market was in a vicious competition in 2018, the daily depreciation cost of Mobike bikes was 2.69 times its average daily revenue and 2.5 times its daily operating expenses, and Ofo's average daily loss was even more severe. The relevant variables were adjusted in order to make the simulation general.

In this study, these two enterprises were selected as the research subjects, and Mobike bikes were considered as environment-friendly shared products, and Ofo bikes were considered as environment-unfriendly shared products. The initial values of variables in the SD model are presented in Table 1 after pretreatment.

The model setting is as follows: initial time = 0, final time = 100, time step = 1, units for time: month, and integration type: Euler. This is equivalent to the simulation of a discrete dynamic system. After setting the above initial values, the quantity of environment-friendly shared bikes (QE) and environment-unfriendly shared bikes (QN) changes as shown in Figure 7 and the rate of change in the quantity of environment-friendly shared bikes (CR) is shown in Figure 8.

This simulation result shows that the quantity of environment-friendly shared bikes first increases, then decreases, and finally reaches a steady state. In the steady state, the quantity of both types of shared bikes in the market remains nearly unchanged, that is, the rate of change is close to zero. The final quantity of environment-friendly shared bikes is 1,577,000, and the environment-friendly shared bikes will gradually dominate the market, which is consistent with reality.

4.2.2. Simulation of Different Strategies. (1) Subsidy Factor for Environment-Friendly Shared Products (s). In the following simulation, we change the value of the subsidy factor for environment-friendly shared products (s). The value is set to 0, 0.1, and 0.15, that is, the maximum government subsidy for operating environment-friendly shared bike enterprises is ¥0, ¥0.1, and ¥0.15 per rental. The quantity of environment-friendly shared bikes (QE) is shown in Figure 9. When the value of s is 0, 0.1, and 0.15, the final quantities of environment-friendly shared bikes are 1,563,000, 1,590,000, and 1,602,000, respectively. As the value of s increases, the quantity of environment-friendly shared bikes increases.

*(2) Subsidy Factor for Consumers Using Environment-Friendly Shared Products (*cs*).* In the following simulation, we change the value of the subsidy factor for consumers using environment-friendly shared products (cs), which is set to 0.05, 0.1, and 0.15, that is, the maximum government

Table 1: Initial value.

Variables	Values	Unit
QT	1,912,000	Bikes
QE	714,000	Bikes
QN	1,198,000	Bikes
CEP	0.5	¥
PEH	1	¥
CNP	0.6	¥
PNH	0.8	¥
QC	11,000,000	People
NT	0.129	Times/day/user
s	0.05	¥
i	0.35	¥
r	0.45	¥
e	0.6	1
cs	0	¥
ep	0.5	¥

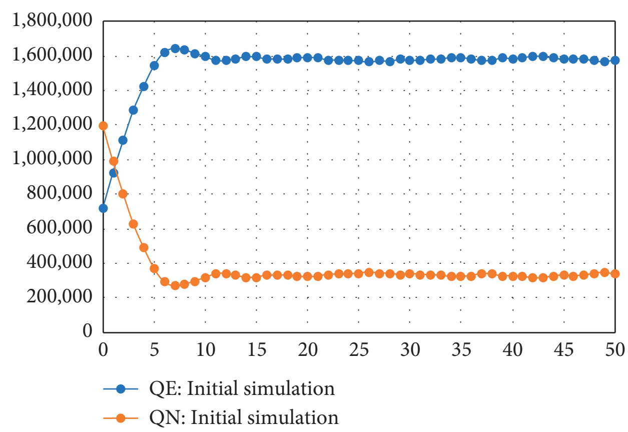

Figure 7: Quantity of environment-friendly shared bikes (QE) in the initial simulation.

subsidy for consumers renting an environment-friendly shared bike is ¥0.05, ¥0.1, and ¥0.15 per time. The quantity of environment-friendly shared bikes (QE) is shown in Figure 10. When the value of cs is 0.05, 0.1, and 0.15, the final quantities of environment-friendly shared bikes are 1,640,000, 1,698,000, and 1,751,000, respectively. Compared to Figure 9, the change in the value of cs has a greater impact on the quantity of environment-friendly shared bikes.

(3) Consumer Experience and Environmental Preference Payment Factor (ep). In the following simulation, we change the value of the consumer experience and environmental preference payment factor (ep), which is set to 0.3, 0.4, 0.6, and 0.7, that is, the maximum payment of consumers for environment-friendly shared bikes is ¥0.3, ¥0.4, ¥0.6, and ¥0.7. The quantity of environment-friendly shared bikes (QE) is shown in Figure 11. When the value of ep is 0.3, 0.4, 0.6, and 0.7, the final quantities of environment-friendly shared bikes are 1,194,000, 1,456,000, 1,647,000, and 1,693,000, respectively. The larger the value of ep, the smaller effect of the change in the value of ep on the quantity of environment-friendly shared bikes.

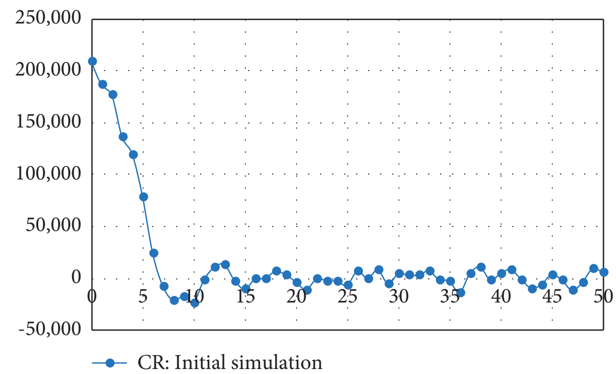

Figure 8: Rate of change in the quantity of environment-friendly shared bikes (CR) in the initial simulation.

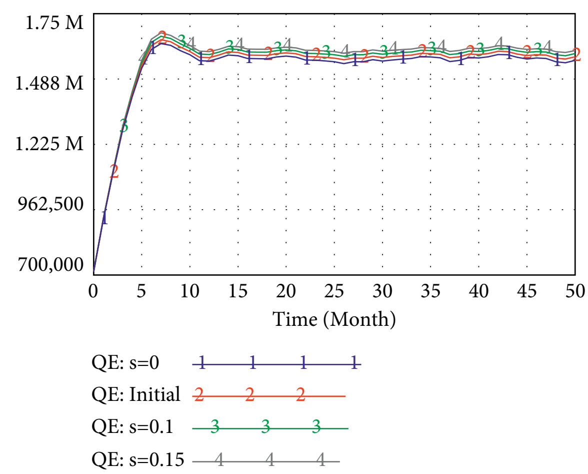

Figure 9: QE of different values of the subsidy factor s.

4.3. Analysis of Simulation Results. From the above simulation results, we can get the following implications.

First, Figures 7 and 8 show that the quantity of environment-friendly shared products in the market increases rapidly and gradually reaches a steady state. At that time, the benefit of enterprises operating environment-friendly shared products is equal to the benefit of enterprises operating environment-unfriendly shared products, and this result is consistent with the basic theory of evolutionary games [39]. The value of this steady state is similar to the evolutionary stable strategy (ESS) in games.

Figures 9 and 10 show that government subsidies for enterprises operating environment-friendly shared products and consumers renting environment-friendly shared products will lead to more and more enterprises choosing to operate such products. When subsidies increase, the quantity of environment-friendly shared products in the market also increases. Moreover, the change in subsidies is proportional to the change in quantity, which is consistent with the existing literature [46].

Although government subsidies to both enterprises and consumers increase the quantity of environment-friendly shared products, the effects of both are different. Comparing Figures 9 and 10, when the subsidies are the same, the

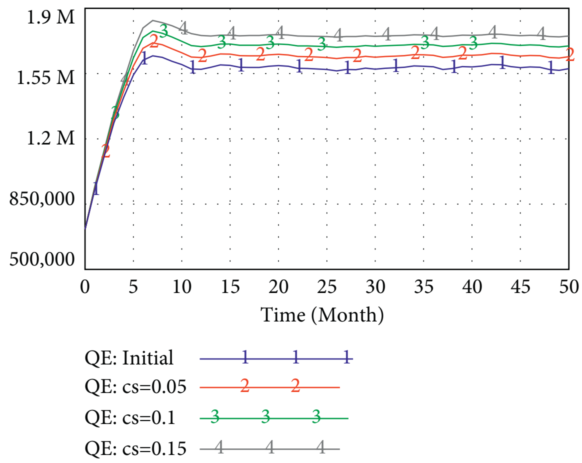

Figure 10: QE of different values of the subsidy factor cs.

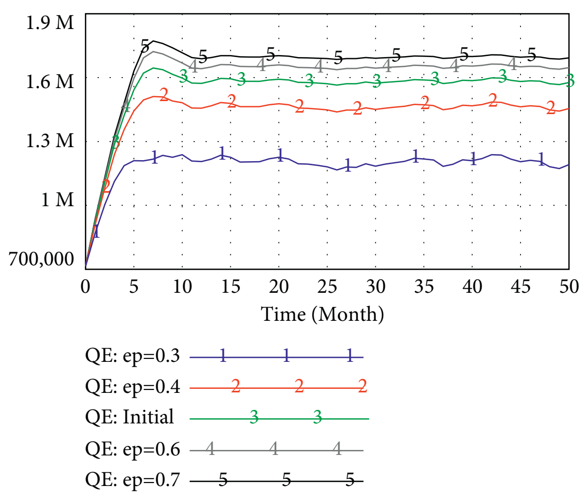

Figure 11: QE of different values of the payment factor ep.

government has a better effect in providing subsidies to consumers. Therefore, the government should develop appropriate policies and invest some of its finances to encourage consumers to rent environment-friendly shared products.

Figure 11 shows that consumer experience and environmental preference also influence the quantity of environment-friendly shared products. When the payment factor of this factor is at a low value, this factor will largely prevent the increase of the quantity of environment-friendly shared products. Therefore, the government can increase consumer awareness and education on environmental protection. Enterprises should focus on enhancing the consumer experience in the pursuit of their shared products to be environment-friendly. From these two aspects, it makes consumers willing to pay more money to use environment-friendly shared products. However, moderate investments are needed from the government and enterprises. The higher the value of the payment factor, the less significant the effect of increasing the value of the payment factor on increasing the quantity of environment-friendly shared products, and this result refines the findings of previous literature [47, 48].

Overall, the quantity change of environment-friendly shared products is a dynamic process influenced by government, enterprises, and consumers over time. Most of the simulation results in this paper validate and refine the previous studies. In addition, this paper successfully adopts a combination of evolutionary game theory and system dynamics to study the quantity change pattern of environment-friendly products in a sharing industry.

5. Conclusions and Limitations

The environmental protection of the products themselves is an emerging research area and a vital issue to be considered by the government when developing the sharing economy. In this paper, we study the quantity change pattern of environment-friendly products in the sharing economy and establish a system dynamics model by analysing the actual situation and related influencing factors and combining evolutionary game theory. The model is simulated based on the case of shared bikes in Beijing, and it can be found that the government and consumers influence the choice of enterprises. The simulation results are consistent with the analysis of evolutionary game theory. Government subsidies to both enterprises and consumers can lead to higher quantities of environment-friendly shared products in the market. However, government subsidies to consumers are more effective in increasing the quantity than subsidies to enterprises. In addition, consumer experience and environmental preference are also important influencing factors. The model can be applied to other sharing industries similar to bike sharing. The findings of this paper can provide some reference for the government to formulate policies.

However, there are some limitations to this study. First, the influencing factors in the model are relatively simple, and other stakeholders can affect the quantity of environment-friendly shared products; for example, manufacturers can jointly research and develop with enterprises to improve the degree of environmental protection of their products. Second, the model is only simulated based on bike sharing in Beijing, and there may be some different influencing factors in each sharing industry. After that, we need to refer to more data of sharing industries to improve the model.

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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