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Research Article

Research on Evolutionary Game of Value Co-Creation Behavior of Shared Private Charging Piles of Electric Vehicles

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To study the sharing behavior of private charging piles of electric vehicles, an asymmetric evolutionary game model is constructed based on the formation of respective investment costs and benefits of charging service operators and private charging pile owners; and considering the interactive factors such as the investment scale of shared charging platform construction and the number of private charging piles participating in sharing, this study explores the evolution process of value co-creation between the two parties in the private pile sharing mode, analyzes the evolution mechanism of their respective strategy choices, and explains the impact of sudden variable interference such as investment scale, sharing quantity, marginal cost, and income on the evolution results. The simulation results show that (1) the spillover effect of value co-creation between operators and private pile owners is the fundamental reason affecting the strategic choice of both sides. The initial willingness of both sides to cooperate will affect the evolution path of value co-creation, and the evolution speed of operators is the fastest; (2) under certain conditions, there is an optimal investment scale for both shared charging platform and the private pile, but the increase of marginal cost of both sides will lead to the dilemma of value co-creation, and the marginal cost of operation platform has a greater impact on value co-creation than the private pile; and (3) there is an optimal bearing quantity in the number of shared private piles, and the ratio of marginal cost to income is the key factor affecting value co-creation.

1. Introduction

The private charging pile discussed in this paper refers to other piles except for the public charging pile. The construction and operation of private charging piles for electric vehicles across China are facing dual problems. On the one hand, it is difficult to install, and on the other hand, many of them are idle. Private charging piles sit idle 70% of the time. The widespread phenomenon of “zombie pile” causes a waste of charging resources. Charging pile sharing can solve this dilemma. Charging pile sharing means that charging pile operators coordinate private charging piles by creating a sharing platform, fully using idle private charging piles, and befitting operating enterprises and private pile owners. According to the statistics of the charging alliance, by April 2022, there are 1.992 million private charging piles in China, of which less than 7% are shared. Assuming that only a quarter can be shared, if a single charging station can provide 15 piles, the supply of shared private charging piles is basically close to tens of thousands of public charging stations. Therefore, private charging piles have the potential to become another emerging business in the sharing economy industry. Star charging, State Grid, and China Southern Power Grid began to layout private pile sharing business, and the private pile intelligent charging sharing platform has been put into market operation.

The increasing electric vehicle market has brought huge market development space for private pile sharing. The success of the private pile sharing model lies in the joint participation of both parties, which is a typical “one-to-many” platform economy. Private charging piles can be regarded as a whole, and their participation ratio represents the behavioral decisions of this group. The operating enterprise creates a sharing platform, and the data value generated by the platform far exceeds the charging value; The charging pile sharer gave up part of the private charging utility and reaped the charging value. Previous studies have shown that value co-creation is the key to the development of private pile sharing model. The inconsistency of profits and losses between the two sides may lead to both asymmetric and non-zero-sum games. Cooperation between the two sides may produce spillover effects, and neither side will benefit if they do not cooperate. Private piles change their private nature. Are they willing to provide charging-sharing services? What factors affect sharing decision-making, and what is the evolution trend? How can the two sides promote the sharing development of private piles? These are the questions to be answered in this paper.

Through the evolutionary game method, this paper analyzes the conditions for the evolution of value co-creation between operators and private piles towards the "win-win" strategy. Theoretically, it discusses the internal mechanism of value co-creation between operators and private piles to provide policy reference for promoting private pile sharing.

2. Literature Review

Most of the research literature on charging pile sharing regards the government as one of the essential subjects of operation. Wang et al. [1] used the ecosystem theory and grounded theory to find that consumers, platform service providers, charging pile manufacturers, and the government are the key actors in the operation of shared charging piles. Yue et al. [2] found that the optimal investment and construction quantity of new energy vehicle charging pile operators positively correlate with government subsidies. Zheng and Xu [3] found that government participation is the crucial factor in promoting the cooperation between charging operators and enterprises or individuals. Most of the literature suggests that charging facilities are invested and constructed by the market, the government plays a guiding role, and enterprises are the main body of investment and construction.

Private pile sharing is a user-driven charging pile operation mode. Shaobulina et al. [4] found that private piles sharing mode can be profitable. Gao et al. [5] studied the mechanism of shared charging piles based on users' social networks. Wu et al. [6] studied the private pile sharing trading strategy based on blockchain technology. Liu and Li [7] proposed a blockchain-based security supervision scheme to address information security issues. It shows that this model is feasible from the aspects of technology, economy, and security.

Private pile sharing is a typical platform economy. Value co-creation is the key to operation, and network effect and positive feedback will occur with the increase of the number of participants [8]. Wei and Liu define shared value as "improving the competitiveness of companies and the economic and social conditions of their communities" [9]. Xiao [10] believes that value co-creation is one of the core value processes. In the existing studies, Wang [11] believes that revenue is the main factor in the shared parking market. Yu and Li [8] found that the initial scale and income are the key factors for the operation of the sharing model.

As for the value and distribution of shared charging piles, the paper is mainly divided into three categories. The first is to study the value formation relationship of each subject in the operation mode. Zeng et al. [12] evaluated the comprehensive benefits of various subjects in the commercial operation mode of electric vehicle charging. Liu et al. [13] studied the network relationship among charging infrastructure manufacturers, charging service operators, and overall solution providers, as well as stakeholders, including users, from the network perspective. Huang and Lu [14] summarized the current typical business model of China's charging infrastructure industry and the value formation model of various participants. The second is to study the value change of each subject under the application scenario of information technology. Luo et al. [15] analyzed from the perspective of information technology application scenarios. The participating roles in each scenario of charging facility operation ecological construction tend to be diversified, and the value composition of each participating role in the business model is constructed. The third is to study the distribution of shared charging value from the pricing perspective. Li et al. [16] proposed a private pile sharing benefit distribution model from the perspective of charging pricing. Tong [17] and Hu et al. [18] studied the optimal behavior of all parties in the charging operation business model from a third-party operation platform perspective. Shi et al. [19] studied the charging price between charging stations and the optimal charging behavior of users to maximize the income of aggregators and select the optimal charging station.

Previous studies have regarded charging service as the primary shared value, but there are few studies on the spillover value effect caused by sharing. The spillover value shared by charging piles far exceeds the charging function. One end is connected to users, and the other is connected to the power grid. The charging network integrates big data from energy, payment, cars, users, and other aspects. The realization of the data value is greatly affected by uncertain factors, such as the technology and the market. At the same time, there is great uncertainty in the benefits from the decision-making of both sides. There is little analysis on the behavior selection process of each subject in the process of private pile sharing in the existing literature. Sharing a platform is a typical one-to-many feature. There is a dynamic value co-creation process between platform operators and private charging pile owners. Value co-creation is affected by the profit and loss of shared behavior of both parties. Value co-creation is the dynamic evolution result of the private pile owner and the operating platform learning from each other and constantly adjusting over time in the game process on the basis of bounded rationality. The game behavior between operators and private pile owners belongs to an asymmetric game. Information asymmetry is mainly reflected in the asymmetry of each subject's actual willingness to participate in the other party's information before the decision. Both sides need to consider the internal game of their own population and the impact of opponent population game on their population strategy.

3. Construction of an Asymmetric Evolutionary Game Model

Evolutionary game theory is usually used to study the dynamic evolution process of a group and analyze the reasons and paths to reach a particular state. This paper analyzes the interaction process between operators and private piles based on evolutionary game theory. The selection process of operators and private pile owners is a two-population evolutionary game process. If the expected return exceeds the average return, the evolutionary game process between the two sides will continue. There is information asymmetry between the two sides. So, it is a nonevolutionary game.

3.1. Model Assumptions. Suppose that, at a particular time t, the service provider and the private pile owner play the game simultaneously. Operators have two strategies of "create 1" and "do not create 0" shared platform. The variable Y indicates the proportion of operators and enterprises that select the "create 1" strategy at time t. It is assumed that the fixed investment scale for creating a shared charging platform is I_1, including investment costs such as workforce, equipment investment, and maintenance. The expected income from the operator's unit investment R_1 includes charging service cost, considerable data value, corporate image improvement, brand competitiveness, and market competitiveness. The expected return will increase with the investment scale, and the platform will obtain the spillover effect R_1I_1. The investment cost of private pile owners is also a part of the investment scale of the platform. Set the investment cost I_2 paid by each private pile sharing, and the total number of private piles participating in the sharing is N, the larger the scale of N, the greater the value revenue $R_1(I_1+\mathrm{N}I_2)$ created by the platform. C_1 is the marginal cost of platform investment. The service provider can obtain the lowest rate of return L without creating a shared platform.

Private pile owners have two strategies: "share 1" and "do not share 0." Variable Z represents the proportion of private piles selected for "share 1" strategy at time t. If it is not shared, the utility value brought by the owner's free charging is U (including charging convenience value, pile maintenance, parking expenses, etc.). If participating in sharing, the unit investment will obtain the expected income R_2, including both charging services and parking income generated during charging. The marginal operation and maintenance cost C_2 of private piles includes maintenance, property communication, and information transmission to the platform. The private pile owner must pay the service usage fee I_2. If both parties choose (create and share) strategies, both parties will have spillover effects. At this time, the net income obtained by private piles is $U + R_2(I_1/N) + R_2I_2 - C_2I_2$, where (I_1/N) represents the proportion of the value-added brought by the platform investment scale spread equally, and $(R_2I_1/N + R_2I_2 - C_2I_2)$ represents the value spillover effect brought by private piles through sharing cooperation. This spillover effect makes the profit and loss difference between the two sides of the game under different strategies, which is also the fundamental reason affecting the decision-making of operators and private pile owners.

Based on the above assumptions, to maximize their interests under the market mechanism, both sides of the game continue to play multiple games over time. The income matrix is shown in Table 1.

3.2. Replication Dynamics and Evolutionary Game. When expected return $R_{1,2} \geq C_{1,2}$, it can be seen that (create, share) is a dominant strategy equilibrium. At that time $R_{1,2} < C_{1,2}$, according to R, C, I and to judge the equilibrium strategy, the evolutionary game method is used to deal with this problem.

Operators choose to create the expected benefits of the platform $\pi_{11} = Z(L + R_1I_1 + R_1NI_2 - C_1I_1) + (1 = Z)(L + R_1)$; the expected return not created is $\pi_{10} = L$, then the average expected return is the average expected return: $\pi_1 = Y\pi_{11} + (1 - Y)\pi_{10}$.

Expected income of private pile choosing "sharing platform" $\pi_{21} = Y(U + R_2I_1/N + R_2I_2 - C_2I_2) + (1 - Y) \quad (U + R_2I_2 - C_2I_2)$, expected benefits of "nonshared platform" $\pi_{20} = U$, and the average expected return is $\pi_2 = Z\pi_{21} + (1 - Z)\pi_{20}$.

According to the dynamic replication principle of strategy selection in evolutionary game theory, the strategy whose expected return is higher than the average expected return can spread among operators and private pile owners. Then, the dynamic replication equations of operators and private piles are, respectively, as follows:

$$\begin{aligned} f(Y) &= \frac{dY}{dt} \\ &= Y(\pi_{11} - \pi_1) \\ &= y(1 - y)(ZR_1NI_2 + R_1I_1 - C_1I_1), \end{aligned} \tag{1}$$

$$\begin{aligned} f(Z) &= \frac{dZ}{dt} \\ &= Z(\pi_{21} - \pi_2) \\ &= Z(1 - Z)\left(\frac{YR_2I_1}{N} + R_2I_2 - C_2I_2\right). \end{aligned} \tag{2}$$

The differential equations composed of dynamic replication equations (1) and (2) are the dynamic replication system of the asymmetric game between operators and private piles. This equation system represents the population proportion of both sides over time t dynamic change speed. The solution curve of differential equations is a dynamic evolution process, and its stable solution is the equilibrium point, which can resist the disturbance of small mutation.

3.3. Analysis of Evolutionary Stability Strategy. According to the stability theorem, the operator's evolutionary stability strategy condition is $F(Y) = 0$ and $F'(Y) < 0$.

Table 1: Income matrix of operators and private pile owners.

Service provider	Private pile owner Share proportion Z	Unshared Proportion $(1-Z)$
Create shared platform proportion Y	$(L+R_1I_1+R_1NI_2-C_1I_1, U+R_2I_1/N+R_2I_2-C_2I_2)$	$(L+R_1I_1-C_1I_1, U)$
Do not create shared platform proportion (1-Y)	$(L, U+R_2I_2-C_2I_2)$	(L, U)

(1) At that time $Z=((C_1I_1-R_1I_1)/R_1NI_2)$, be $F(Y)=0$. It shows that the operator's strategy is stable regardless of the value of the private pile Z.

(2) At that time $Z\neq((C_1I_1-R_1I_1)/R_1NI_2)$, make $F(Y)=0$, get $Y=0$ and $Y=1$ are the two stable points for the operator's strategy to copy the dynamic equation. At this time, there are two cases:

① If $ZR_1NI_2+R_1I_1-C_1I_1>0$, there are $F\prime(Y)|Y=0>0$, $F\prime(Y)|Y=1<0$, indicating that the operator's choice of creation strategy is stable, and the choice not to create is unstable.

② If $ZR_1NI_2+R_1I_1-C_1I_1<0$, there are $F\prime(Y)|Y=0<0$ and $F\prime(Y)|Y=1>0$, indicating that the operator's choice not to create the policy is stable and the choice to create is unstable.

Similarly, the conditions for private piles to choose the shared stability strategy are $F(Z)=0$ and $F\prime(Z)<0$.

(1) At that time $Y^*=NI_2((C_2-R_2)/R_2I_1)$, $F(Z)=0$, indicating that the operator selects the creation strategy in any proportion Y, and the private pile strategy is stable.

(2) At that time $Y^*\neq NI_2((C_2-R_2)/R_2I_1)$, let $F(Z)=0$, get $Y=0$ and $Y=1$, which are the two stable points for the private pile strategy to copy the dynamic equation. At this time, there are two cases:

① If $YR_2I_1/N+R_2I_2-C_2I_2>0$, there are $F\prime(Z)|Z=0>0$, $F\prime(Y)|Z=1<0$, indicating that the private pile selection sharing strategy is stable and the selection not to share is unstable.

② If $(YR_2I_1/N)+R_2I_2-C_2I_2<0$, there are $F\prime(Z)|Z=0<0$, $F\prime(Z)|Z=1>0$, indicating that the private pile selection sharing is unstable and the not sharing strategy is stable.

Let $F(Y)=0$, $F(Z)=0$, get 5 equilibrium points (0, 0), (0, 1), (1, 0), (1, 1), and (Y^*, Z^*), and $Y^*\neq NI_2((C_2-R_2)/R_2I_1)$, and $Z^*\neq((C_1I_1-R_1I_1)/R_1NI_2)$. According to the Lyapunov stability theory, the stability is analyzed according to the Jacobian matrix of the evolutionary game system.

Substitute the equilibrium point into the above matrix, J is the Jacobian matrix corresponding to the copied dynamic equation. If the determinant $\mathrm{Det}(J)>0$, $tr(J)<0$ is satisfied, the equilibrium point is a locally asymptotically stable fixed point, that is, the evolutionary stability strategy. According to the local stability analysis method of the Jacobian matrix, the stability of the above five Nash equilibrium points is analyzed. The Jacobian matrix of this model is as follows:

$$J=\begin{vmatrix}(1-2Y)\left(ZR_1NI_2+R_1I_1-C_1I_1\right) & Y(1-Y)R_1NI_2\\ Z(1-Z)\left(\dfrac{R_2I_1}{N}\right) & (1-2z)\left[\dfrac{YR_2I_1}{N}+R_2I_2-C_2I_2\right]\end{vmatrix}. \quad (3)$$

The specific values of 5 local equilibrium points in the corresponding $\mathrm{Det}(J)>0$, $tr(J)<0$ are shown in Table 2.

Because $0\leq Y^*\leq 1$, $0\leq Z^*\leq 1$, we can deduce the existence of inequality conditions: $R_1\leq C_1\leq R_1(1+NI_2/I_1)$, $R_2\leq C_2\leq R_2(1+I_1/NI_2)$.

Under these two conditions, there are (0,0) and (1,1) two stable evolutionary solutions at the same time, resulting in the problem of chicken laying eggs and egg laying chickens: operators are willing to build platforms when private piles are willing to participate in sharing; on the contrary, private piles are willing to participate if operators are willing to build platforms.

As for what kind of stable state and critical point will the strategic choice between the operating enterprise and the private pile owner evolve $E=[(NI_2(C_2-R_2)/R_2I_1), (I_1(C_1-R_1)/R_1NI_2)]$; therefore, we study the changes of some variables to observe the changes of the critical point E and then analyze the evolution track of operating enterprises and private pile selection. At the same time, affected by inertia, the initial proportional value selected by both parties also greatly impacts the results.

4. Case Analysis and Model Parameter Setting

4.1. Case Analysis. Next, combined with the actual situation of existing private pile sharing, set the main parameters in the asymmetric model constructed, and then explore the dynamic evolutionary process of value creation between the two sides.

The values of each variable are as follows:

(1) Investment scale. To simplify the processing, the scale of the operator's investment in the sharing platform and the expenses incurred by private pile sharing are

TABLE 2: Equilibrium points and eigenvalues of the Jacobian matrix.

Equilibrium point	Det(J) expressions and symbols		$tr(J)$ expressions and symbols		Result
(0, 0)	$(R_1I_1 - C_1I_1)(R_2I_2 - C_2I_2)$	+	$R_1I_1 - C_1I_1 + R_2I_2 - C_2I_2$	−	ESS
(0, 1)	$[R_1(I_1 + NI_2) - C_1I_1]I_2C_2I_2 - R_2)$	−	$R_1(I_1 + NI_2) - C_1I_1 + C_2I_2 - R_2I_2$	+	Unstable point
(1, 0)	$[R_2(I_1/N + I_2) - C_2I_2]C_1I_1 - R_1I_1)$	+	$R_2(I_1/N + I_2) - C_2I_2 + C_1I_1 - R_1I_1$	+	Unstable point
(1, 1)	$[C_2I_2 - R_2(I_1/N + I_2)]C_1I_1 - R_1(I_1 + NI_2))$	+	$C_2I_2 - R_2(I_1/N + I_2) + C_1I_1 - R_1(I_1 + NI_2)$	−	ESS
(Y^*, Z^*)	$-(C_1 - R_1)(C_2 - R_2)(R_2NI_1 + I_1R_1 - I_1C_1)(R_2I_2 + NI_2R_2 - NI_2C_2)/R_1R_2N$	−	0	0	Saddle point

measured in currency (assuming that the unit is 10,000 yuan). When providing shared services, operators should be responsible for the platform's design, construction, operation, and maintenance, and the investment scale is generally much higher than that paid by a single private pile to participate in the platform. For this purpose, it is assumed that the operator invests $I_1 = 1000$. Different private pile investments, construction and maintenance costs vary greatly, and private piles are set to participate in the cost expenditure $I_2 = 1$.

(2) Expected return. Expected revenue of sharing platform $R_1 = 1.06$, which means the net return on unit investment is 6%. According to the private pile sharing scheme of the State Grid, the income sharing is "minimum income 30 yuan/month +70% sharing proportion," and the shared slow charging price is about 1 yuan–1.2 yuan/kWh, while the State Grid changes the private pile price at the household price of 0.475 yuan/kWh; that is, 1 kWh of electricity is consumed for each "sharing," and the pile owner can earn about 0.5 yuan. Since most private piles are installed in private parking spaces, the instability of shared income is large, so the expected rate of return is also high, set at 3%, i.e., $R_2 = 1.03$.

(3) Marginal cost. The marginal cost is higher than the expected investment income, which is mainly based on the following considerations: for operators, the construction, operation, and maintenance costs include many hidden costs, such as human investment and manager talent. For private piles, when adopting the sharing strategy, in addition to paying the use fee, it may also incur other costs, such as the cost of communication with the property, the penalty of nonsharing of equipment, and the opportunity cost of normal private use. Combined with the analysis in the theoretical model, it is assumed that the operator invests in the marginal cost of the sharing platform $C_1 = 1.5$. In addition, it is assumed that the marginal cost of participating in sharing is lower than that of the operator $C_2 = 1.3$.

(4) Share private pile scale. For simplicity, it is assumed that the private piles involved in the shared platform are homogeneous, and the number of private piles in the benchmark analysis is set as $N = 1000$.

4.2. Parameter Setting and Description. From the above analysis, the initial value setting of parameters needs to reach the optimal evolutionary stability point [1], that is, it needs to meet $R_2 \le C_2 \le R_2(1 + I_1/NI_2)$, $R_1 \le C_1 \le R_1(1 + NI_2/I_1)$; therefore, the initial values of each parameter are set as shown in Table 3.

5. Economic Subject Behavior and Value Co-Creation

The decision-making results of private stake owners and charging operators directly affect the size of value co-creation, and the factors that affect the decision-making directly affect the possibility of value co-creation. The derivation above also proves this point. MATLAB simulates the evolutionary game model of both parties, and the initial participation intention, cost, and income of both parties are analyzed.

Table 3: Initial values of parameters.

Game participants	Main variables	Value
Operator	Investment scale I_1	1000
	Expected rate of return R_1	1.06
	Marginal cost C_1	1.50
Private pile owner	Expenses I_1	1.00
	Expected rate of return R_2	1.03
	Marginal cost C_2	1.30

5.1. Impact of Investment Scale on Evolution Results

5.1.1. Changes in Operator Investment Costs. Operators create operation-sharing platforms. Generally, the larger the investment cost, the larger the investment scale, and the greater the probability of private pile sharing value profit. Private pile owners will choose operators with the large investment scales to cooperate. The initial values of each parameter are set in Table 3, $T = 10$. On this basis, the influence of the change of the investment costs of the operators I_1 on the evolution path of the asymmetric game is investigated.

As shown in Figure 1, the initial scale is $Y = Z = 0.5$, $T = 10$, and $I_1 = 1000$. Other situations evolved from situation 2. Case 1: when the operator's investment cost is low ($I_1 = 500$), the platform provides limited ability to create value together, and the profit of a single pile is limited. Therefore, most private piles gradually choose the sharing strategy, and the change speed is slow. Scenario 2: operators increase investment ($I_1 = 1000$), the co-creation value spillover effect increases, and private piles will choose the sharing strategy. In case 3, when the investment increases to 1500, the willingness to share private piles gradually decreases, and both parties' strategies gradually evolve into (no creation, no sharing). In summary, it shows that when other conditions remain unchanged, there is an optimal value of shared platform investment, which is in line with the law of economies of scale. No matter how the investment changes, the operator's strategy can always choose in the shortest time, while the private pile response lags.

5.1.2. Influence of Private Pile Investment Scale on Evolution Results. As shown in Figure 2, case 2 is the basic case, and the initial ratio is $Y = Z = 0.5$, $I_2 = 1$. In reality, the installation and maintenance subjects of charging piles are inconsistent, so the investment shared by private piles is quite different. The investment I_2 changes are from 0.5, 1, and 1.5, as shown in cases 1–3, respectively. The lower the scale of private pile investment, the value created by both parties is not enough to attract private pile owners to participate in sharing, so the proportion of nonsharing intention will gradually decrease (see case 1); on the contrary, the higher

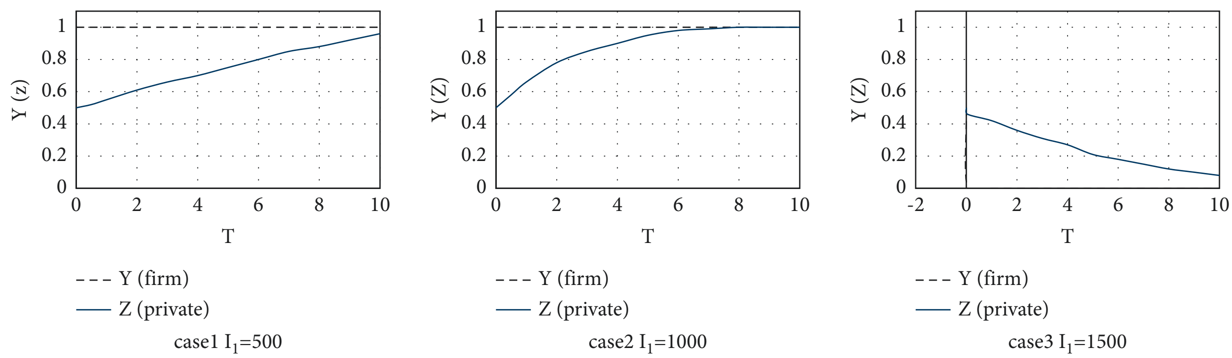

Figure 1: I_1 impact of changes on the evolution of co-created value.

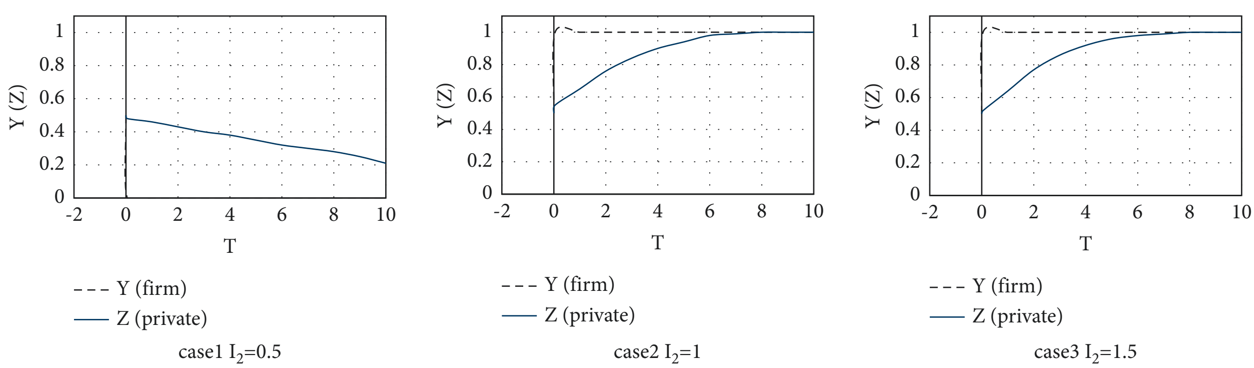

Figure 2: I_2 impact of changes on the evolution of co-created value.

the investment scale, the higher the value created by both parties, so the proportion of private pile owners' willingness to share will increase (see case 3). Compared with case 2, the curve of case 3 is relatively flat, indicating that the increase rate of private pile sharing intention is relatively slow and also indicating that there is an optimal investment scale for the realization of the value of both parties.

5.2. Impact of the Number of Private Pile Sharers on the Evolution Results. The realization of value creation requires a sufficient number of private piles to be shared. The choice of single pile strategy has little impact on the co-creation of value, once the number or proportion of shared piles adopting the same strategy reaches a certain scale; if the investment scale remains unchanged, there must be a crowding effect; even if there is spillover effect in the value co-creation of both sides, then the proportion of private piles adopting the sharing strategy will continue to decrease. With $Y = Z = 0.6$ as an example, in case 1, the share proportion of private piles is small and gradually tends not to be shared. In figure 3 case 2, when N = 1000, the private piles with an initial proportion value of 0.6 is starred as a sharing policy, and the private piles with a proportion value of 0.3 is starred as a nonsharing policy. In Figure 3 case 3, as the number of private piles is increasing, when N = 1500, The reason is that the number of participants increases, and the co-created value apportioned to a single pile increases first and then decreases. The initial share ratio is 0.3. At this time, the share intention ratio increases rapidly, indicating that both parties have created an immense value-added.

5.3. Impact of Marginal Cost on Evolution. Once private piles are installed, the parking and installation costs have been formed, and the marginal cost mainly includes maintenance and operation costs. The marginal cost of charging operators mainly includes platform information collection, transmission, feedback, maintenance, etc. The level of marginal cost affects the decisions of both parties. As shown in Figure 4, other conditions remain unchanged. Case 2 is the benchmark case. Case 2 is the reference case with an initial ratio of 0.6. With the increase of C_1 from 1.05 to 2.3, the net income decreases, and the value of CO-creation decreases. The evolution of the game between the two sides is stable (0, 0), and the proportion of operators that choose not to create changes quickly. As shown in Figure 5, similarly, the marginal cost of private piles gradually increases, the income decreases, and the proportion of private piles selected for sharing decreases, and the decline rate is fast. Whether it is a private pile or an operator, with the increase of marginal cost, if the initial proportion is 0.3, the proportion of both parties' choice (not create, not share) will increase rapidly, as shown in Figure 4 (case 3) and Figure 5 (case 3), indicating that the change of initial value will affect the value co-creation choice strategy of both parties.

Compared with benchmark case 2, if C_1, C_2 increase or decrease at the same time and change separately, the private piles with an initial value of 0.3 tend to be shared, but with the simultaneous increase of C_1 and C_2, the two sides evolve into (not created and not shared) (see Figure 6 case 3).

If C_1 increases and C_2 decreases, both parties evolve into (not created and not shared) (see case 4); if C_1 decreases and

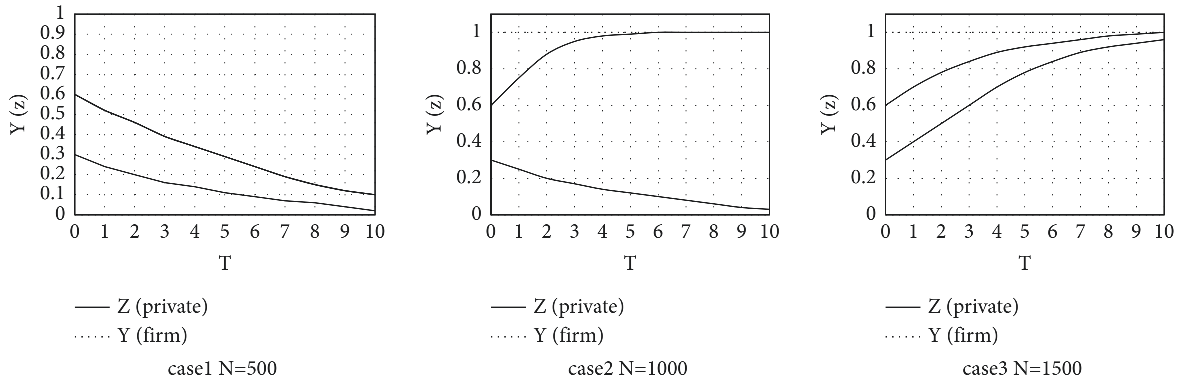

Figure 3: N impact of changes on the evolution of co-created value.

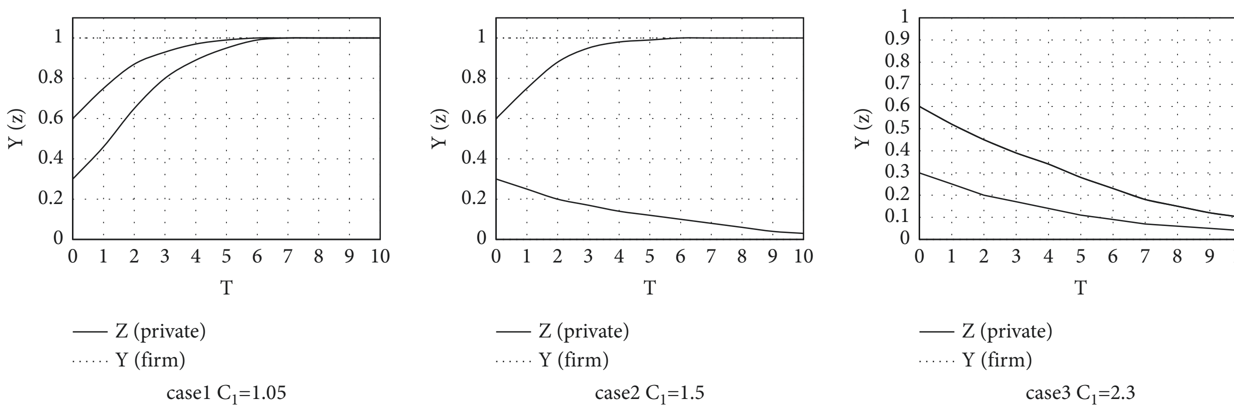

Figure 4: C_1 impact of changes on the evolution of co-created value.

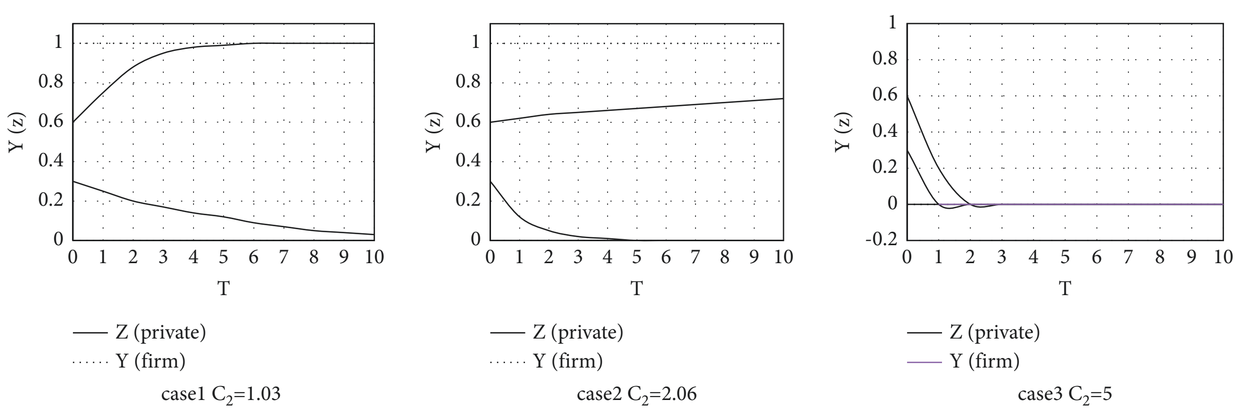

Figure 5: C_2 impact of changes on the evolution of co-created value.

C_2 increases, both parties form (create, share) a combination strategy (Figure 6 case 5). It shows that the marginal cost of operators has a greater impact on the evolution results than private piles.

5.4. Impact of Income Change on the Evolution. Revenue can increase the proportion of operating enterprises and private pile selection (create, share) strategies to a certain extent.

As shown in Figures 7 and 8, R_1 increases, and the initial proportion is 0.6. Both sides gradually evolve into (create and share) combination strategies. With an initial probability of 0.3, private piles still evolve to nonsharing, but the rate gradually decreases, and operators still choose not to create them. The results show that increasing the operators' revenue can effectively enhance enterprises' willingness to choose the strategy of "creating a shared charging pile platform." R_2 increases, and the initial probability is 0.6. The proportion of private pile sharing intention gradually increases with the increase of yield. The initial probability is 0.3, and the private pile still evolves to nonsharing, but the speed slows down. It shows that the initial intention greatly

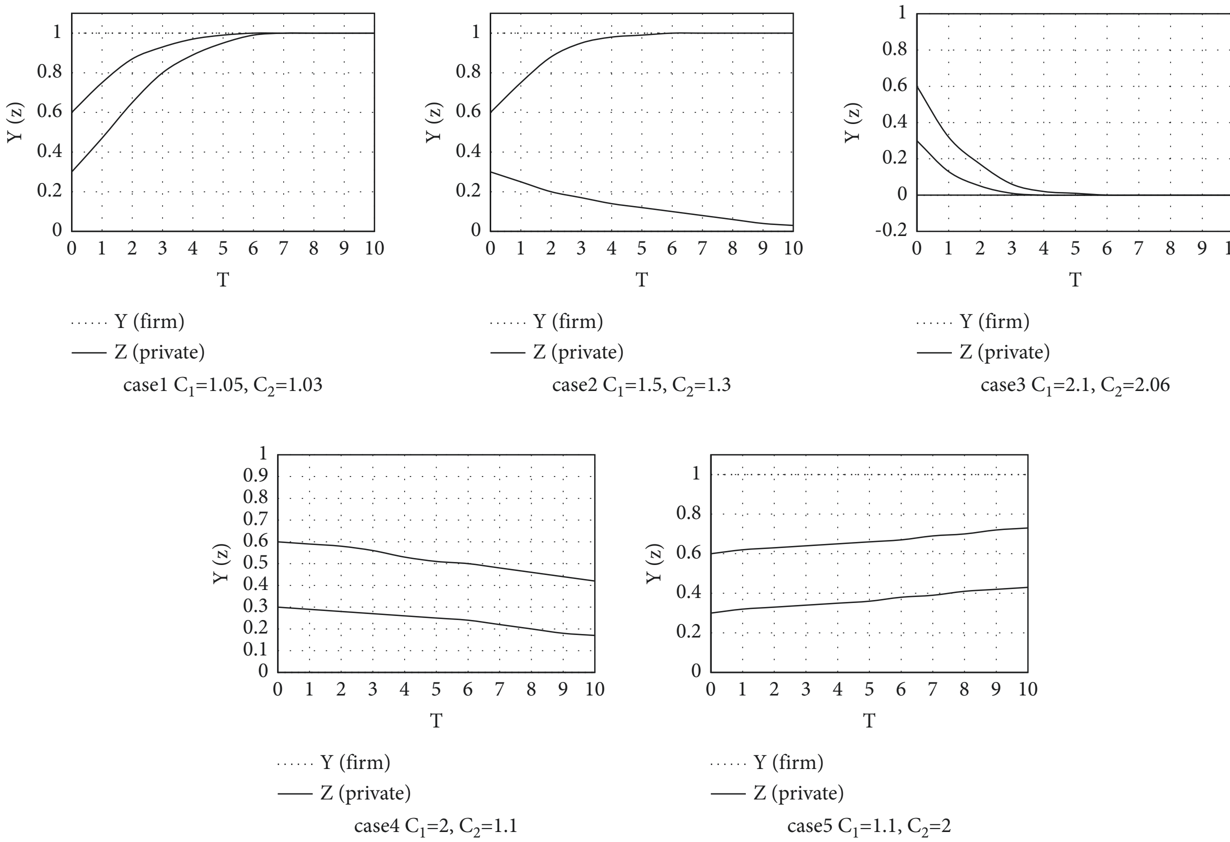

Figure 6: C_1, C_2 impact of changes on the evolution of co-created value.

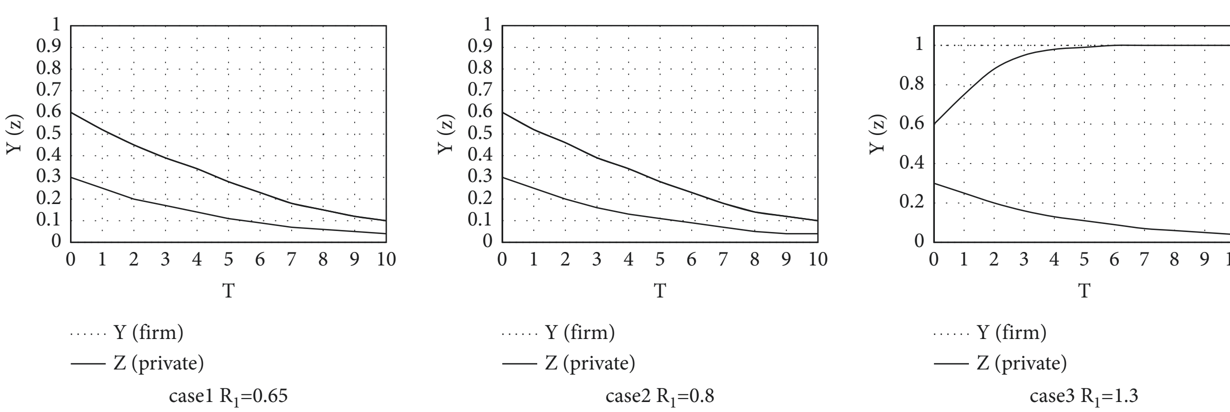

Figure 7: R_1 impact of changes on the evolution of co-created value.

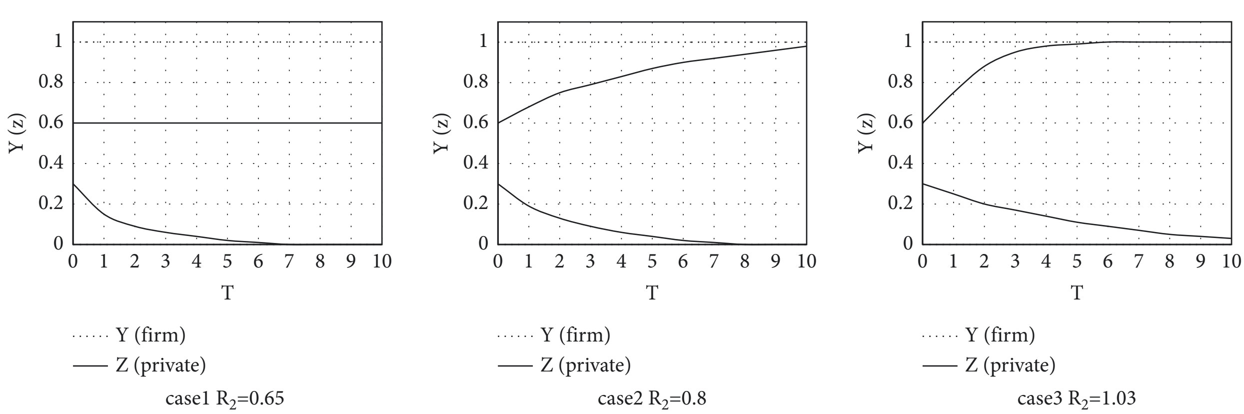

Figure 8: R_2 impact of changes on the evolution of co-created value.

impacts the choice (create, share) of both parties. R_1 has more influence on evolution than R_2.

6. Conclusions and Suggestions

This paper studies the asymmetric game in the value creation process between operators and private piles. The paper shows that (1) the probability of initial intention will affect the strategic choice of both sides. Improving the initial creation and sharing probability will help both sides create value together; (2) there is an optimal scale for operators to invest in creating a shared charging platform; (3) the change in the proportion of marginal cost and income will affect the strategic choice of both parties. The private pile yield has a more significant impact on the evolution results of both parties than operators. The marginal cost change of operators has a more significant impact on the evolution results of both parties than private piles; (4) due to the "one-to-many" relationship between operators and private piles, there is an optimal bearing scale for the number of private piles on the shared platform under certain conditions. Too few or too many may make the value co-creation of both sides evolve to (not created or shared) combination; (5) private piles and operators have a "chicken lays eggs" cycle. Operators can make decisions in time. Operators' decisions are more timely affected by private pile operation decisions.

To guide operators and private piles to create value together and avoid the dilemma of both sides (not creating or sharing), combined with the research conclusions, the following enlightenment can be put forward.

First, encourage the initial probability of operators and private piles (creation, sharing). Strengthen the efficiency of the pilot operation of shared charging piles, encourage more private piles to participate in sharing, and encourage more social resources to participate in the construction of charging infrastructure. Reasonably, set the charging and parking prices of shared private piles, balance the benefits of both operating enterprises and those sharing private piles, and make them in a balanced possession equilibrium strategy.

Second, improve the probability of operators creating a shared platform strategy. Currently, the operation mode of private pile sharing by Chinese operators still needs continuous innovation and perfection. To promote the orderly development of this industry, operators need to enhance their awareness of creating a sharing platform. Regarding the occurrence of the "egg" problem, operators are encouraged to pilot first and then promote it in a large area.

Third, reducing the marginal cost of private pile sharing is conducive to private pile sharing. The charging company bears the maintenance fee in the star charging method, which is conducive to increasing the possibility of private pile sharing strategy. It is suggested to learn from this experience. Property management should adapt to the development of private pile sharing and make appropriate management measures in time.

Fourth, it is suggested that government departments guide social charging pile resource sharing to prevent value co-creation from getting into trouble: ① when operators adopt the "creation" strategy, government departments will appropriately subsidize according to the development of the electric vehicle demand market, reduce the construction and operation cost of sharing platform, and increase the possibility of adopting the "creation" strategy; ②encourage the management environment of private pile sharing in the community, make it possible for private pile sharing in the community, and increase the possibility of adopting the "sharing" strategy.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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