Evolutionary game analysis of recycling management of waste power batteries of new energy vehicles

Cheng gong Wang¹, Juan juan Liu²*
¹School of Shanghai, Maritime University, Shanghai, China
²School of Shanghai, Maritime University, Shanghai, China
*Corresponding author e-mail: jjliu@shmtu.edu.cn

Abstract. Based on the evolutionary game theory, this paper constructs a game model between the government and power battery manufacturers with the aim of promoting the innovation of recycling technology to achieve sustainable development of energy and environment. The effects of penalties and subsidies on the behavior of power battery manufacturers in adopting green innovation technology strategies under unilateral and bilateral government policies are compared. Numerical simulations are used to verify the validity of the model and conclude that: penalties and subsidies can change the final choice of power battery manufacturers only when a certain threshold is exceeded; penalties can make power battery manufacturers adopt green innovation technology strategies more steadily than subsidies at an earlier stage when the green innovation technology surplus is negative; the number of recycling and the degree of technological innovation are also important factors affecting the evolutionary process of power battery manufacturers. Meanwhile, the above conclusions can provide some suggestions for the government to effectively manage the recycling of waste power batteries.

1. Introduction
In the field of transportation, new energy vehicles are promising solutions to environmental problems and oil safety issues [1]. The life span of power batteries in electric vehicles is generally 7 years, and once the battery capacity decays to a certain level (generally 80%), it is easy to cause driving safety and the battery enters the renewal end-of-life stage [2]. Organic chemicals and toxic electrolytes in used power batteries will damage the natural environment if not treated properly; meanwhile, the valuable metals in batteries such as: cobalt, lithium, and nickel will cause waste of resources if not recycled [3].

In order to effectively manage the recycling of waste power batteries, the Chinese government has implemented the Extended Producer Responsibility (EPR) system [4], which means that producers are not only responsible for the performance and information of products, but also for the recycling and utilization of end-of-life products, while specifying Power battery manufacturers are the main recycling body. Battery manufacturers hold a series of core technologies in battery design, R&D, and production. To implement the EPR system, enterprises can consider recycling issues in the battery design process, and innovate technologies to design products that are easy to unpack and perform preliminary performance tests.

2. Literature Review
Most scholars currently focus their research on power battery recycling on the process, economic and environmental benefit analysis, and the impact of government policies on recycling.
In terms of recycling processes: Leon and Miller [5] compared the magnitude of variable costs and time required for thermal and mechanical recycling of waste power batteries and found that mechanical recycling has a higher maximum recoverable metal value. Yun, Linh [6] summarized two basic aspects of recycling battery packs, mechanical procedures for recycling include smart disassembly systems for battery packs, and metallurgical processes including new pyrolysis, wet, biological, and hybrid methods. In terms of economic and environmental benefits of power battery recycling: Qiao, Zhao [7] analyzed the economic and environmental benefits that can be obtained by recycling used power batteries through the existing recycling technology in China, and the results showed that the level of recycled products significantly affects the benefits, and the recycling of traction batteries will be more favorable in the future. Sun, Su [8] proposed a new cost-benefit model for energy storage systems with lithium-ion batteries to discuss the economic benefits of different investment agents, concluding that grid companies have good prospects for investing in battery storage systems. In terms of the impact of government policies on power battery recycling: Gao, Liu [9] developed fixed and dynamic penalty models to explore the impact of government regulatory strategies on informal recycling channels for electric vehicle power batteries, and the results show that evolutionary stabilization strategies of the government and battery groups can be achieved under the dynamic penalty model and reduce the probability of informal recycling channels. Joshi, Vipin [10] modeled the Indian lead-acid battery recycling system using system dynamics and analyze the government's economic policies, the results show that subsidies and tax breaks for recyclers can reduce pollution.

In summary, incentive subsidies and administrative penalties are typical government policies to promote electric battery recycling, but few articles have compared the two policies and discussed whether incentive subsidies are effective in any market environment and analyzed the impact of other factors on the subject of participation. Considering evolutionary game theory, a preliminary model is developed in this paper to analyze the situation under government administrative penalties; a second one is extended to analyze the situation under subsidies; and finally, numerical simulations are used to analyze the sensitivity of the relevant influencing factors.

3. Evolutionary game model of government and power battery manufacturers

The government has a social responsibility to create a better environment for the people, so it plays a guiding role in the benign development of the power battery recycling industry. However, the goal of power battery manufacturers is to create the maximum economic benefit for themselves under any circumstances. The government and power battery manufacturers influence each other in the development of the industry, and their interactions will be studied through evolutionary game theory. In this paper, we chosen them as the participants in the evolutionary game model.

3.1. Model assumptions

Assumption 1: The government and the power battery manufacturer each adopt independent behavioral strategies and change their strategies dynamically according to the actual situation, and they will make strategic choices according to the benefits gained.

Assumption 2: The government and power battery manufacturers, as two sides of the game, each have two strategies to choose from. Government: First, "strict regulation" to urge power battery manufacturers to adopt green innovation technology, and administrative penalties for power battery manufacturers who do not adopt green innovation technology; second, "lax regulation" where the government only regulates but does not take any action. Power battery manufacturers: one is to "adopt" green innovative technology; the other is to "not adopt" green innovative technology. Green innovative technology means that battery manufacturers consider the dismantling of end-of-life power battery packs and modules from the time of production design to reduce the difficulty of dismantling and realize green design.

Assumption 3: If the government chooses to "strictly regulate" should pay the corresponding cost for the solution because it is labor-intensive to make green innovations acceptable to interested parties. At the same time, widespread adoption of green innovations by power battery manufacturers will have
significant social benefits (environmental improvements, increased citizen satisfaction, sustainable economic development, etc.). In the long run, this will outweigh the additional costs paid by the government.

Assumption 4: If power battery manufacturers choose to "adopt" green innovations, their market competitiveness can be improved in the long run, leading to increased revenues. At the same time, this behavioral strategy will incur additional costs (R&D investment costs, upgrading old equipment, new production processes, etc.).

3.2. Model establishment and parameter settings

The assumptions can be made: the probability that a power battery manufacturer chooses to "adopt green innovation technology" is x, the probability that it chooses to "not adopt" is 1-x; the probability of the government choosing "strict regulation" is y, and the probability of choosing "lax supervision" is 1-y; where, 0 ≤ x ≤ 1, 0 ≤ y ≤ 1. The symbols and meanings in the model are shown in Table 1.

| Symbols | Meaning |
|---------|---------|
| \( R_u \) | power battery unit recycling revenue (\( R_u > 0 \)) |
| \( C_u \) | power battery unit recycling cost (\( R_u > C_u > 0 \)) |
| \( Q \) | Power battery recycling quantity (\( Q > 0 \)) |
| \( C_e \) | additional costs invested by power battery manufacturers in adopting green innovations (\( C_e > 0 \)) |
| \( h \) | degree of technological innovation (incremental rate of revenue per unit from adoption of green innovations \( 1 > h > 0 \)) |
| \( R_s \) | social benefits gained from strict government regulation (increased government credibility and public satisfaction \( R_s > 0 \)) |
| \( C_g \) | Cost of government regulation (\( C_g > 0 \)) |
| \( C_r \) | the cost of remediation taken against power battery manufacturers who do not adopt green innovations (\( C_r > 0 \)) |
| \( P \) | administrative fines for power battery manufacturers that do not adopt green innovations (\( P > 0 \)) |
| \( S \) | government incentives for power battery manufacturers to adopt green innovative technologies (\( S > 0 \)) |

**Table 2. Government and power battery manufacturer game payment matrix**

| Power Battery Manufacturer | Strict regulation y | lax regulation 1-y |
|---------------------------|---------------------|--------------------|
| adopt green innovative technologies \( x \) | \( Q(1+h)(R_u-C_u)-C_e \) | \( Q(1+h)(R_u-C_u)-C_e \) |
| | \( R_u-C_g \) | \( -C_g \) |
| Not adopt green innovative technologies \( 1-x \) | \( Q(R_u-C_u)-P \) | \( Q(R_u-C_u) \) |
| | \( P-C_r+C_r-C_g \) | \( -C_g \) |

According to Table 2, the expected benefit of the "adopt green innovation technology" strategy of the power battery manufacturer is defined as \( U_{11} \), the expected payoff of the "not adopt green innovation" strategy is defined as \( U_{12} \). The overall average expected return of the manufacturer is defined as \( U_1 \). Also, the expected return for the government to choose the "strict regulation" strategy is defined as \( U_{21} \) and the expected payoff of choosing the "lax regulation" strategy is defined as \( U_{22} \). The overall average expected return of the government is defined as \( U_2 \). The relevant expressions are shown below.
Thus, five game of power battery manufacturer's strategy by Eqs (1)-(3) is:

\[ U_{11} = [Q(1 + h)(R_u - C_u) - C_e]y + [Q(1 + h)(R_u - C_u) - C_e](1 - y) \]
\[ = Q(1 + h)(R_u - C_u) - C_e \]

\[ U_{12} = y(Q(R_u - C_u) - P) + (1 - y) [Q(R_u - C_u)] = Q(R_u - C_u) - yP \]
\[ U_1 = xU_{11} + (1 - x)U_{12} = [Qh(R_u - C_u) - C_e]x + Pxy - Py + Q(R_u - C_u) \]
\[ U_{21} = x(R_e - C_g) + (1 - x)(P + R_e - C_r - C_g) \]
\[ = (C_r - P) + R_s - P C_g + P - C_r \]
\[ U_{22} = y(-C_g) - (1 - x) C_g = -C_g \]
\[ U_2 = yU_{21} + (1 - y)U_{22} = y(R_s + P - C_r) + (C_r - P) xy - C_g \]

3.3. Model solving

According to the theory of replication dynamics, the replication dynamic equation of the evolutionary game of power battery manufacturer's strategy by Eqs (1)-(3) is:

\[ \frac{dF(x)}{dt} = x(U_{11} - U_1) = x(1 - x)[Qh(R_u - C_u) - C_e + yP] \]

From Eqs (4)-(6), the evolutionary game replication dynamic equation for the government's decision strategy is

\[ \frac{dy}{dt} = y(U_{21} - U_2) = y(1 - y)[(C_r - P)x + R_s + P - C_r] \]

Solve the set of dynamic equations consisting of (7)-(8): let \( F(x) = 0 \) and \( F(y) = 0 \), we obtain \( x_1 = 0 \), \( x_2 = 1 \), \( x_3 = \frac{R_s + P - C_r}{p - C_r} \). \( y_1 = 0 \), \( y_2 = 1 \), \( y_3 = \frac{Qh(C_u - R_u) + Ce}{P} \). Thus, five local equilibrium points of the system are obtained: E1(0,0), E2(0,1), E3(1,0), E4(1,1) and E5(x*, y*).

\( x^* = \frac{R_s + P - C_r}{p - C_r} \), \( y^* = \frac{Qh(C_u - R_u) + Ce}{P} \); because \( x^* > 1 \) \( (P - C_r > 0) \) or \( x^* < 0 \) \( (P - C_r < 0) \), and by assumption \( 0 \leq x \leq 1 \), so E5(x*, y*) does not exist.

The stability of the equilibrium point in the system can be analyzed according to the Lyapunov stability theory using the Jacobi matrix of the system [11], dynamical system of the power battery producer and the government game is:

\[ J = \begin{pmatrix}
\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\
\frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y}
\end{pmatrix}
\]
\[ = \begin{pmatrix}
[Qh(R_u - C_u) - C_e + yP](1 - 2x) & x(1 - x)P \\
(C_r - P)y(1 - y) & (1 - 2y)(C_r - P)x + R_s + P - C_r
\end{pmatrix} \]

The determinant equations and traces of this Jacobi matrix J are, respectively:

\[ detJ = [Qh(R_u - C_u) - C_e + yP](1 - 2x) + [(C_r - P)x + R_s + P - C_r](1 - 2y) - Px(1 - x)(C_r - P)y(1 - y) \]
\[ trJ = [Qh(R_u - C_u) - C_e + yP](1 - 2x) + [(C_r - P)x + R_s + P - C_r](1 - 2y) \]

Table 3 lists the results of the four possible equilibrium points brought into the determinant equation and matrix trace. We found, the signs of detJ and trJ are determined by five components: Qh(R_u - C_u) - C_e, Qh(R_u - C_u) - C_e + P, R_s + P - C_r, R_s and R_s - C_r. From the hypothesis, it follows that R_s - C_r > 0, P > 0, R_s > 0, according to stability theory, the evolutionary stabilization strategy (ESS) is ultimately determined by Qh(R_u - C_u) - C_e and Qh(R_u - C_u) - C_e + P are determined. Therefore, the stability of the equilibrium point can be discussed in three scenarios.

| Local equilibrium point | Equation of detJ | Equation of trJ |
|-------------------------|------------------|-----------------|
| E1(0,0)                 | ( Qh(R_u - C_u) - C_e )( R_s + P - C_r ) | Qh(R_u - C_u) - C_e + R_s + P - C_r |
| E2(0,1)                 | Qh(R_u - C_u) - C_e                           | Qh(R_u - C_u) - C_e + R_s + P - C_r |
| E3(1,0)                 | Qh(R_u - C_u) - C_e                           | Qh(R_u - C_u) - C_e + R_s + P - C_r |
| E4(1,1)                 | Qh(R_u - C_u) - C_e                           | Qh(R_u - C_u) - C_e + R_s + P - C_r |
| E5(x*, y*)              | Qh(R_u - C_u) - C_e                           | Qh(R_u - C_u) - C_e + R_s + P - C_r |
E2(0,1) \[ (Qh(R_u - C_u) - C_e + P)(C_r - R_s) - P \]  
E3(1,0) \[ (C_e - Qh(R_u - C_u))R_s \]  
E4(1,1) \[ (Qh(R_u - C_u) - C_e + P)R_s \]

3.4. Model analysis

![Diagram on the dynamic evolution of equilibrium points.](image)

Figure 1. Diagram on the dynamic evolution of equilibrium points.

Scenario 1. \[0 < Qh(R_u - C_u) - C_e < Qh(R_u - C_u) - C_e + P\]
In this case, for the power battery manufacturer, the increased benefit of adopting the green innovation technology outweighs the cost of investing in it. According to the judgment criteria, local stability analysis is performed for four possible equilibrium points. Figure 1 (a) shows that point starts from E1 (0,0), and after E2 (0, 1) or E3 (1, 0) finally converges to E4 (1, 1). So E1 (0,0) is the unstable point, E2(0,1) and E3(1,0) are the saddle points, and E4(1,1) is the stable point. The analysis shows that E4(1,1) is the evolutionary stable strategy (ESS), so finally the government chooses the "strict regulation" strategy, and the power battery manufacturers choose the "adopt green innovation technology" strategy.

Scenario 2. \[Qh(R_u - C_u) - C_e < 0 < Qh(R_u - C_u) - C_e + P\]
The above conditions indicate that the increased revenue of power battery manufacturers who adopt green innovation technologies is less than the cost of additional investment in them, and the penalty paid by manufacturers who do not adopt is greater than the loss of profit after adopting green innovation technologies. According to the judgment criteria, the panel (b) in figure 1 shows that all of the points starting from E3(1,0), pass through E1(0,0) and E2(0,1) finally converges to E4(1,1). Thus, E3(1,0) is the unstable point, E1(0,0) and E2(0,1) are the saddle points, and E4(1,1) is the stable point. This result reveals that E4(1,1) is the ESS, so finally the government chooses to strictly regulate and the power battery manufacturers choose to adopt green innovative technologies.

Scenario 3. \[Qh(R_u - C_u) - C_e < Qh(R_u - C_u) - C_e + P < 0\]
In this case, for the power battery manufacturer, the increased benefit of adopting green innovation technology is smaller than its additional investment cost, and the government penalty is smaller than the profit loss after adopting green innovation technology. As shown in Figure 1(c), points starting from E3(1,0), passing through E1(0,0) and E4(1,1), and eventually converging to E2(0,1). It is obtained that E3(1,0) is the unstable point, E1(0,0) and E4(1,1) are the saddle points, and E2(0,1) is the stable point. Finally, the government and power battery manufacturers choose the "strict regulation" strategy and the "not adopt green innovation technology" strategy, respectively.

4. Model extension
In the recycling market, government subsidies can reallocate resources and are necessary as a macro-regulatory tool. Government subsidies help guide and promote the survival and growth of firms [12]; an
important means of guiding firms to invest in technological innovation [13]. Therefore, both penalties and subsidies are considered as a means for the government to promote the adoption of green innovative technologies by power battery producers in order to further analyze the stability points and evolutionary paths among the game players.

For power battery manufacturers, government subsidies mean reducing the additional cost of adopting green innovation technologies. Suppose, when the government chooses the "strict regulation" strategy, penalizes the manufacturers who do not adopt green innovation technologies, and gives financial subsidies to the power battery manufacturers who adopt it. In the long run, social benefits to the government are much larger than the sum of financial subsidies and remediation costs and S is defined as incentive subsidy. Table 4 presents the benefit matrix under the government providing subsidy incentives.

Table 4. Government and Power battery Manufacturer Game Payment Matrix

| Power Battery Manufacturer | Government                  |
|----------------------------|-----------------------------|
| adopt green innovative technologies x | Q(1+h)(Ru-Cu) - Ce + S  |
|                             | R_s - C_g * S              |
| Not adopt green innovative technologies 1-x | Q(R_u-C_u) - P |
|                             | P - C_r + R_s - C_g       |

Similarly, five equilibria points are obtained: E_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1) and E_5(x^*, y^*). where ( x^* = \frac{R_s + P - C_g}{P - C_r + S} , y^* = \frac{Q h (R_u - C_u) + C_e}{P + S} ) ; because x^* = \frac{R_s + P - C_g}{P - C_r + S} > 1 , and by assumption 0 \leq x \leq 1 , so E_5(x^*, y^*) does not exist.

The results of this extended model are similar to the results of the initial model. And final election strategy is the same as the initial model, with almost the same evolutionary path for each subject, but the conditions for the application of the stabilization point are changed.

When 0 < Q(R_u-C_u) - h-C_e < Q(R_u-C_u) - h-C_e + P + S, the system ESS point is E_4(1,1).
When Q(R_u-C_u) - h-C_e < 0 < Q(R_u-C_u) - h-C_e + P + S, the system ESS point is E_4(1,1).
When Q(R_u-C_u) - h-C_e < Q(R_u-C_u) - h-C_e + P + S < 0, the system ESS point is E_2(0,1).

It is found that government subsidies are beneficial to promote power battery manufacturers to choose the "adopt green innovation technology" strategy, but they cannot change the stable strategy of both sides of the final game. When Q h (R_u - C_u) - C_e > 0, which is the benefits of adopting green innovation technology are greater than the additional input costs, the government does not need to intervene, and the final stable strategy of power battery manufacturers is to adopt. While, Q h (R_u - C_u) - C_e < 0 , the final strategy chosen by the manufacturer is related to the government intervention.

5. Numerical simulation and discussion

To better analyze the impact of government incentive subsidies and administrative penalties on the decision-making behavior of power battery manufacturers. This paper uses MATLAB2020a software to verify the results of the model. We set the strategic probability of strict government regulation and adoption of green innovation technology by power battery producers to 0.5, respectively, and the remaining relevant parameters are set as follows: Q = 300 , h = 0.1, R_u = 0.4, C_u = 0.3, C_e = 10, R_s = 32, C_r = 10, P = 3, and S = 3.

Keeping the remaining parameters unchanged, set P=5,10,15,20,25,30 and S=0; similarly make S=5,10,15,20,25,30 and P=0, so as to compare the impact of P and S on X. The results are shown in Figure 2. When both P and S are 5, the curve eventually converges to the x-axis and the ultimate stabilization strategy for power battery manufacturers is to not adopt green innovations. As P and S increase, the curve eventually converges to the y-axis, and the final stabilization strategy of the
manufacturer is to adopt green innovation technology. When taking values greater than 5, the curve about P is always above the curve about S, indicating that the evolution to the steady state is fast. Conclude that, both fines and subsidies as government interventions are effective in promoting the adoption of green innovative technologies by power battery producers, but too low penalties and subsidies are not sufficient for the change of manufacturers' strategies, and administrative penalties are more beneficial than incentive subsidies to change the strategic choices of power battery producers when the surplus of adopting green innovative technologies is negative. Therefore, the government should increase administrative penalties and moderately reduce subsidies to reduce regulatory costs.

Figure 2. The impact of P and S comparison on x.

Holding the other parameters constant, let h = 0.1, 0.3, 0.5, 0.7, 0.9, and study the effect of technology innovation degree on the decision behavior of power battery manufacturers and depict the results in Figure 3. As h increases, the rate of return of green innovation technology increases, the willingness of manufacturers to choose the "adopt" strategy also increases. This indicates that the increase in technology innovation will bring more benefits to power battery manufacturers, thus accelerating the rate of "adoption" and increasing enthusiasm. From the perspective of enterprises, this can improve the recycling efficiency of power batteries, reduce the number of damages, and benefit from the green product market, thus increasing their profitability.

As shown in Figure 4, other parameters remain unchanged, and the power battery manufacturers converge to 1 at different rates when Q takes different values. When Q = 300, the curve converges to the green innovation technology at the slowest rate, and when Q = 1500, the curve converges to 1 at the fastest rate. This shows that as the number of recycling increases, the probability of manufacturers choosing the "adoption" strategy increases. Therefore, manufacturers should positively increase recycling channels and expand the scale of recycling, so as to increase the number of recycling and form a scale effect.
6. Conclusions

In this paper, we use evolutionary game theory to compare the initial model and the extended model in order to investigate the impact of government penalty and subsidy measures on the decision-making behavior of power battery producers. The findings of the study are shown in the following.

(1) In the case that the benefits of adopting green innovative technologies by power battery producers outweigh their additional input costs, the evolutionary game system eventually converges to government strictly regulates and the manufacturer adopts this technology. At this time, power battery manufacturers have enhanced the recovery efficiency and corporate reputation in the adoption of green innovation technology and have achieved greater competitive advantages in the recycling market.

(2) When the benefits of adopting green innovation technologies by power battery manufacturers are less than their additional input costs, government intervention is required to guide enterprises to green innovation. Both penalties and subsidies are beneficial to the change of power battery manufacturers' strategies, but they must be greater than a certain threshold \((Q_h(R_u - C_u) - C_e + P + S > 0)\), otherwise it cannot effectively promote it. Bilateral government policies are more effective than unilateral policies in promoting, penalties are likely to cause resistance from
enterprises, and subsidies can reduce the input costs of enterprises, but the research results show that penalties are more effective than subsidies in making power battery manufacturer change their decision-making behavior. Therefore, considering the government's financial pressure, subsidies can be moderately reduced to avoid enterprises' fraudulent subsidies and rent-seeking behaviors.

(3) Factors such as the recycling quantity and degree of technological innovation also influence the decision-making behavior of power battery manufacturers. The increase of recycling quantity can increase the willingness of enterprises to innovate greenly, and manufacturers should expand recycling channels and build recycling centers. Likewise, the increase of degree of technological innovation will enable manufacturers to design standardized, easy to disassemble and test, environmentally friendly battery modules, reduce disassembly costs and improve recycling efficiency, thus stimulating the green innovation behavior of power battery manufacturers.

Acknowledgments
This work was supported by The National Social Science Fund of China with grant number 15BGL084.

References
[1] Lin, B.Q. and R.P. Tan, *Estimation of the environmental values of electric vehicles in Chinese cities*. Energy Policy, 2017. 104: p. 221-229.
[2] Saxena, S., et al., *Quantifying EV battery end-of-life through analysis of travel needs with vehicle powertrain models*. Journal of Power Sources, 2015. 282: p. 265-276.
[3] Lv, H., et al., *Electric field driven de-lithiation: A strategy towards comprehensive and efficient recycling of electrode materials from spent lithium ion batteries*. Applied Catalysis B-Environmental, 2021. 283.
[4] Ministry of Industry and Information Technology, *Notice on Printing and Distributing the Interim Measures for the Administration of New Energy Automobile Power Battery Recycling*. 2018.
[5] Leon, E.M. and S.A. Miller, *An applied analysis of the recyclability of electric vehicle battery packs*. Resources, Conservation and Recycling, 2020. 157: p. 104593.
[6] Yun, L., et al., *Metallurgical and mechanical methods for recycling of lithium-ion battery pack for electric vehicles*. Resources, Conservation and Recycling, 2018. 136: p. 198-208.
[7] Qiao, Q., et al., *Electric vehicle recycling in China: Economic and environmental benefits*. Resources Conservation and Recycling, 2019. 140: p. 45-53.
[8] Sun, B., et al., *Economic analysis of lithium-ion batteries recycled from electric vehicles for secondary use in power load peak shaving in China*. Journal of Cleaner Production, 2020. 276.
[9] Gao, H., et al., *OPTIMIZATION DECISION ON INFORMAL RECYCLING CHANNEL OF ELECTRIC VEHICLE BATTERIES AND SUPERVISION STRATEGY*. Applied Ecology and Environmental Research, 2019. 17(4): p. 8749-8762.
[10] Joshi, B.V., et al., *Impact of policy instruments on lead-acid battery recycling: A system dynamics approach*. Resources, Conservation and Recycling, 2021. 169: p. 105528.
[11] Zhang, Z., Y. Niu, and J. Song, *Input-to-State Stabilization of Interval Type-2 Fuzzy Systems Subject to Cyberattacks: An Observer-Based Adaptive Sliding Mode Approach*. IEEE Transactions on Fuzzy Systems, 2020. 28(1): p. 190-203.
[12] Peng, H.T. and Y. Liu, *How government subsidies promote the growth of entrepreneurial companies in clean energy industry: An empirical study in China*. Journal of Cleaner Production, 2018. 188: p. 508-520.
[13] Jia, L.L., E. Nam, and D. Chun, *Impact of Chinese Government Subsidies on Enterprise Innovation: Based on a Three-Dimensional Perspective*. Sustainability, 2021. 13(3).