Driving Force Mechanism of the Core Green Technology Innovation of Equipment Manufacturing Enterprises towards Industry 5.0 in China

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Received 28 May 2022; Revised 11 July 2022; Accepted 15 July 2022; Published 9 August 2022

Green innovation is an important way for enterprises to achieve high-quality economic development, and it is also the way to achieve the goal of double carbon. Green innovation has therefore become a research hotspot. With the acceleration of the digitalization process in equipment enterprises, intelligent manufacturing equipment enterprises located at the top of the industrial chain are in urgent need of green core technology innovation activities. In order to explore the internal mechanism of core green technology innovation, this research introduces reputation theory into the evolutionary game analysis process. By constructing an evolutionary game model between the government and intelligent manufacturing equipment enterprises, this research analyzes the dynamic factors that affect the selection and evolution of the main strategies of the players in the evaluation game. The results show that corporate reputation, core green technology innovation profit, government subsidies, government reputation, and the cost for the government to support core technology, among other factors, importantly affect the game between the government and the enterprises. At the same time, since both the government and the enterprises are affected by the initial state and the maximization of the interests of both sides of the game, it is difficult for them to spontaneously reach an ideal stable and balanced state through a virtuous circle. The greater the profits and the reputation premium the core green technology innovation brings to the enterprises, the more favorable it is for the enterprises to choose core green technology innovation; government subsidies within a certain range will also drive enterprises to choose core green technology innovation. When the value of enterprise core green technology innovation is low, the cost for the government to support core green technology innovation is lower, enterprises will lose more opportunities and decline in global competitiveness, and it will become more favorable for the government to evolve towards supporting core green technology innovation. On the contrary, the government will gradually transfer its tangible hand to the intangible hand of the market based on the consideration of subsidies, innovation costs, and reputation. The results of this research are intended to provide a theoretical basis and practical reference for Chinese intelligent manufacturing equipment enterprises to better achieve green core technology innovation.

1. Introduction

The adoption of green technology is imperative for the industrial and agricultural sectors to reduce their GHG emissions and address the climate change [1–3]. As a new strategic industry in China, intelligent manufacturing equipment enterprises are the core link of the industrial chain [4] and the top priority of Made in China 2025 [5]; they are also the way to Industry 5.0 [6]. The core green technology innovation of intelligent manufacturing equipment enterprises is an inevitable requirement to enhance the core competitiveness of China’s industry and a necessary requirement for achieving the double carbon goal and strategic choice in order to seize the commanding point of future economic, technological, and ecological development [7]. At present, China’s intelligent equipment
manufacturing industry has just begun, and its core technology relies on imports [8], which causes industry hollowing [9] and makes China’s manufacturing industry firmly locked in the low end of the global value chain [10]. On the other hand, the double carbon target has a short lead time and a heavy task to achieve, driving a strong demand for green products and services in the manufacturing sector, which is still dependent on imports. Therefore, promoting the core green technology innovation of China’s equipment manufacturing industry as an industry leader which will eventually enable China’s manufacturing industry to achieve a real technological leap and harmonious coexistence will become an urgent problem to be solved.

Along with China’s rapid economic growth, the development model of high energy consumption, high pollution, and high emissions has brought about serious damage to the ecological environment. The development of green technology innovation is a fundamental solution to environmental problems and economic development, and has become a research hotspot for scholars at home and abroad [11]. Green technology innovation has the attribute of Public Goods and positive externality [12], only relying on the market mechanisms to achieve technological innovation [13], and it is also easy to cause market failure of the technological supply [14]. Therefore, the government needs to use direct and indirect means to guide [15] and participate in research and development activities [16]. Research on green technology innovation has been conducted by scholars from the following three aspects. The first is on the factors influencing green technology innovation. The mechanism of the influence of government policies, the environment, and the internal factors of enterprises is proposed. These include the impact of government policies on corporate green technology innovation, such as environment policy [17], government subsidies, environmental regulation [18, 19], and government market regulation [20] factors; the impact of environmental factors on green technology innovation, such as network embedding and resource concordance [21]; and the influence of internal factors on green technology innovation, such as the nature and resources of the company, the executive team, the organizational culture, and environmental investment. Second, the path of green technology innovation, which proposes that the government and the market work together, deepens the reform of key areas, etc. [22]. Thirdly, the research methodology is also relevant. The evolutionary game model can provide a more specific game strategy choice for exploring the micro-driven paths of green technology innovation behavior [23]. In recent years, more and more scholars have begun to adopt the evolutionary game approach to study green technology innovation, such as constructing a tripartite evolutionary game among the government, enterprises, and public consumers to study the evolutionary mechanism of the green technology innovation of enterprises under environmental regulation [24]. Research has addressed the evolutionary path and law of the green technology innovation of enterprises under market-oriented mechanisms [25], constructed two-sided game and three-sided game models among the government, enterprises, and the public, studied the simulation of policies under different scenario models and implementation strengths, and explored the behavioral strategy choices of the three parties for green technology innovation [23]. For intelligent manufacturing equipment enterprises in the process of moving towards industrial 5.0, scholars have focused on combining green and intelligent research and innovation, building a tripartite evolutionary game between the government, industry, academia, and research, and studying the evolutionary mechanism of green and intelligent technology research and development in collaboration with industry, academia, and research under government participation [11]. The clustering and driving factors of a green innovation space driven by smart manufacturing have also been addressed, and a study found that technology, the market, and environmental regulation have a significant impact on the synergy of green innovation systems [26].

In summary, scholars at home and abroad have conducted abundant research on green technology innovation, but relatively few have studied the green core technology innovation of intelligent manufacturing equipment enterprises. Technological innovation in key areas of China’s green industry is still lagging behind, and there is much room for innovation in the field of key core technologies to break through the bottleneck [27]. The question how to drive green core technology innovation in intelligent manufacturing equipment enterprises has become urgent for solving the problem of high-quality economic development.

The main driving force of the core green technology innovation of intelligent manufacturing equipment enterprises arises from two aspects. First, the external driving force is created by the government through constructing and implementing the hard conditions and soft environment for core green technology innovation. The role of the government in influencing the pressure, confidence, and power of the independent core technology development of enterprises is more fundamental [28] for correcting market failures to a certain extent. The innovation policies of the government, such as tax policies and subsidy policies, encourage the intelligent manufacturing equipment enterprises to make dynamic choices concerning core green technology innovation. The second aspect is the internal drive of the market mechanism. Externally, the products, services, and experiences brought through green core technology innovation can better meet the green development requirements of enterprises; internally, they improve the production efficiency of enterprises, reduce their production costs, enhance their ecological benefits, and allow enterprises finally to obtain significant future benefits while reducing the environmental pollution. In other words, the value realization from the consumer’s side is the core driver for intelligent manufacturing equipment enterprises to choose green core technology innovation. However, core green technology innovation involves high investment, high risk, a high threshold, a long cycle [29], etc., so that it is difficult for enterprises to predict its future value in the short term and realize the optimal allocation of innovation resources. The reputation resource is the sustainable driving source for enterprises to enhance their innovation ability.
In order to simplify the decision variables, the following assumptions are made for the evolutionary game model:

Hypothesis 1. The evolutionary game [36] model includes two types of participants: the government and intelligent manufacturing equipment enterprises. For reasons of simplification, it is assumed that the government and the intelligent manufacturing equipment enterprises are limited rational groups. Each game is a game in which one member is randomly selected from the enterprise group and the government group, and one member of each group has two pure strategy choices.

Innovation content is either core green technology innovation or non-core green technology innovation [37]. The strategy set of the enterprises is: \{core green technology innovation, non-core green technology innovation\}. The strategy set of the government departments is: \{support core green technology innovation, let non-core green technology innovation go\}.

Hypothesis 2. When enterprises choose the core green technology innovation strategy, once the innovation is successful, the modern equipment and production efficiency of the manufacturing industry may not only be improved [5], but subversive changes in new industries may also occur. Consequently, enterprises can occupy the top of the global value chain and obtain competitive advantages in future competition. The profit brought to the enterprises after deducting the relevant costs and expenses is recorded as the total profit of core green technology innovation \(\pi_1\). When the government chooses to support enterprises to carry out core green technology innovation, it will generally provide certain subsidies \(A\) to enterprises. The signals based on technology and supervision certifications released by innovation subsidies enable market investors to give enterprises higher credit recognition due to their trust in the government credit evaluation system [38]; meanwhile, enterprises can strive for more social resources, such as an increase in external venture capital and in upstream and downstream enterprise cooperation [29], and the joining of excellent scientific and technological innovation talents and excellent entrepreneurs indicates that the reputation of enterprise \(a\) is relatively high. Once the enterprises master the core technology, they can reconstruct the value ecosystem through the core technology, and will be able to share the complementary spillovers, competitive spillovers, information exchange platform spillovers, and other values [39] through interaction among the enterprises. If the enterprises choose the strategy of non-core green technology innovation, the balance of the income of non-core green technology innovation after deducting the cost is recorded as the total profit of non-core green technology innovation \(\pi_2\).

Hypothesis 3. When the government chooses to support enterprises in carrying out the core green technology innovation strategy, the government’s expenditure on technological review and supervision, the efficiency of the core green technology innovation, and the optimization of the project selection criteria and procedures [29] is the input cost of the government’s implementation of the core green technology innovation incentive policies \(C_1\). The reputation gained by supporting the core green technology innovation of enterprises and the improvement in the credibility of the government is recorded as \(b\). When the government supports core green technology innovation, the enterprises will lose the opportunity to cooperate with the government when they choose the non-core green technology innovation strategy: the public sector, which functions as the demand
side and the first buyer of innovative products, can expand the demand [29] for green technology innovation through government procurement, with this becoming an incentive for enterprise innovation. In 2006, China launched the government procurement system of independent innovation. Similarly, the pilot market plan was launched by the EU in 2008. The loss caused by the reduction in cooperation opportunities is recorded as $T$. If the government chooses to allow the enterprises make their own decisions on non-core green technology innovation, the government will not bear the cost of innovation and will have no innovation income. However, if the enterprises give up decision making about core green technology innovation, then the government will lose national core competitiveness, which is recorded as $C_2$.

**Hypothesis 4.** Given a background of government support for core green technology innovation, the core green technology innovation value of intelligent manufacturing equipment enterprises is the sum of the total profit of core green technology innovation $\pi_1$, the reputation of the enterprises, and the amount of the government subsidy. The value of non-core green technology innovation is the balance of the total profit of non-core green technology innovation $\pi_2$ after deducting the loss caused by the reduction in cooperation opportunities after the selection of non-core green technology innovation.

**Hypothesis 5.** In the initial stage of the game, it is assumed that the probability that the government supports the enterprises in choosing the core green technology innovation strategy is $x(0 \leq x \leq 1)$, and the probability that the enterprises carry out core green technology innovation is recorded as $y(0 \leq y \leq 1)$. The income matrix is shown in Table 1:

### Table 1:

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

#### 2.2. Construction of Evolutionary Game between Government and Enterprises.

The benefits of the government’s strategy of supporting enterprises to carry out core green technology innovation are as follows:

$$E_{11} = y(-A + b - C_1) + (1 - y)(-C_1).$$

The benefits of the government’s choice not to interfere with enterprises in making core green technology innovation decisions are

$$E_{12} = (1 - y)(-C_2).$$

The average benefits of the government are

$$E_1 = xE_{11} + (1 - x)E_{12}. \hspace{1cm} (3)$$

When enterprises choose to carry out a core green technology innovation strategy, the benefits are

$$E_{21} = x(\pi_1 + A + a) + (1 - x)(\pi_1 + a). \hspace{1cm} (4)$$

When enterprises choose to carry out a non-core green technology innovation strategy, the benefits are

$$E_{22} = x(\pi_2 - T) + (1 - x)\pi_2. \hspace{1cm} (5)$$

The average benefits of the enterprises are

$$E_2 = yE_{21} + (1 - y)E_{22}. \hspace{1cm} (6)$$

Enterprises and governments adjust their choice of strategies according to the results of multiple evolutionary games. When the relative adjustment rate of the choice frequency is directly proportional to the extent that the income exceeds the average income, the evolution in core green technology innovation strategies of enterprises and governments can be represented by a dynamic replication system composed of the following differential equations:

$$F(x) = \frac{dx}{dt} = x(1-x)[(C_2-C_1) + (-A + b - C_2)y],$$

$$G(y) = \frac{dy}{dt} = y(1-y)[(\pi_1 - \pi_2 + a) + (A + T)x]. \hspace{1cm} (7)$$

#### 2.3. Stability Analysis.

Make $\frac{dx}{dt} = 0$ the possible state of the government group; that is: $x_1 = 0, \ x_2 = 1, \ y_d = C_1 - C_2/ - A + b - C_2$ (if and only if $0 \leq C_1 - C_2/ - A + b - C_2 \leq 1$ holds). Similarly, the possible stable state of the enterprise group is: $y_1 = 0, \ y_2 = 1, \ x_d = \pi_2 - \pi_1 - a/ - A + T$ (if and only if $0 \leq \pi_2 - \pi_1 - a/ - A + T \leq 1$ holds). Therefore, the five local equilibrium points of the evolutionary game that can be obtained on the plane are: $E_1(0,0), \ E_2(0,1), \ E_3(1,0), \ E_4(1,1)$, and $E_5(x_d, y_d)$, and among these $x_d = \pi_2 - \pi_1 - a/ - A + T$, $y_d = C_1 - C_2/ - A + b - C_2$.

The determinant $(\text{Det}J)$ and trace $(\text{Tr}J)$ of matrix $\frac{dy}{dt} = 0$ are calculated in turn. If the sign of the determinant $(\text{Det}J)$ and that of the trace of the matrix $(\text{Tr}J)$ are the same, then they are unstable stationary points. If the two symbols are different, then they are stable stationary points, and if the symbols are uncertain, then they are saddle points. The local stability of the Jacobian matrix is used to analyze the stability of the equilibrium point. The Jacobian matrix $J$ of the system is expressed as follows:

$$J = \begin{bmatrix}
(1 - 2x)[(C_2 - C_1) + (-A + b - C_2)y] & x(1-x)(-A + b - C_2) \\
(y(1-y)(A + T) & (1 - 2y)[(\pi_1 - \pi_2 + a) + (A + T)x]
\end{bmatrix}. \hspace{1cm} (8)$$
The stability of the above five local equilibrium points was analyzed, and the following results were obtained.

The determinant of $J$ is
\[
(1 - 2x)[(C_2 - C_1) + (-A + b - C_2)y] + x(1 - x)(-A + b - C_2)y (1 - y) (A + T).
\]
\[
(1 - 2x)[(C_2 - C_1) + (-A + b - C_2)y] + (1 - 2y)[(\pi_1 - \pi_2 + a) + (A + T)x].
\]

The trace of $J$ is

When the equilibrium point of replication dynamics is an local asymptotic stability point of the evolutionary dynamic process, the equilibrium point is the evolutionary stability strategy, which needs to satisfy the determinant Det$_j > 0$ and trace Tr$_j < 0$ of the matrix at the same time. The expressions of the matrix determinant and trace at 5 equilibrium points are shown in Table 2.

According to the local stability of the Jacobian matrix, the stability of the above five local equilibrium points was analyzed, and the following results were obtained.

### Table 1: Payment matrix of enterprise: core green technology innovation evolutionary game.

<table>
<thead>
<tr>
<th>Government</th>
<th>Core green technology innovation ($y$)</th>
<th>Non-core technology innovation ($1 - y$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support ($x$)</td>
<td>$-A + b - C_1$ [\pi_1 + A + a]</td>
<td>$-C_1$ [\pi_2 - T]</td>
</tr>
<tr>
<td>Non-interference ($1 - x$)</td>
<td>$0$ [\pi_1 + a]</td>
<td>$-C_2$ [\pi_2]</td>
</tr>
</tbody>
</table>

### 3. Analysis

According to the differences between the value of core green technology innovation and that of non-core green technology innovation, different conditions were set to analyze the path of the core green technology innovation strategy of the government and the intelligent manufacturing enterprises.

#### 3.1. When the Sum of the Core Green Technology Innovation

When $\pi_1 + a + A < \pi_2 - T$, the government makes strategic choices based on a comparison between the two. Whether the intelligent manufacturing equipment enterprises opt for the core green technology innovation or not depends on the respective benefits of the two types of green technology innovation.

**Conclusion 1.** When $\pi_1 + a + A < \pi_2 - T$ and $C_1 > C_2$, the system has four equilibrium points, and $(x, y) = (0, 0)$ is the evolutionary stable point of the system. This kind of steady state is very unfavorable to core green technology innovation, because the government and the enterprise do not act at the same time.

At the stage of technology research and development, enterprises are rational economic men: based on the consideration of their economic interests, enterprises will eventually choose to abandon the core green technology innovation strategy due to the high cost of core technology investment and the uncertainty of future profits. Even at the initial stage, some enterprises choose the core green technology innovation strategy and obtain innovation subsidies, as well as reputation and cooperation opportunities with the government through core green technology innovation. In the end, however, the strategy of core green technology innovation will be abandoned because the total income of core green technology innovation is low in the short term.

When the cost of the government’s support of enterprises in carrying out core green technology innovation $C_1$ is relatively high, then the risk of the government supporting enterprises in carrying out core green technology innovation will also be high. If the government supports non-core green technology innovation, the reputation and credibility of the government will not be greatly affected. As a result, after long-term and multiple games, the government will gradually adjust the direction of its policy support, and gradually increase the incentive for non-core green technology innovation on the part of intelligent manufacturing equipment enterprises. At present, especially for the core green technology innovation of intelligent equipment manufacturing enterprises, the local government policies have remained at the document level, and practical measures have not yet been issued. For example, there is almost no support for government procurement and service outsourcing [40].

**Conclusion 2.** When $\pi_1 + a + A < \pi_2 - T$, $C_1 < C_2$, there are four equilibrium points in the system, and $(x, y) = (1, 0)$ is the evolutionary stable point of the system. Generally speaking, in the four kinds of steady states, the steady state is poor, which is relatively consistent with the actual state of our country.

When the initial conditions meet the situation that negative effects brought by the government’s inaction $C_2$ is greater than the input cost of the government’s support for core green technology innovation $C_1$, then the government can be forced to formulate and implement specific and operable incentive innovation policies. Modern manufacturing technology becomes the key to attaining long-term global competitiveness by shaping the adaptability and dynamic capability of a country’s entire innovation ecosystem, as well as positioning the domestic enterprises in the global innovation ecosystem [5]. Governments have realized the importance of core green technology innovation and promoted it from a macroscopic. For example, the EU proposed Industry 5.0, and the Chinese government proposed the double carbon goal.
proposed to raise the core technology to the level of the national strategy.

Intelligent equipment manufacturing enterprises are the main body of core innovation. Although our government increases innovation subsidies year by year, reduces the innovation tax rate, and improves financial support to encourage enterprises to carry out core green technology innovation, the low total income of enterprise core green technology innovation, and the insufficient influence of implementation on enterprise innovation, and the low recognition of the market for enterprise core green technology innovation. The power of core green technology innovation is still insufficient. Core green technology innovation finally evolves to the (1,0) stable point.

3.2. Scenario 2: When the Sum of the Benefits Brought by Core Green Technology Innovation Is π1 + a + A > π2 − T, the Reputation of the Government Determines the Government’s Strategic Choice. The choice of a core green technology innovation strategy for intelligent manufacturing equipment enterprises will change the range of the value consideration of green technology innovation due to the change in government strategy choice.

Conclusion 3. When π1 + a + A > π2 − T, b > A + C1, the system has four equilibrium points, and (x, y) = (1, 1) is the evolutionary stable point of the system. This situation is the state that we strive to achieve in terms of policy effect and the realization of complementarity between the government and the market mechanism in the allocation of core technological innovation resources.

The government increases the amount of subsidies that are invested into the core green technology innovation, and creates a positive atmosphere of the whole society’s recognition of innovation, so that the enterprises can give full play to their propensities toward innovation and succeed in innovation. The total income from the core technology brought in this manner is greater than the total income from non-core green technology innovation in both the short term and the long term. Driven by profits, more and more enterprises will choose core green technology innovation strategies after many games. The implementation effect of the policy is positive, the reputation and credibility of the government are improved, and the double carbon goal is achieved. The comprehensive national strength of the whole country is increased due to the mastery of the core technology, and the intelligent manufacturing equipment enterprises will occupy the middle- and high-end market of the global value chain. At the same time, the core technology is subject to great changes in local areas, and the innovation ability of the manufacturing industry is improved to achieve economic quality development. The core green technology innovation finally evolves to the (1,1) stable point.

3.3. When π1 + a + A > π2 − T, b < A + C1, the Market Mechanism Dominates the Allocation of Core Technological Innovation Resources

Conclusion 4. When π1 + a + A > π2 − T, b < A + C1 and π1 + A < π2, the system has four equilibrium points; however, (x, y) = (0, 0) is the evolutionary stability point of the system. That is, the visible hand of the government leads innovation but fails to instigate the invisible hand of the market mechanism. Therefore, once the visible hand is withdrawn, the invisible hand will fail again. When π1 + A > π2, (x, y) = (0, 1) is the evolutionary stability point of the system. That is, enterprises as innovation subjects have the invisible hand of the market mechanism to lead them to make core technological innovation choices.

The economics literature has been treating the market as the invisible hand. Mainstream economics has been content to study the market as an automatic black box or an invisible hand. The tangible hand of the government includes government subsidies, income tax incentives, and government purchase policies. The original purpose of implementing the tangible hand is to compensate for market defects and promote the optimal allocation of resources.

The total cost of innovation input for government C1, such as the cost of building a healthy economic and legal environment, and the innovation subsidy that is given to enterprises, is far from improving the government’s reputation and credibility. This shows that when the reputation value of the government reaches a certain value, and then the reputation is increased, the cost will be increased faster. In this situation, the government, as a rational economic man, will inevitably choose to withdraw from the core green technology innovation field and transfer itself to the market. Moreover, it will play the role of innovatively allocating resources and guiding enterprises to make strategic choices. If the sum of core green technology innovation profit and the enterprise reputation is low, enterprises will choose non-core green technology innovation strategies. On the contrary, in the context of a substantial increase in the profits from core green technology innovation, the enterprise demonstration effect will lead more and more enterprises in the game group to enter the field of core green technology innovation.

<table>
<thead>
<tr>
<th>Equilibrium point</th>
<th>Det</th>
<th>Tr</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,0)</td>
<td>{C_2 - C_1}[(π_1 + a) - π_2]</td>
<td>{C_2 - C_1} + [(π_1 + a) - π_2]</td>
<td>0</td>
</tr>
<tr>
<td>(0,1)</td>
<td>−[b(C_1 + A)][(π_1 + a) - π_2]</td>
<td>−[b(C_1 + A)] + [(π_1 + a) - π_2]</td>
<td>0</td>
</tr>
<tr>
<td>(1,0)</td>
<td>−(C_2 - C_1)[(π_1 + a + A) - (π_2 - T)]</td>
<td>−(C_2 - C_1) + [(π_1 + a + A) - (π_2 - T)]</td>
<td>0</td>
</tr>
<tr>
<td>(1,1)</td>
<td>[b - (C_1 + A)][(π_1 + a + A) - (π_2 - T)]</td>
<td>[b - (C_1 + A)] - [(π_1 + a + A) - (π_2 - T)]</td>
<td>0</td>
</tr>
</tbody>
</table>

Among these, M = (π_2 - π_1 - a)[(π_1 + a + A) - (π_2 - T)]/(C_1 - C_2)[b - (C_1 + A)]/(A + T)[b - (C_1 + A)].
3.4. Factors Influencing System Evolution to Equilibrium and Its Influence Direction

Conclusion 5. When \( \pi_1 + a < \pi_2, \pi_1 + a + A > \pi_2 - T, b > A + C_1, C_1 > C_2 \), the system has five equilibrium points and two evolutionary stable points, \((x, y) = (0, 0)\) and \((x, y) = (1, 1)\). The stable point is \((0, 0)\) when the government allows enterprises to innovate non-core technology; the stable point is \((1, 1)\) when the government supports core green technology innovation and enterprises’ core green technology innovation. Which equilibrium point the system eventually evolves toward depends on the position of the initial state.

From the verification, it was found that:

(1) The greater the improvement in government reputation \( b \), and the greater the loss from non-core green technology innovation, the more conducive to the evolution of the game to equilibrium (support innovation, core green technology innovation). The increase in government innovation input cost is just the opposite. However, the increase in government subsidy \( A \) involves uncertainty regarding the evolution of the game to equilibrium (support innovation, core green technology innovation).

(2) For the evaluation process of the profits brought by the core green technology innovation of enterprises \( \pi_1 \) and the increase in the reputation of the enterprise \( a \) (support innovation, core green technology innovation), the smaller the income of non-core green technology innovation \( \pi_2 \), the more favorable it is for the evolution to equilibrium (support innovation, core green technology innovation).

4. Numerical Simulation

According to the evolutionary game model of green core technology innovation, the initial parameter values are set for simulation analysis. For this paper, experts in the field of green core technology innovation were consulted, and the initial assignments are shown in the table based on the policy documents issued by local governments on green technology innovation as well as based on the green core technology innovation of intelligent manufacturing equipment enterprises. The following simulation parameters that were not specified are the initial values.

4.1. Probability of \( x \) and \( y \) Values. The impact on \( x \) and \( y \) was analyzed when the analysis parameters were taken to be 0.2, 0.4, 0.6, and 0.9. The evolution impact on the system is shown in Figures 1 and 2.

According to Figures 1 and 2, the final choice of the government and intelligent manufacturing equipment enterprises is not affected by the value of \( x \) and \( y \). The change in the value of \( x \) and \( y \) only affects the speed of both sides to reach equilibrium. The government can promote the green technology innovation of intelligent manufacturing equipment enterprises by making and implementing more innovation incentive policies; the willingness of intelligent
manufacturing equipment enterprises to choose core green technology innovation will increase, and the tangible hand of the government will gradually give way to the invisible hand of the market.

4.2. Corporate Reputation. In the scenario of $\Pi_1 + a + A > \Pi_1 - T$, other parameter values are shown in Table 3, and $(x_0, y_0) = (0.5, 0.5)$; when the values of $a$ were 1.5, 2, 3, or 4.8, respectively, the impact on government and enterprise strategy selection is as shown in Figures 3 and 4. From Figure 3, it can be seen that when the values were 1.5, 2, 3, or 4.8, the government evolution equilibrium was stable at 0, which verified result 3. If the cost of obtaining a higher reputation was high, the government’s tangible hand would transfer the right of allocation of innovative resources to the invisible hand of the market. As shown in Figure 4, when $a$ was taken as 1.5 and 2, enterprises chose non-core green technology innovation behavior. Even if enterprises chose core green technology innovation behavior at first, they would gradually withdraw from the ranks of core green technology innovation because the total income value was not attractive. However, when we chose $a$ as 3 and 4.8, the core green technology innovation would help enterprises gain a higher reputation, and the enterprise would have core green technology innovation behavior. This shows that when the market allocates innovation resources by the invisible hand and enterprises choose a core green technology innovation strategy, the measurement standard includes not only the direct input–output of core green technology innovation, but also the corporate reputation brought by it. With the continuous improvement in the reputation brought by the core green technology innovation, intelligent manufacturing equipment enterprises will change from non-core green technology innovation strategies to core green technology innovation strategies even though the core green technology innovation profit is relatively low.

4.3. Government Reputation. In the scenario of $\Pi_1 + a + A > \Pi_2 - T$, other parameter values are shown in Table 3, $(x_0, y_0) = (0.5, 0.5)$; when the value $b$ was 2.5, 3.4, 4.5, or 5, respectively, the impact on the government and enterprise strategy selection is as shown in Figures 5 and 6 (with results 3 and 4 validated). From Figure 5, it can be seen that when the value of $b$ was 2.5 or 3.4, respectively, the government evolution equilibrium was stable at 0, which verifies the result 3. When the value of $b$ was 4.5 or 5, respectively, the government evolution equilibrium was stable at 1, which verifies the result 4. The government’s reputation and credibility affect the government’s final strategic choice. If the government improves its reputation and credibility by formulating and implementing core green technology innovation policies, and the government will strive to promote
Figure 3: Government behaviors.

Figure 4: Enterprise behaviors.
Figure 5: Government behaviors.

Figure 6: Enterprise behaviors.
Figure 7: Government behaviors.

Figure 8: Enterprise behaviors.
the process of core green technology innovation. After the subprime mortgage crisis in 2008, the global economy returned to the real economy. In order to occupy the top of the value chain in the future reconstruction of the global value chain, the governments of all countries have issued policies to encourage enterprises to carry out core green technology innovation. At the same time, we should vigorously implement innovation policies and increase subsidies to encourage enterprises to carry out core green technology innovation. According to Figure 6, for enterprises, the selection is more complicated. When \( b > A + C_1 \), the value \( b \) was 4.5 and 5, and enterprises chose the core green technology innovation strategy under the incentive of the government innovation policy. When \( b < A + C_1 \) and \( \pi_2 > \pi_1 + a \), the value \( b \) was 2.5 and 3.4, and the enterprise abandoned the core green technology innovation strategy. This shows that when the government no longer supports core green technology innovation activities, and if the core green technology innovation profits and external reputation cannot compensate for the non-core green technology innovation profits, then the wise choice for a rational economic person is to abandon the core green technology innovation strategy.

4.4. Government Subsidy. In this scenario, other parameter values are shown in Table 3, \((x_{0}, y_{0}) = (0.5, 0.5)\); when the values of \( A \) were 1, 2.5, 4, or 7, respectively, the impact on government and enterprise strategy selection is as shown in Figures 7 and 8. When \( A \) had a value of 1 or 2.5, the government supported the core green technology innovation of enterprises, and the innovation policy had a positive incentive effect on the selection of the core green technology innovation strategy. However, as the value of \( A \) exceeded a certain range, the negative effect of the core green technology innovation strategy incentive became more and more obvious, which verifies result 5. According to Figure 7, when \( A \) had values of 4 and 7, on the one hand, although the subsidy was greater than the profit of the enterprise, some enterprises in the group adopted the core green technology innovation strategy at first, but finally chose to give up core green technology innovation; on the other hand, the increase in a value accelerated the evolution of the system to all enterprises in the group that chose the non-core green technology innovation strategy. The government’s increase in subsidies did not necessarily have the effect of encouraging enterprises to carry out core green technology innovation. According to Figure 8, when the amount of government subsidies was within a certain range, the increase in subsidies would encourage enterprises to adopt core green technology innovation strategies. When the government subsidy exceeded this range, increasing the subsidy investment would restrain the enterprises from choosing the core green technology innovation strategy. Therefore, the government should adopt a reasonable level of subsidy input according to the specific situation of the core green technology innovation enterprises.
Figure 10: Enterprise behaviors.

Figure 11: Government behaviors.
4.5. The Loss from the Government Not Interfering with Non-Core Green Technology Innovation. In the scenario of $\pi_1 + a + A < \pi_2 - T$, other parameter values are shown in Table 3, $(x_0, y_0) = (0.5, 0.5)$; when the value of $C_2$ was 1, 1.6, 2.5, or 3.5, respectively, the impact on government and enterprise strategy selection is as shown in Figures 9 and 10. From Figure 9, we can see that when the value of $C_2$ was 1 or 1.6, respectively, $C_1 > C_2$; that is to say, the evolution equilibrium of the government was stable at 0, which verifies the result 1. When the values were 2.5 and 3.5, $C_1 < C_2$, and the evolution of government was stable at 1, which verifies the result 2. From Figure 10, it can be seen that so long as the total income of core green technology innovation is less than that of non-core green technology innovation, enterprises as rational economic people will choose non-core green technology innovation strategies. This will affect the final strategy choice of the government, but it will not have a significant impact on the choice of enterprises.

4.6. The Influence of the Change in the Core Green Technology Innovation Income of Intelligent Manufacturing Equipment Enterprises on the Behavior of Enterprises and Government. When other parameter values are shown in Table 3, $(x_0, y_0) = (0.5, 0.5)$; when the value of $\pi_1$ was 0.5, 1.5, 2.5, or 3.5, respectively, the impact on government and enterprise strategy selection is as shown in Figures 11 and 12. It can be seen from the observation in Figure 11 that when $\Pi_1 + a + A > \Pi_2 - T, b < A + C_1$, the evolution equilibrium of the government was stable at 0 whether the value of $\pi_1$ changed or not. This result explains that the choice of the government’s strategy was not affected by $\pi_1$. However, it can be seen from Figure 12 that as the value of $\pi_1$ increased, the enterprise strategy selection evolved from non-core green technology innovation to core green technology innovation, and the evolution rate became higher and higher. When the value of $\pi_1$ was 2.5 or 3.3, the accelerated evolution speed caused the enterprise quickly to invest in core green technology innovation activities, and the enterprise evolved from non-core green technology innovation to core green technology innovation, which verifies the result 4. When the market mechanism played its role in the allocation of innovation resources, enterprises still chose the core green technology innovation strategy, so long as the sum of the profits of core green technology innovation and its reputation was greater than the profits of nontechnical core innovation, and even if there were no government subsidies.

5. Conclusions and Suggestions

5.1. Main Research Conclusions. Based on evolutionary game theory in conjunction with reputation theory, this paper constructed a payment matrix for a core green technology innovation game between the government and enterprises, analyzed the evolution process of the government and enterprise behaviors, and then focused on a discussion of the dynamic mechanism of the core green technology innovation of intelligent manufacturing equipment enterprises. This paper analyzed the influence of $a, b, A, C_2$, and $\pi_1$ on the...
evolutionary equalization strategy with different values through a numerical simulation. The results are as follows.

(1) The driving force of the core green technology innovation of the intelligent manufacturing equipment enterprises consists in the government innovation subsidy A and tax preference enjoyed by adopting core green technology innovation; the core green technology innovation achievements meet the needs of customers and will be accepted by the market, resulting in an increase in innovation profits \( \pi_1 \). The reputation premium \( a \) introduced through the Internet and through the industry demonstration effect will attract more intelligent manufacturing equipment enterprises to invest in core green technology innovation.

(2) The driving force of the government in supporting an enterprise’s core green technology innovation consists in, on the one hand, the losses caused by giving up core green technology innovation, and on the other hand, the improvement in the government’s reputation and credibility \( b \) by supporting core green technology innovation. Once the government’s incentive measures for core green technology innovation become insufficient, the country will lose its dominant position in the future fourth industrial revolution and the opportunity to transition from the low end of the global value chain. The harsher result is that it will be difficult to meet the double carbon commitment. The greater the loss, the greater the number of the incentives that are needed for the governments to construct the ecological environment of core green technology innovation and to devise and implement supporting policies. To this end, the media, public participation in politics, and other solutions are needed to enhance the government’s perception of the loss caused by the abandonment of core green technology innovation, and to enhance the sense of urgency and crisis of the government, so as to promote the government’s support for core green technology innovation.

(3) The government’s visible hand tends to yield to the invisible hand of the market mechanism, which is the most ideal strategic choice for the allocation of core green technological innovation resources in the future. When government subsidy A exceeds a certain range, it will increase its value; although this by itself cannot motivate enterprises to carry out core green technology innovation, it will promote the government to realize to a certain extent that the time to withdraw from core green technology innovation has come, causing the government to withdraw from the core innovation field. Instead, the government can focus on the establishment of an improvement in green innovation ecology. Green innovation ecology is a dynamic equilibrium system composed of a green innovation subject, green innovation elements, and a green innovation environment.

5.2. Contribution to This Article. This paper used an evolutionary game model to dissect the evolutionary laws governing the relationship between the government and equipment manufacturing enterprises in the process of moving towards Industry 5.0, and to provide effective decision support for driving the green core technology innovation behavior of equipment manufacturing enterprises. The marginal contributions of this paper are as follows.

(1) This paper explored the mechanisms of government and market influence on green core technology innovation. Its results help the Chinese government to scientifically formulate green policies to compensate for market failures caused by technological innovation and to assume the role of the tangible hand of the government in driving green core technological innovation in equipment manufacturing enterprises.

(2) This paper introduces a reputation mechanism to construct a game model for the evolution of green core technology innovation in equipment manufacturing enterprises, and analyzes the stability conditions of government reputation and equipment manufacturing enterprise reputation for green core technology innovation behavior strategies.

5.3. Suggestions and Prospects. According to the research results and the current situation of core green technology innovation in China, the following suggestions are put forward to promote the core green technology innovation behavior of intelligent manufacturing equipment enterprises.

(1) It is important to strengthen the incentive and restraint effect of the reputation mechanism on intelligent manufacturing equipment enterprises. The reputation mechanism is the invisible driving factor supporting the core innovation of enterprises, especially in the Internet + environment. At present, Internet + has changed the way information is disseminated, and enterprises are in a weak relationship and strong trust pattern. The core green technology innovation behavior of intelligent manufacturing equipment enterprises is accompanied by a reputation premium through Internet communication. The reputation premium simultaneously brings with it resources such as venture capital, excellent innovative talents, and innovative entrepreneurs, and improves the core green technology innovation ability of the intelligent manufacturing equipment enterprises. The construction of a reputation mechanism is inseparable from the fair and open competition environment created by the government, as well as the introduction of science and technology. Moreover, an awareness of the integrity of consumers, peers, and other stakeholders is also required. Only through joint efforts can we realize the driving effect of the reputation mechanism on the core green technology innovation.
(2) By sharing common innovation and value, intelligent manufacturing equipment enterprises bring in innovative individuals from society, organizations (small- and medium-sized enterprises), and consumers—the future business model is the model of consumer experience. Consumers join the innovation industry, accelerate the core green technology innovation achievements, and achieve common innovation and the sharing of innovation achievements.

(3) Accurate fiscal and tax policies and financial support measures are also required. First, to a certain extent, we should increase the subsidies for core green technology innovation and reduce the tax burden, which is a traditional means of encouraging green technology innovation. According to the core green technology innovation ability and international competition situation of intelligent manufacturing equipment enterprises, the subsidy and support policies are set accurately. Second, the government can use modern technologies such as information, big data, and the Internet to build an efficient, open, and shared innovation ecosystem. The innovation ecosystem starts from the formulation and implementation of the government's core green technology innovation policy, realizes the tracking of the whole process, until the real-time feedback, and continuously adjusts the government's core green technology innovation policy. At the same time, advanced science and technology can reduce the cost of government innovation investment, promote government reputation and credibility, and then reduce the cost of government innovation policy implementation.

(4) Moreover, we recommend strengthening investment in basic research and development. The government will release more innovation policies in infrastructure to support the development of the infrastructure that matches best with the core green technology innovation of intelligent manufacturing equipment enterprises, such as investment in the research and development of universities and the cultivation of innovative talents. The government uses the visible hand to promote the invisible hand and drives the intelligent manufacturing equipment enterprises to adopt the core green technology innovation strategy from the outside.

In terms of hard environment innovation, the government has increased long-term stable support for basic research, and highlighted the importance of hard science and technology research, including building an efficient, open, and shared innovation platform, precise fiscal and tax policies and financial support measures. On the basis of the integration of traditional industry, the innovation platform introduces innovative individuals from society, organizations (small- and medium-sized enterprises), and consumers—the future business model is the model of consumer experience. Consumers join the innovation industry, accelerate the core green technology innovation achievements, and achieve common innovation and the sharing of innovation achievements. The soft environment of innovation includes (1) constructing the mechanism of talent incentive and restriction. Talents include not only research and development talents engaged in core green technology innovation, but also entrepreneurs with an innovative consciousness and spirit. On the one hand, great efforts should be devoted to protecting intellectual property rights and the sharing mechanism of innovation achievements so as to stimulate the enthusiasm and creativity of researchers and entrepreneurs in core green technology innovation; on the other hand, a personal reputation mechanism should be constructed to ensure that misconduct against research morality and ethics is seriously investigated and punished. The soft environment of innovation also includes (2) building a market reputation environment, guiding customers to participate in the core green technology innovation of intelligent manufacturing equipment enterprises through the market reputation mechanism, and realizing the smooth transformation of technical achievements. Consequently, this will lead more enterprises to join in promoting the core green technology innovation.

5.4. Future Prospects. This paper studied the manners in which we can encourage intelligent manufacturing equipment enterprises to actively choose a core green technology innovation strategy and counter the hollowing out of core technology with core green technology innovation power. Although reputation theory was introduced to study the core green technology innovation power mechanism of enterprises, it is still unable to produce relevant data or cases because the core green technology innovation in China is still at the stage of exploration. Therefore, this research remained at the level of theoretical deduction. In the future, it will be important to start from case studies to carry out empirical research on the core green technology innovation of intelligent manufacturing equipment enterprises. In addition, the choice of a green technology innovation strategy and the implementation behavior are inseparable from the innovation consciousness and behavior choice of enterprise leaders, and the reputation mechanism is an important factor affecting the people’s consciousness and behavior [41]. Therefore, with the development of the Internet, information disintermediation has an impact on the strategy selection of the core green technology innovation of intelligent manufacturing equipment enterprises by changing the reputation of entrepreneurs.

Data Availability

The data presented in this study are available upon request from the corresponding author.
Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research was funded by the Philosophy and Social Science Research Planning Project of Heilongjiang Province (20JYB030).

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