

Game analysis of green technology innovation by financial institutions, governments and enterprises

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Abstract: The investment choice of government policy and financial institutions will determine the decision-making of enterprises, and the decision-making of enterprises will in turn affect government policies. In this article, we explore and simulate in detail the complex game processes between businesses, governments, and financial institutions. By building a detailed simulation model, we aim to reveal the interactions and impacts between the three at multiple levels, such as economic development, policy making, and financial integration. This simulation not only helps us better understand our respective roles and decision-making mechanisms, but also provides us with a powerful tool for analyzing and predicting changes in economic dynamics. Finally, it is concluded that the number of enterprises that carry out green technology innovation under the government's incentive will eventually reach an equilibrium state in the market with the number of enterprises that do not carry out green technology innovation, and the government regulation will only affect the market for a short time.

1. Introduction

In the 1860s, the Industrial Revolution in Britain made Britain the first industrialized country in the world. Since then, worldwide industrialization has become the development trend of national economies. However, while industrialization brought about economic growth, it also brought about a series of problems and challenges such as the destruction of the ecological environment, the destruction of mineral resources, and environmental pollution. To solve these problems, organizations and enterprises in various countries have carried out green technological innovations, including clean energy technology, pollution control technology, and ecological restoration technology. Green technology innovation not only helps to protect the environment but also plays an important role in economic development. It can transform the traditional mode of economic development, reduce the cost of high energy consumption and high pollution, improve resource utilization efficiency, reduce production costs, and develop new market opportunities through technological innovation, to achieve sustainable economic development. Therefore, green technology innovation has become a hot issue that has been widely discussed by governments and enterprises all over the world.

In practice, enterprises, financial institutions, and governments each play a unique role in influencing enterprises' green technology innovation. As the main body and practitioner of green

technology innovation, enterprises can effectively reduce environmental pollution and ecological damage, improve resource utilization efficiency, reduce production costs, and achieve sustainable development by introducing new environmental protection technologies. At the same time, enterprises can also use green technology innovation to develop new market opportunities and promote product upgrading and industrial upgrading. Financial institutions provide financing channels for green technology innovation, play a financing support role, and provide financial guarantees. The government plays the role of leader and regulator. The government can guide, encourage, and compel enterprises to carry out green technology innovation by formulating a green technology innovation strategy, integrating it into the overall development system of the national economy, and comprehensively utilizing economic, fiscal, financial and taxation means.

Given the influence of enterprises, financial institutions, and the government on the decision-making of green technology innovation on enterprises" green technology innovation, this paper includes the three aspects in the research framework and game analysis to explore the influence mechanism of the three aspects on green technology innovation.

2. Literature Review

Chinese economists have carried out extensive research on whether enterprises should carry out green innovation, the specific plan of implementing green innovation, and the impact of enterprise transformation.

Here are their main points:

From the government perspective: Li Tangrong and Lin Hui found that, region all green finance not only supports the high-quality economic development of the local area, but also has a good spillover effect on surrounding areas. Sun Xiaohua and Li Mingshan pointed out that, the stronger the government intervention motivation is, the more prominent the over-investment of state-owned enterprises is. Although the over-investment has significant positive effects on regional economic development, but also results in loss of productivity^[1]. Ahsan Highlights the impact of corporate culture, employees' environmental awareness and behaviour can reduce the negative impact of an organization's operations on the natural environment^[2].

From the perspective of enterprises: Li Wenjing and other scholars believe that, Green technology innovation may not directly bring economic benefits to enterprises, but enterprises need to invest a lot of sunk costs in the research process, which may lead to various challenges, including the difficulty of maintaining market competitiveness. According to Pan Shulin and Tian Hong, environmental leadership has positive impact on environmental organizational culture, green organizational identity has a positive mediating effect on the relationship between environmental leadership and corporate green innovation performance^[3]. The resource-based view (RBV) points out that each enterprise is an aggregation of various heterogeneous resources characterized by scarce, valuable, irreplaceable and non-imitationable resources^[4]. Many scholars have conducted research on the influencing factors of green innovation. Mario believes that companies are subject to growing stakeholder and institutional pressures towards environmentally responsible behavior that may have distinct impacts on green innovation activities^[5]. Green technological innovation has two external features (Shen, Li, Jin & Li, 2022). Traditional research only considers the influence of a single tool of environmental regulation on green technology innovation (Lin, Wang & Wu, 2022). Still, a single policy of environmental regulation, due to the constraints of its characteristics, makes it difficult to play the role of incentive for technological innovation and control of environmental pollution. The combinational strategies of different types of environmental regulations often offer complementary advantages^[6]. Andrea thinks that systematically reward responsible corporate practices by applying government leverage to spur innovation in development and uptake of

sustainable development technologies and business practices^[7]. In short, the existing research on green technology innovation mainly covers the aspects of technology development and optimization, policy and law, market and business model, social impact and acceptance, ecosystem and sustainable development.

From the perspective of financial institutions: Han Kezhen's research shows that, Green financial instruments such as green securities, green credit, green insurance and carbon finance will help improve the efficiency of green technology innovation in China and support enterprises to carry out green innovation^[8]. Zhang Ting et al pointed out that green finance and environmental regulation have different effects and impacts on industrial transformation in different regions and when different financial instruments are used. Over the past decades, these concepts have been increasingly used in the literature to study green finance. These studies focus on the conceptualization of green finance and green credit policies. Financial development is key to promote the innovation process that improves energy efficiency and thus to reduce emissions). Financial development may stimulate the innovation process in the energy sector by expanding public budget on energy research, development, and demonstration^[9]. The critical importance of investing in green financial capital and ecological control to reduce environmental deterioration's consequences^[10]. Liu argued that government subsidies could lower the cost of capital for enterprises, enhancing their motivation to innovate^[11].

In general, whether enterprises should conduct green innovation and how to implement green innovation depends on a variety of factors, including government policies, corporate culture, environmental regulation and financial support. These factors may have different effects in different regions and situations. Green innovation is a complex task that requires collaboration between governments, businesses, and financial institutions to drive sustainable development and environmental goals. The study of evolutionary game models is expected to help understand the interactions and impact of all parties in this field, providing guidance for the development of more effective policies and strategies.

3. Main Idea

While green innovative technologies have great potential to address climate change and sustainable development, there are also many problems, including insufficient R&D funding, widespread market demand for green innovative technologies, sharing of green innovation knowledge and transfer of property rights, continuous supply of limited resources, and challenges such as regulatory and policy support. The existing literature has conducted in-depth research on green finance and government environmental regulation policies, but the impact of the three has not been discussed dialectically together. Based on the above questions, we will focus on three main decision-makers: government, corporations, and financial institutions. Companies invest in R&D to improve carbon emissions and resource efficiency and optimize supply chains. The government formulates relevant statutory regulations to protect the environment, supports enterprises in innovative research and development through market incentives and monitoring, and provides enterprises with the resources and information they need for green innovative technologies. Financial institutions provide funding and financing channels to help enterprises innovate green. Government policies and investment from financial institutions will have a differentiated impact on different types of green innovative enterprises. First of all, government policies have an important impact on the development direction and strategic positioning of enterprises. For example, the government can introduce a green tax policy to reduce taxes or provide subsidies to enterprises that adopt green technologies, which will help promote the development of green innovative technologies and encourage enterprises to adopt green production methods. In addition, the

government can also set up a green fund to provide financial support for enterprises to help them solve problems such as broken capital chains, so as to promote the research and development and application of green technologies. The investment of financial institutions also has an important impact on the green technology innovation of enterprises. Financial institutions can provide financial support for enterprises by providing low-interest loans, venture capital, guarantee funds, etc., to help enterprises solve their financial problems. In addition, financial institutions can also provide technical consulting, market research, and other services to help enterprises better understand market demand and trends, and improve their green technology research and development capabilities and market competitiveness. The impact of these differentiations will influence the decision-making of the business. For example, for enterprises that are short of funds, government policies and investment from financial institutions will help alleviate financial pressure and help enterprises better carry out green technology innovation. For enterprises with low technical levels, the investment and technical support of financial institutions will help improve the technical level of enterprises and promote the development of green technology innovation; For enterprises that pursue short-term benefits, government policies and investment from financial institutions will help improve their long-term profitability and sustainable development. Therefore, the support of the government and financial institutions plays an important role in the innovation of green technology by enterprises. Different types of enterprises can make corresponding decisions according to their own circumstances and needs, and make full use of the support of the government and financial institutions to promote the development of green technology innovation. However, the government will also choose whether to make current affairs policies and the specific types of policies according to the specific situation of enterprises, and financial institutions will also choose whether to invest according to the behavior of the government and enterprises.

4. Game Analysis of Green Technology Innovation by Financial Institutions, Governments and Enterprises

Benchmark model for enterprises not to carry out green technology innovation:

Let's first consider the situation when a firm does not engage in green innovation, and to compare this with the firms that do green technology innovation, we assume that there are a total of N firms in the economy that have a firm number of $(1--N)$, and among these firms, the top X firms choose to carry out green technology innovation, then there are $(N-X)$ companies choose not to innovate in green technology. Suppose the government taxes the profits of state-owned enterprises at a rate of $a\%$, and the rest is used as retained earnings of the enterprise. This paper assumes that the profit of the enterprise is Π and the output is q , then the income that the government can get from the enterprise g is $a\%$ enterprise Π , the enterprise will subsidize the enterprise that carries out green technology innovation, and the enterprise that does not carry out green technology innovation will be fined for environmental governance, assuming that the fine is B (B is a constant greater than or equal to zero, and the government can choose to supervise or impose a fine), assuming that the government's subsidy fund is M , $M=m\% [(a\%\Pi_1+ a\%\Pi_2+ a\%\Pi_3+.....+ a\%\Pi_n)+B(N-X)]$, according to the equal distribution of subsidy funds for all enterprises engaged in green technology innovation, the specific amount of subsidy funds that each enterprise can obtain is M/X

Therefore, the budget funds for government investment subsidies are certain, but the information between different competing enterprises and the government is asymmetrical, assuming that enterprises decide to choose to carry out green innovation or not to carry out green technology innovation at the same time, and the more enterprises that choose to carry out green technology innovation at the same time, the fewer government subsidies the enterprises can receive. In addition, the innovation of green technology by enterprises has a certain effect on their reputation, which can

indirectly improve the competitiveness of their products. With the intensification of market competition, there will be more enterprises to choose to carry out green technology innovation, but this number will not always increase, with the gradual increase the number of enterprises that choose to carry out green technology innovation, according to the Nash equilibrium, the number of enterprises that finally choose to carry out green innovation and not to carry out green technology innovation will reach an equilibrium state, at this time any enterprise chooses to carry out green innovation or not to carry out green technology innovation will not increase their income.

It is assumed that the investment strategy of financial institutions is mainly affected by the profitability of enterprises, the market competitiveness of enterprises, and national policies. Assuming that the investment amount of the financial institution is W , we assume that the probability of the financial institution investing in the enterprise that carries out green technology innovation is $b\%$, and the probability of investing in the enterprise that does not carry out green technology innovation is $(1-b)\%$, and according to the above assumptions, we can know that ($b > 0.5$), that is, financial institutions are more inclined to invest in enterprises that carry out green technology innovation. In addition, considering that when enterprises make decisions, it is uncertain whether they will receive financing from financial institutions, but financial institutions will choose to invest in those enterprises that have already made decisions according to market conditions, and there is also information asymmetry between financial institutions and enterprises. But governments, corporations, and financial institutions alike want to maximize returns.

Game 1:

Period 1: Under the intervention of government policies, if X enterprises choose to carry out green technology innovation, $(N-X)$ enterprises choose not to carry out green technology innovation, where the assumption X is much smaller than $(N-X)$.

Period 2: Financial institutions invest in enterprises based on merit, and the government subsidizes enterprises

Period 3: Some enterprises that choose green technology innovation for the first time face two situations: (1) give up green technology innovation or are squeezed out of the market (2) enterprises innovate successfully and continue to maintain green technology innovation.

Enterprises that have not carried out green technology innovation for the first time face three situations: (1) continue to use traditional technology, (2) choose to carry out green technology innovation, and (3). Squeezed out of the market.

Period 4: The government will no longer subsidize, and the market will reach a new equilibrium, that is, enterprises that choose to carry out green technology innovation and those who do not carry out green technology innovation in a short period will reach a new equilibrium.

For the above game, it is necessary to make several explanations: under the intervention of government policies, X enterprises choose to carry out green technology innovation. This choice may be based on government incentives, such as subsidies, tax incentives, etc., or it may be based on factors such as the corporate leader's sense of social responsibility. In this period, enterprises that choose green technology innovation need to make investments, such as R&D costs, equipment renewal costs, etc. However, these costs may be partially or fully compensated with the support of government policies. At the same time, $(N-X)$ companies have chosen not to innovate in green technology. These companies may choose to wait and see for the effects of green technology innovation to become clearer, or at this point, the R&D costs are already greater than the possible benefits of green technology innovation.

Financial institutions invest based on merit. At this stage, companies that have already made green technology innovations may receive more investment due to the advantages of their technology and policy support. These investments may allow these companies to grow better and further expand their market share. However, those companies that do not choose green technology

innovation, may reduce production due to lack of investment, and their market competitiveness will be reduced.

Some of the companies that choose green technology innovation in the early stage may give up on green technology innovation or be squeezed out of the market. This may be because the cost of green technology innovation exceeds their expectations, or they feel that the benefits of green technology innovation are not enough to cover their costs without sufficient market support. At this time, if they continue to choose to carry out green technology innovation, they may face continuous losses and eventually have to withdraw from the market, so these companies will choose to give up green technology innovation. Some companies that have not carried out green technology innovation may choose to remain the same, some choose to carry out green technology innovation, and some are squeezed out of the market. These companies may have seen the advantages of green technology innovation in some of the enterprises that have carried out green technology innovation and decided to follow up, or they may have felt the pressure of market competition and must improve their competitiveness through green technology innovation.

Finally, following the development trend of new energy vehicles, with the market competition, the number of enterprises that choose to develop new energy vehicles and those who do not conduct research and development has reached an equilibrium in the market, and enterprises that are not suitable for the market will withdraw from the market in such transformation opportunities. In the same way, the number of enterprises that choose to carry out green technology innovation and those who do not carry out green technology innovation will also reach a new equilibrium with the development, and the high-pollution and low-yield enterprises with no development potential will gradually withdraw from the market, and several enterprises focusing on green innovation technology will gradually pour into the market, reaching a short-term equilibrium state.

Proposition 1, the refinement equilibrium of the sub-game of the above game is:

1) If $M/X+W+\Pi X \geq \Pi^* - B$, then some enterprises that engage in green innovation choose to continue to carry out green technology innovation, and in the same way, when the result is the opposite, enterprises will face the risk of giving up on green technology innovation or being squeezed out of the competitive market.

2) If $\Pi X + M/X+W \leq \Pi^* - B$, enterprises that have not carried out green technology innovation will continue to maintain the traditional production model, and the same can be seen when the result is opposite, enterprises will face the choice of choosing to carry out green technology innovation or be squeezed out of the market.

Proposition 1:

The equation can be simplified so that $\Pi X = \Pi^* - \text{Cost}_x$, where Cost_x is the cost of green innovation of enterprise x

$$M / X + W \geq \text{Cost}_x - B \quad (1)$$

$$M / X + W \leq \text{Cost}_x - B \quad (2)$$

$$M = m\%[(a\%\Pi_1 + a\%\Pi_2 + a\%\Pi_3 + \dots + a\%\Pi_n) + B(N-X)], \quad (3)$$

$$M = m\%[a\%\Pi^* X + a\%(N-X) * \Pi^* + B(N-X)], \Pi = \Pi^* - \text{Cost}_x \quad (4)$$

$$M = m\%[a\%\text{Cost}_x * X + a\%N * \Pi^* + B(N-X)] \text{The ratio of companies that innovate is: } X \quad (5)$$

$$M / X = m\%[a\%\text{Cost}_x + a\%/x * \Pi^* + B(1/x-1)] \quad (6)$$

$$M / (N * x) = m\%[a\%\text{Cost}_x + a\%/x * \Pi^* + B(1/x-1)] \quad (7)$$

From the first proposition, the condition for the enterprise not to carry out transformation is obtained: $f(x) = M/X+W+\Pi X = \Pi^* - B$, that is, the profit of not carrying out transformation is the same as that of transformation.

$f(x) = m\% [a\%Costx + a\%1/x * \Pi^* + B(1/x-1)] + W + IIX$, according to the assumption of period one, X should increase from 0 at this time X will increase: the government and financial institutions will attract enterprises to transform, and the subsidy at this time must be greater than the difference between R&D costs and fines, and there will be more enterprises to transform at this time. When $f(x) \leq \Pi^* - B$, the enterprise will not transform, but there will be some green innovation enterprises that do not carry out R&D and innovation and will continue to use the traditional way, at this time, X decreases, and $f(x)$ increases. Discovery: The process goes on and on, and eventually it reaches equilibrium.

And: if the number of enterprises is large enough (N), compared to the number of enterprises small (n), the time to reach the equilibrium point from the beginning of the transformation (exponential quantity, and there is deviation, the deviation is the same proportion $\alpha * n$) will be longer than the number of enterprises, but the time to reach the equilibrium will be smaller. That is, there are enough enterprises that $f(x)$ can be regarded as a continuous function. It is very likely that the discrete function will not reach equilibrium and can only maintain a small range of fluctuations, but the time from the beginning to the fluctuation will be small.

Model optimization: For $f(x) \leq Cost$, the green innovation enterprise needs to transform to the traditional way, and if it does, there will be a cost. However, for the above-mentioned conclusion, the ratio of green enterprises at the time of equilibrium is X is a "fixed value", which has nothing to do with the number of enterprises, so at this time all enterprises are faced with a problem: whether to transform? The transformation is faster, and the profit will be greater at this time, and the transformation is slower or not the transformation will be relatively less profitable; however, for the enterprises that have been transformed, it is relatively difficult to switch to the traditional model, and we can consider the $Cost_t$ at this time doesn't have to be less than the development cost.

Analyzing proposition one, we can get the following inferences:

Corollary 1: After the implementation of government policies, some enterprises with serious pollution high cost of modification, and difficulty in transformation will eventually withdraw from the market.

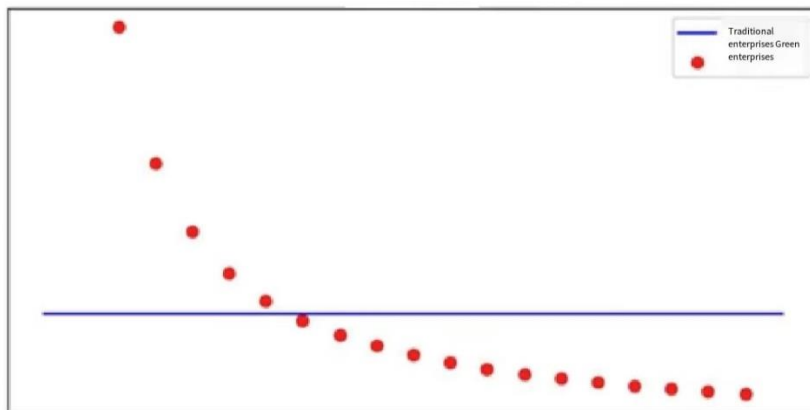


Figure 1: Small number of enterprises

Corollary 1 shows that in the case of information asymmetry, enterprises cannot predict market conditions and the choices of governments and financial institutions when making decisions. In the early stage, a small number of enterprises attempted to innovate in green technology, some of which successfully transformed and developed better under the dual blessing of government subsidies and financing from financial institutions. The initial enterprises obtained higher subsidy funds, faced less market competition, and improved their income. This encouraged more enterprises to undertake green transformation (see figure1). However, as the number of enterprises gradually joining green technology innovation increased, some encountered difficulties in transformation. After choosing to

carry out green technology innovation, due to the high cost of innovation research, enterprise income decreased. Two situations arose: enterprises chose not to carry out green technology innovation due to high research costs, or their income was greatly reduced and they were squeezed out of the market.

Corollary 2: There will be some enterprises in the market that carry out green innovation and eventually succeed in transformation, and there will also be some enterprises that maintain the traditional production mode in a short period, and the number of the two enterprises will remain balanced for a certain period.

Corollary 2 shows that the government's macroeconomic adjustment role will temporarily change the state of the market. With the increase of X , M/X gradually decreases, the market competition advantage of enterprises that choose to carry out green innovation is also decreasing, at this time, the government's R&D subsidies to enterprises will gradually decrease, and the two types of enterprises will not transform each other, and some enterprises will withdraw from the market, that is, the number of two types of enterprises in the market has reached a temporary equilibrium state. The research and development of new energy vehicles provide a good illustration of inference two. In the early stage, the state encouraged enterprises to carry out research and development of new energy technologies by providing funding and corresponding subsidies to consumers who purchased new energy vehicles, significantly increasing the market competitiveness of such vehicles (see figure2). As a result, a large number of enterprises opted to develop new energy vehicles. With the gradual increase in the number of enterprises entering research and development, government subsidy funds decreased, and consumption subsidies for consumers buying new energy vehicles also declined. However, traditional cars have not completely withdrawn from the market, but have reached an equilibrium with new energy vehicles to a certain extent, and consumers choose the type of car according to their preferences. From the second inference, we can also understand the entire development process of new energy vehicles, the government's macro-control measures will temporarily affect the market, and the market will self-regulate to an equilibrium state with the price mechanism.

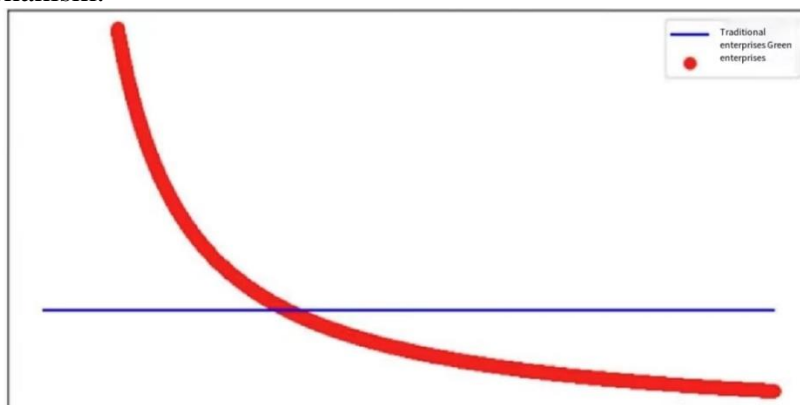


Figure 2: Large number of enterprises

5. Use This Conclusion to Explain the Process of Labor Transfer

In the first 30 years of reform and opening up, the process of labor transfer from rural to urban areas was mainly divided into three stages, the first stage was 1949-In 1957, with the development of urbanization, the transfer of agricultural surplus labor was directly proportional to it. The second stage, from 1958 to 1963, was a period of "Great Leap Forward" and economic adjustment, with a "sharp shift" first, followed by a "reverse shift" to the rural areas. The third stage was between 1964 and 1978, which was a slow transition phase. We can view the transfer of rural surplus labor as a

process of green technology innovation decision-making by enterprises. Initially, a small number of people choose to shift from rural to urban development. Those who remain in a "wait-and-see" state in the countryside will opt to join when they see better development prospects in cities. This will result in many labor forces being transferred to cities. However, with the increase in urban population and the shortage of urban resources, some people find that life in cities is not as good as the income level of returning to the countryside. They will return to the countryside when they find such opportunities. Based on the Nash equilibrium, the number of people who finally choose to move to cities and those who choose to stay in the countryside will reach a temporary equilibrium. That is, if economic conditions do not change, there will be no large-scale transfer of labor.

6. Conclusion

Under the framework of a dynamic game, this paper simulates the decision-making of governments, financial institutions and enterprises in the context of green technology innovation. The main conclusion of the paper is as follows: in the case of information asymmetry, the decision-making of enterprises is known to the government and financial institutions, but the competition of enterprises and the policies of government policies and financial institutions of other enterprises are unknown at the same time in the market, so there will be a dynamic adjustment of the decision-making of enterprises in green and innovation and not in green technology innovation. Incentives from both government and financial institutions are consistent for both state-owned and private companies, but private companies are more likely to exit the market after poor decision-making. With the gradual increase in the number of green innovative technologies carried out by enterprises and the gradual reduction of government subsidies, the number of the two types of enterprises has reached a new equilibrium, that is, the government's macroeconomic adjustment role will only temporarily change the state of the market.

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