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Research on Innovation Investment Behavior of High-Tech Industry under Government Subsidy Policy based on Evolutionary Game Method of Government and Enterprise

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Abstract

Based on the premise that the government and high-tech enterprises are limited rationality, this study uses evolutionary game method to study the interactive mechanism between the government's supervision strategy selection and the innovation investment strategy selection of high-tech enterprises in the process of government subsidy distribution. It is found that the government's punishment for the illegal use of government subsidies by enterprises, the cost and benefit of the rational use of government subsidies by enterprises will have a direct impact the result of the game. In the unstable strategy, when the government tends to choose the strategy of "no verification", the enterprises tend to choose the strategy of "no investment" to maximize their own interests. At this time, the government of limited rationality tends to choose the strategy of "verification", and the enterprises will choose the strategy of "investment", while the government tends to choose the strategy of "no verification" again, entering a circular state, unable to reach the optimal. If we want to form a good relationship of mutual trust and mutual benefit between the government and enterprises, we will continue to have this " unable to reach optimal state " cycle. Therefore, it is necessary to add constraints to the game process.

Keywords

High-Tech Enterprises; Government Subsidies; Evolutionary Game.

1. INTRODUCTION

With the deepening of the reform of "deregulation services" and the creation of high-level "mass entrepreneurship and innovation", the innovation enthusiasm of the market players in our country is constantly bursting out, new energy continues to accumulate and grow, new industries and new products grow rapidly, and new business forms and new models flourish. China's high-tech industry has experienced more than 30 years of development, with new features in the development and innovation of high-tech industry. High-end manufacturing industries such as aerospace, aviation, high-speed rail, nuclear power, communication, electronics, etc. have gained global influence. In 2018, there were 181000 high-tech enterprises in China, and the turnover of technology contracts exceeded 1.7 trillion yuan. However, the innovation level of China's high-tech industry is still at a medium level, with slow progress. The high-tech industry has not yet mastered the core technology. In addition, the high-tech industry enterprises have great complexity, uncertainty and high risk in R & D innovation, which requires the government to guide and encourage the high-tech industry to continue R & D innovation.

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The total amount of R & D government subsidies for high-tech industries is increasing year by year. The purpose of government policies is to correct market failure, implement effective resource allocation, and promote scientific and technological innovation in high-tech industries. However, with the increasing support of government financial funds, the phenomenon of enterprises' mismatching of resources and defrauding of government subsidies is also constantly emerging. When the government subsidies are used for other high-income project investment, the behavior of enterprises seriously distorts the purpose of government subsidies, and also causes the differences in the research results of government subsidies in China. Many scholars study whether government subsidies can really improve the R & D and innovation investment and innovation ability of high-tech industry through empirical research.

The first view: government subsidies can encourage enterprises to invest in innovation and improve their innovation ability. Xu Minli (2019) government subsidies promote the innovation performance of enterprises, with significant regulatory effect and ease financing constraints [1]. The research results of Zhan Jintao (2019) found that the incentive effect of government subsidies on the R & D investment of agricultural enterprises is significant, but there is a large difference between industries; the performance growth of agricultural enterprises will have leverage effect on the R & D investment of main business in the short term, but the effect is weak in the long term, and the R & D investment behavior has a certain tendency of subsidy dependence [2]. Li Jing (2018) Government R & D funding also plays a role in promoting the innovation performance of high-tech industries in neighboring areas [3]. Liang Jie (2019) believes that the government needs to provide appropriate subsidies for the R & D activities of enterprises, so as to reduce the R & D risk and cost of enterprises and encourage the enhancement of their R & D intensity. At the same time, government subsidies can also alleviate the financing constraints of enterprises through the certification effect of signal transmission mechanism on external financing, so as to ensure the source of R & D funds [4]. The second view is that the incentive effect of government subsidies on enterprise innovation is not obvious. Jiang Xilin (2018) believed that pre subsidy is a policy tool with extremely limited value, and the effect of subsidy is easily affected by the reputation of the enterprise; post subsidy can internalize the R & D spillover effect, and the government can issue subsidies according to the enterprise's efforts and R & D achievements, which can more effectively encourage enterprises to carry out technological R & D and innovation activities [5]. Chen Mingming (2015) the promotion effect of government subsidies on enterprise innovation supply depends on the degree of state-owned enterprise control, that is, state-owned enterprise control weakens the incentive effect of government subsidies on enterprise innovation supply [6]. Zhou Zejiong (2019) government subsidies have no significant effect on improving the independent innovation of enterprises [7]. The third view is that the relationship between government subsidy and innovation investment is not linear. Zhang Hui (2016) believes that there is a significant double threshold effect of government subsidies on R & D investment of enterprises, and when the intensity of government subsidies is between 0 and 0.0214, the subsidy efficiency is the highest [8]. Zhao Kai (2019) believes that government subsidies will change the direction and intensity of their effect on corporate profitability with the change of industry concentration: when the industry concentration is low, the allocation of production factors is scattered, and corporate profitability has no significant relationship with government subsidies; when the industry concentration is at a medium level, government subsidies will hinder the improvement of corporate profitability; when the industry concentration is relatively high When it is high, the government subsidy will play a significant positive role in promoting the profitability of enterprises, and the degree of its influence will show an inverted U-shaped change with the increase of quantile [9]. Zhang Xiangda (2018) showed a "U" type change in subsidy intensity and R & D investment, while the effect of subsidy growth on R & D investment was an inverted "U" type distribution [10]. Xie Yanming (2018) showed an inverted U-curve relationship

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between government subsidies and enterprise capacity utilization. Government subsidies play a "worse" role in the capacity utilization rate of state-owned enterprises. Asset specificity has a significant negative impact on the capacity utilization rate of state-owned and non-state-owned enterprises, and the negative adjustment of the impact of government subsidies on the capacity utilization rate of enterprises [11].

The relationship between government subsidy and enterprise innovation investment has always been a hot and difficult point for scholars, but there is no unified research conclusion in China. In the end, whether the government's subsidy behavior decision encourages enterprises to make innovation input decision or whether the innovation input decision affects the government's subsidy behavior, or whether there is no stable decision behavior between the two behaviors. Therefore, from the perspective of game theory, this paper constructs the combination strategy model of government and enterprise, and deduces the game relationship between government and enterprise. Under the condition that the government checks and does not check the government subsidies of high-tech industrial enterprises, enterprises choose to invest in innovation or not.

2. THE EVOLUTIONARY GAME MODEL OF GOVERNMENT AND ENTERPRISE

2.1. Assumption of Evolutionary Game Model

2.1.1 Players in the game

The two players in the game are the government that provides government subsidies (hereinafter referred to as "the government") and the enterprises in the high-tech industry)hereinafter referred to as "the enterprise"), both sides of the game are limited rational.

2.1.2 Behavior strategy

Enterprises adopt two strategies: using government subsidies for R & D innovation investment or using government subsidies for other profit earning behaviors of enterprises. The "use of government subsidies for enterprise innovation investment measures" here includes that enterprises use government subsidies for technology improvement, technology innovation, achievement transformation, etc. (hereinafter referred to as "investment"). "Use of government subsidies for other profit earning activities of enterprises" means that enterprises use government subsidies for other profit earning activities of enterprises unrelated to the development of high-tech industries, such as reinvestment of enterprises, and investment of subsidies in other high investment and high-income industries (hereinafter referred to as "no investment"). At the same time, the government has the responsibility to supervise the government subsidies of enterprises. There are also two strategies: to supervise and inspect whether enterprises use subsidies for the development of high-tech industries (hereinafter referred to as "supervision") and not to supervise and inspect whether enterprises use subsidies for the development of high-tech industries (hereinafter referred to as "no supervision"). Whether enterprises use government subsidies for the development of high-tech industry can be seen as the result of the game between the government and enterprises.

2.1.3 Probability of action strategy adoption

In the initial stage of the game between the government and the enterprise, assuming that the probability of the government choosing "supervision" is y ($o \le y \le 1$), the probability of choosing "no supervision" is 1-y, the probability of the enterprise choosing "input" is x ($o \le x \le 1$), the probability of choosing "no input" is 1-x, then the game strategy combination between the government and the enterprise is shown in Table 1.

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Table 1. Game strategy combination of government and enterprise

Policy mix		enterprise	
		input x	no input 1-x
government	supervision y	(supervision, input)	(supervision, no input)
	no supervision 1-y	(no supervision, input)	(no supervision, no input)

2.1.4 Parameter hypothesis and basic explanation

C1 refers to the cost of R & D and production of high-tech products after the enterprise obtains the government subsidy, R1 refers to the income obtained from R & D and production of high-tech products, W refers to the comprehensive benefit obtained from the enterprise's use of government subsidy for technology development, achievement transformation and product production of high-tech industries, C2 refers to the cost of other profit-making activities after the enterprise obtains the government subsidy, R2 refers to the cost of R & D and production of high-tech products for the income of enterprises using government subsidies for other purposes, S represents government subsidies for enterprises, C3 represents the supervision cost of government subsidies for enterprises, F represents the fine for enterprises, and L represents that enterprises use government subsidies for other profit-making activities. The income matrix of both sides of the game is shown in Table 2.

Table 2. Income matrix of game between government and enterprise

income matrix		enterprise	
		input	no input
government	supervision	(W-C3-S, R1-C1+S)	(-L-C3-S+F, R2-C2-F+S)
	no supervision	(W-S, R1-C1+S)	(-L-S, R2-C2+S))

2.2. Establishment of Evolutionary Game Model

Assuming that the expected return and the average expected return of "supervised" and "unsupervised" government are EGY, EGN, and $\overline{E}_G$ respectively, the replication dynamic equation of government strategy is as follows:

$$F(y)=\frac{dy}{dt}=y(E_{GY}-\overline{E}_G)=y(1-y)(F-xF-C_3) \tag{1}$$

Assuming that the expected return and average expected return of "input" and "no input" adopted by high-tech enterprises are EGY, EGN, and $\overline{E}_G$ respectively, the replication dynamic equation of enterprise strategy is as follows:

$$F(x)=\frac{dx}{dt}=x(E_{CY}-\overline{E}_C)=x(1-x)(R_1-C_1-R_2+C_2+yF) \tag{2}$$

3. ANALYSIS ON THE STABILITY OF EVOLUTIONARY GAME BETWEEN GOVERNMENT AND HIGH-TECH ENTERPRISES

3.1. Evolution Stability Analysis of Government Strategy

In the replication dynamic equation (1) of government strategy,

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If $x=\frac{F-C_3}{F}$, let $F(y)=0$, it is a stable strategy for y.

If $x\neq\frac{F-C_3}{F}$, let $F(y)=0$, then y = 0 and y = 1 are the solution of the equation of government policy. The derivation of formula (1) can be obtained as follows:

$$\frac{dF(y)}{dy}=(1-2y)(F-xF-C_3) \tag{3}$$

Further discussion is made on $F-C_3$.

If $F-C_3<0$, y = 0 is the evolutionary stability strategy, then the government with limited rationality will choose the strategy of "no supervision"; if $F-C_3>0$, that is, the government's fine for enterprises without reasonable use of government subsidies is greater than the cost of checking the use of enterprise funds. When $x>\frac{F-C_3}{F}$, y = 0 is the evolutionary stability strategy; $x<\frac{F-C_3}{F}$, y = 1 is the evolutionary stability strategy.

3.2. Analysis of the Evolution Stability of High-Tech Enterprise Strategy

In the replication dynamic equation (2) of high-tech enterprise strategy, the same conclusion can be drawn.

If $y=\frac{R_2-C_2+C_1-R_1}{F}$, let $F(x)=0$, then it is a stable strategy for X.

If $y\neq\frac{R_2-C_2+C_1-R_1}{F}$, let $F(x)=0$, then x = 0 and x = 1 are the solution of the government policy equation.

The derivation of formula (2) is as follows:

If $R_2-C_2+C_1-R<0$, then x = 1 is the evolutionary stability strategy, and the limited rational enterprises will choose the "input" strategy;

If $R_2-C_2+C_1-R>F$, then x = 0 is the evolutionary stability strategy, and the limited rational enterprises will choose the "no input" strategy.

If $F<R_2-C_2+C_1-R_1<0$, $y>\frac{R_2-C_2+C_1-R_1}{F}$, then x=1 is the evolutionary stability strategy;

If $F<R_2-C_2+C_1-R_1<0$, $y<\frac{R_2-C_2+C_1-R_1}{F}$, then x = 0 is the evolutionary stability strategy.

3.3. Analysis on the Evolutionary Stability of the Mixed Strategy of Government and High-Tech Enterprises

The dynamic replication equations (2) and (3) are used to describe the evolution of government and enterprise strategic system. The system has two stable equilibrium points (0,0) and (1,0), two unstable equilibrium points (0,1) and (1,1), and one saddle point ($\frac{F-C_3}{F}$, $\frac{R_2-C_2+C_1-R_1}{F}$), which do not meet the stability conditions. Therefore, there are stable strategy and unstable strategy in the combination strategy of government enterprise game.

In the stability strategy, the decision-making of innovation investment of high-tech enterprises does not depend on the government decision-making. Therefore, the enterprises will choose to maximize the benefits, the uncertainty and complexity of innovation in high-tech

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industries, resulting in high risk of innovation investment. In the absence of government supervision, the enterprises will choose to use government subsidies in high-income industries. Similarly, government decision-making does not rely on the innovation input decision of high-tech enterprises, which shows that when enterprises use government subsidies for innovation input, the government will choose not to supervise, reduce the cost of supervision, and enterprises will also be free from fines.

In the unstable strategy, in the case of $F - C_3 < 0$ and $0 < \frac{R_2 - C_2 + C_1 - R_1}{F} < 1$, the enterprise punishment is greater than the cost of supervision. Generally speaking, enterprises actually use government subsidies in other high-income industries. Fines can offset the cost of government supervision. The comprehensive benefits of high-tech enterprises will be less and less. Enterprises will abide by the principle of government subsidies, incorporate government subsidies into innovation investment, and carry out research and development of high-tech products. If government supervision is not continuous, enterprises will continue to use government subsidies for high-yield industries, which is much higher than fines, and has been in a vicious circle. Therefore, in this case, there is no evolutionary stability strategy, and the final equilibrium of this unstable strategy depends on the enterprise spirit.

In reality, it is an ideal strategy for the government to adopt unsupervised and enterprises to incorporate government subsidies into innovation investment. At this time, a good relationship of mutual trust has been established between the government and the enterprises. The government fully trusts the enterprises, and the enterprises also strive to carry out product research and development and production, which not only reduces the cost of government verification, but also promotes the development of high-tech industry. But in fact, when the government tends to choose the strategy of "no verification", the enterprises tend to choose the strategy of "no investment" to maximize their own interests. At this time, the government of limited rationality tends to choose the strategy of "verification", and the enterprises will choose the strategy of "investment", while the government tends to choose the strategy of "no verification" to enter a circular state, unable to reach the optimal. Therefore, if we want to form a good mutual trust and mutual benefit relationship between the government and enterprises, we will continue to have this "unable to reach optimal state" cycle. Therefore, it is necessary to add constraints to the game process.

On the one hand, we can reduce the income gap between high-tech enterprises using government subsidies for other fields and for R & D and production of high-tech products as much as possible by designing standardized market mechanism and improving policy guidance; on the other hand, we can increase the penalties. With the increase of fines, high-tech enterprises choose to maximize their own interests and use government subsidies for other ways to be found In the long-term learning adjustment process, enterprises will choose to use government subsidies for product R & D and production to ensure their own revenue maximization. In this process, the government can regularly supervise and verify the enterprises to prevent them from using government subsidies in the field of maximizing their own interests. In this way, the evolution balance between government and enterprises is that the government chooses not to check the strategy, and the enterprises choose to invest subsidies in the R & D and production of high-tech products. This is a win-win evolution and stability strategy for both the government and enterprises, which is bound to be conducive to the national strategy of accelerating the cultivation and development of high-tech industries.

4. CONCLUSIONS AND SUGGESTIONS

Based on the analysis and reference of the existing research on government subsidies, this study takes the government and high-tech enterprises as the premise, studies the interactive

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mechanism between the government's supervision strategy selection and the high-tech enterprises' strategy selection in the process of government subsidies distribution by using evolutionary game method, and finds out the punishment strength of the government's illegal use of government subsidies and the rational use of government subsidies by enterprises The cost and benefit of affixing will directly affect the result of the game. In order to reduce the risk of high-tech enterprises using government subsidies for other purposes, maximize the utility of government subsidies, truly improve the innovation level of enterprises, and promote the development of high-tech industries, the following measures should be taken.

One is to allocate subsidy resources reasonably and improve the level of industrial innovation. The innovation of high-tech industry has the characteristics of high investment and high risk. The government's R & D subsidy can guide and support the innovation behavior of the industry, and reduce the innovation pressure of enterprises in the industry. But the strength of government subsidies should be controlled in a proper range, in line with the laws of industrial and technological development. Therefore, the government needs to build a sound project funding approval system to support the common technology, forward-looking technology and technology with great economic and social benefits in the high-tech industry. We will support small and medium-sized enterprises and emerging enterprises that are capable of innovation and lack of innovation funds. We should rationally allocate government subsidy resources and effectively play the role of government subsidy policies.

Secondly, we should enrich the forms of government subsidies and support cooperation between industry, University and research institutes. There is a risk that the former fixed government subsidy will be used for other purposes by enterprises, which will greatly reduce the efficiency of the use of government subsidies. Therefore, the government should have a deep understanding of the R & D situation of enterprises and form a flexible subsidy mechanism. For the R & D projects that have been carried out but are in financial difficulties, quota subsidy in advance can be adopted; for the projects that have a long innovation cycle and are in the planning period, batch subsidy in advance, in process and after can be adopted. For the R & D projects of enterprises with abundant funds, ratio subsidy can be adopted. After successful innovation, the subsidy amount shall be determined according to the actual innovation cost of enterprises. In addition to the direct use of cash or in kind subsidies, it can also support national scientific research institutions or private scientific research institutions to work closely with enterprises to provide professional guidance and technical support for their R & D activities.

Thirdly, we should improve the subsidy supervision system and establish a mutually beneficial relationship between government and enterprises. In order to grasp the actual use and flow direction of subsidy funds, governments at all levels should establish a complete supervision system for the whole process, involve in the pre, in and post innovation of high-tech industry enterprises, and ensure that the subsidy funds are fully used in the research and development of technology projects. The supervision of project finance and evaluation of technical level need strong professional knowledge. The government can entrust a third-party supervision organization, such as scientific research management company and accounting firm, to monitor the R & D process of high-tech enterprises in the whole process. In the process of regulatory interaction, the government finds out the problems in the innovation of enterprises, helps them as much as possible, and establishes a good relationship of mutual trust and mutual benefit with enterprises, which not only increases the profits of enterprises, but also effectively promotes the growth and development of high-tech industries.

REFERENCES

[1] M.L.Xu,X.J.Zhu. Financing constraints, government subsidies and innovation performance of high-tech enterprises. Cooperative economy and technology, (2019) No.9,p.106-109.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0023

[2] J.T.Zhan, X.J.Shao, M.Xu. Research on the impact of government subsidies on R & D investment behavior of agricultural enterprises. Scientific research management, Vol.40 (2019)No.4,p.103-111.

[3] J.Li, Liu Q.Zhen The impact of Government R & D funding on innovation performance of high-tech industries: a study based on spatial econometric model. Business Review of Nantah University, (2018)No.3,p.148-174.

[4] J.Liang. Government subsidies, financing constraints and R & D intensity of new energy vehicles. Zhejiang University of Finance and economics,(2019).

[5] X.L.Jiang, Y.L.Li. Game Analysis of the impact of government subsidies on technological innovation of enterprises. Special Economic Zone, (2018)No.11,p.56-60.

[6] M.M.Chen, G.S.Zhang. State owned enterprises, government subsidies and enterprise innovation supply: An Empirical Study Based on listed industrial enterprises. Contemporary finance and economics, (2016)No.10,p.34-44.

[7] Z.J.Zhou,M.M.Lu. Study on the driving factors of independent innovation ability of strategic emerging industries. Journal of Jishou University (Social Science Edition), , Vol.40 (2019)No.1,p.30-38.

[8] H.Zhang, J.Y.Liu. The impact of government subsidies on the R & D investment of Enterprises -- Based on the threshold analysis of China's industrial enterprise database. Economic trends, (2016)No.12,p.28-38.

[9] K.Zhao, H.Y.Wang. Does government subsidies promote the profitability of enterprises? [J]. Journal of Central University of Finance and economics, 2019 (04): 92-103.

[10] X.D.Zhang. Is the financial subsidy an incentive or a shackle to the R & D investment of enterprises? -- Based on the empirical data analysis of GEM listed companies [J]. Journal of liaoning university (philosophy and social sciences edition), Vol.46(2018)No.6,p. 36-45.

[11] Y.M.Xie, R.Wang, G.Y.Dang. Government subsidies and excess capacity of enterprises: whether to "deliver carbon in the snow" or "make it worse"--from the perspective of adjustment of government subsidies and asset specificity.Science and technology and economy, Vol.31 (2018)No.4,p.101-105.