Environmental Regulation, Optimal Choice Strategy of Innovation Activities and Enterprise Value in Tobacco Control Cities

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Abstract: With the accelerating the pace of tobacco control legislation step by step, innovation is the primary driving force for development and we should pay attention to the construction of ecological civilization and unswervingly. In this context, tobacco production enterprises must carry out innovation activities. Based on the theory of value creation, this paper studies the relationship between the path of tobacco production enterprise innovation activities and enterprise value and the dynamic evolution process of enterprise innovation activities under the effect of environmental regulation from the perspective of theoretical deduction. The purpose is to provide an important reference for the choice of enterprise innovation activities, and at the same time enrich the theoretical research on the consequences of environmental regulation and the influencing factors of enterprise value. First, according to the process of value creation, the source of innovation results and the choice of strategies are studied to provide theoretical support for the primary link of tobacco production enterprise innovation activities. Second, study the application product types of innovation achievements and provide the selection basis for the important links of tobacco production enterprise innovation activities. Third, from the perspective of evolutionary economics, the equilibrium dynamic evolutionary game process between government environmental regulation and tobacco production enterprise innovation efficiency and innovation effect is discussed.

Key words: tobacco control; value creation theory; innovation activities; environmental regulation
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In recent years, the pace of tobacco control legislation has been accelerated in many cities in China. In 2015, Beijing implemented the "strictest smoking control in history" and banned smoking in all indoor public places. But overall, there is still a great resistance to tobacco control. The effectiveness of tobacco control has not been satisfactory due to decentralized supervision, unclear responsibilities and sporty enforcement. The root of the problem lies in the lack of rigidity

and enforcement of local legislation on tobacco control. Therefore, it is necessary to legislate at the national level to unify the standards of tobacco control, so as to make the work of tobacco control more intimidating, enhance the integration force, and promote the speed of tobacco control. To achieve the goal of tobacco control as soon as possible, it is also necessary to improve the public's awareness of the harm of second-hand smoke and self-protection awareness, to achieve from "I don't care" to "very mind", from "dare not tube" to "please stop", to create the atmosphere of tobacco control in the whole society.

Innovation is the primary driving force for development and the strategic support for building a modernized economy. We should attach importance to basic research, carry out cutting-edge research, strive to achieve major breakthroughs in original science and technology, and make a number of major scientific and technological achievements. We will increase investment in applied basic research, encourage SMEs to innovate, establish a sound mechanism for scientific and technological transformation, and provide a supporting platform for innovative scientific and technological achievements. The report also pointed out that in the process of social and economic development, we should pay attention to the construction of ecological civilization and unswervingly follow the path of sustainable development. Environmental damage should not be the cost of development. Environmental protection and resource conservation should be taken as the prerequisite for development, and the basic state policy of ecological protection should be unswervingly adhered to. Adhere to the concept of sustainable development, increase the publicity of green life, let the concept of green development deeply rooted in the people. We should do a good job in environmental protection, create a green ecological environment, and provide a comfortable and harmonious working and living environment for the people.

With the gradual increase of national tobacco control efforts, tobacco production enterprises for the production and management activities and product quality of higher requirements. In this context, tobacco production enterprises must carry out innovation activities. If tobacco production enterprises want to survive in the fierce competition environment, innovation activities will become the core competitiveness of enterprises. Innovation activities are divided into innovation efficiency and innovation effect. The speed and cost of the transformation of innovation achievements into products reflect the innovation efficiency of enterprises, and the improvement of enterprise value through product sales reflects the innovation effect of enterprises. When adopting innovation strategies, enterprises should attach importance to efficiency, technology and product research and development, accelerate the launch of products with speed or cost advantages, and ensure that they maintain advantages over competitors in the market[1]. The strategy that attaches importance to the innovation effect pays more attention to the degree of product innovation, so as to ensure that the enterprise's own products have certain uniqueness, so as to win the favor of customers[2]. There are certain conflicts between the above two strategies and the corresponding goals, and the enterprise has relatively limited resources, so in the actual operation process, it needs to reasonably control the relationship between the two and choose the appropriate innovation and business strategy. Under the condition of limited resources, an enterprise can achieve better innovation performance in terms of both innovation efficiency and effectiveness[3].

The choice of innovation effect and efficiency has always been the focus of debate in academic circles. Studies have pointed out that excessive emphasis on innovation efficiency in the process of enterprise development will lead to the impact of innovation ability, which is not conducive to enterprise innovatio[4]. However, other studies have pointed out that if enterprises attach too much importance to innovation effect, innovation performance will be damaged[5]. In view of the

above problems, some studies emphasize that in the process of innovation, enterprises should choose the degree of emphasis on innovation efficiency and effect according to specific environmental factors[3]. However, enterprise innovation activities usually require more investment, and the investment cycle is relatively long. It also has high risk at the same time. Usually, enterprises cannot make innovations on their own initiative, but will increase innovation input under the influence of external environment. The external environment will force enterprises to increase innovation input through the reward and punishment mechanism, and this process is also a process of game between enterprises and government. Therefore, it is of great practical significance to study innovative environmental regulation.

The means of environmental regulation policies adopted by the government have always been the focus of attention of enterprises and the public. For the environmental regulation of tobacco control cities, on the one hand, the implementation of environmental regulation policies will increase the operating costs of enterprises and the social costs at the same time. On the other hand, environmental regulation will enable enterprises to obtain certain compensation for innovation. Under such compensation incentive, enterprises will increase innovation input, which will increase the innovation vitality of the whole society. Under the constraints of environmental regulations, enterprises will have to comprehensively consider the benefits from both ecological and economic aspects, so that the efficiency of enterprise innovation activities will be more accurately evaluated. In the actual operation process, enterprises will increase investment in innovation so as to make their operation more in line with the requirements of environmental regulations. In this way, enterprises will improve their innovation efficiency and thus gain more economic benefits. The research objects of early innovation efficiency are mainly countries. Current use of traditional cigarette flavors (ie, tobacco, menthol) may promote sustained smoking[6]. Tobacco prevention should target vulnerable youth, such as adolescents who are non-white, young, and have low parental education[7].Some scholars conducted in-depth investigation on 27 countries and regions in Asia [8]. Chinese scholars [9,10]carried out investigation and research on local enterprises in China, involving 30 provinces and cities across the country. Domestic and foreign scholars use a variety of analysis methods in the research process, parameter method, principal component analysis and so on. Other scholars[11,12,13]all adopted the DEA method to carry out the research. In terms of academic research, there are relatively many researches on the impact of environmental regulation on innovation efficiency, and different scholars put forward corresponding opinions through the researches. Some scholars[14]pointed out in their research that enterprise innovation would be restricted by environmental regulation, while others[15,16]pointed out that environmental regulation policies would promote social and enterprise innovation. One of the scholars [17] pointed out in their study that large enterprises and small and medium-sized enterprises are affected differently. The former will be encouraged to increase innovation input, while the latter will be restricted in innovation. Environmental regulation plays the role of supervision and signal. The supervising role is to produce innovative products that are beneficial to the environment. The signal role is to convey products that are inclined to environmental protection to potential consumers who buy products, thus influencing the purchasing intensity of products. This is in line with national policies and guidelines, and will urge enterprises to improve the innovation results.

According to the above analysis, there are many researches on innovation efficiency and effect at present, some of which have begun to analyze the impact of environmental regulation policies on enterprise innovation efficiency. However, there is no research on environmental regulation of tobacco control cities, and there is no research on how environmental regulation

affects innovation effect. There is still a lack of coordination between innovation efficiency and innovation effect. Based on this, this paper analyzes the process of enterprise innovation and establishes a game analysis model according to different innovation stages. Based on this model, the relationship between environmental regulation and enterprise innovation is analyzed by game evolution, and the effect of urban environmental regulation of tobacco control on enterprise innovation efficiency and effect is quantitatively evaluated, which provides an important reference for Chinese tobacco production enterprises to realize the Nash equilibrium of innovation efficiency and effect.

MODEL HYPOTHESIS AND CONSTRUCTION

Tobacco production enterprises innovation activities can be divided into two links: The first step is the process of transforming innovative achievements into products; the second step is the process of transforming products into enterprise value. At the same time, enterprise value will continue to form innovative achievements. This process seems to be a circular process, but each formation of innovative achievements has a gradually increasing impact on enterprises, to be precise, it is a spiraling process.

There are two sources of tobacco production enterprises innovation achievements. The first is from internal research and development, and the second is from external sources. Internal research and development is usually the most important source of innovation achievements and also the core of enterprise innovation. To achieve sustainable development, an enterprise must have a strong internal research and development capability. Only in this way can it be guaranteed that the tobacco production enterprise has the ability and motivation of continuous innovation. Through internal research and development can help enterprises to form a unique technological advantage, to ensure that enterprises have a higher competitiveness in the market.

External sources usually refer to the enterprises through the purchase of other enterprises' innovation results, among which the technology licensing is the most extensive. In the actual operation process, part of the technology cannot rely on internal research and development to obtain, then most tobacco production enterprises will choose to buy from other enterprises. Enterprises can obtain the right to use the technology by signing authorization agreements with other companies that have a certain technology. Compared with internal research and development, the efficiency of technology licensing is much higher, and corresponding innovation results can be obtained in a short period of time, and the risk of its own innovation can also be significantly reduced. To some extent, technology authorization can avoid many repeated innovations, help the society save precious resources, and improve the innovation and operation efficiency of enterprises. Usually, enterprises will adopt the two innovation strategies of internal research and development and technology authorization at the same time, but the relationship between the two is still controversial in the academic circle. The research points out that if the enterprise completely relies on independent research and development, it may lead to the disconnection between the enterprise and the market, and if the enterprise completely relies on external technology authorization, it will lose its own advantages. Therefore, the two strategies need to be effectively integrated. Other studies have found that internal research and development and external authorization are mutually substituted and complementary, and the specific relationship between the two depends on the actual situation of the enterprise itself.

Based on the above research, the following hypotheses are made:

H1: There are two ways for tobacco production enterprises to produce innovative results: internal research and development and external purchase.

Tobacco production enterprises have two choices in the process of innovation. The first is to innovate based on existing products, and the second is to completely develop new products[18,19].

The above two methods represent two innovative ways of exploration and development respectively. These two concepts are gradually developed from organizational learning research. When an enterprise is engaged in product or service innovation, the choices of the above two strategies depend on the actual conditions. In order to seek new opportunities and obtain some original or breakthrough innovation results, enterprises will choose exploratory innovation. Based on the existing product improvement, through gradual innovation to update the iterative products, to achieve the development of new products. Exploratory innovation can help enterprises gain more innovation advantages, but the innovation cost is higher and the risk is higher. Open innovation is conducive to improving innovation efficiency and helping enterprises to achieve better performance [20]. Many scholars have studied the relationship between exploration and development, pointing out that enterprises need to adopt the two strategies at the same time to achieve complementarity, rather than relying too much on one strategy. If the enterprise cannot properly grasp the relationship between the two, it will lead to excessive exploration or excessive development, which may lead to greater business risks for the enterprise. For example, enterprises that over-rely on exploration and innovation may encounter great innovation risks, which may lead to survival crisis once the risk breaks out. However, enterprises that rely too much on development may lead to insufficient internal motivation of enterprises, and the products developed will be disjointed from the market, thus being eliminated by the market.

Based on the above research, the following hypotheses are made:

H2: There are two ways for tobacco production enterprises to produce innovative products: improving old products and creating new ones.

Dual innovation will be affected by the external environment, and the actual environmental factors will determine the final performance of innovation. Therefore, this paper will focus on this feature.

The government attaches great importance to sustainable development. To this end, it has formulated relatively strict ecological and environmental protection policies. At the same time, it has strengthened support for enterprise innovation and encouraged enterprises to achieve green development through innovation. The government encourages enterprises to carry out technological innovation through certain reward and punishment mechanism, and enterprises will carry out innovation activities independently under the guidance of policies. This paper studies the innovation of enterprises in order to achieve green development. This kind of innovation is mainly to save resources and reduce environmental pollution, which has the characteristics of long cycle and high risk. Usually, enterprises will not carry out these innovative activities independently, but mainly under the influence of government environmental regulations. External environmental regulations will promote enterprises to carry out such activities, and in this process, the game process between the government and enterprises is the focus of this paper.

Based on the above research, the following hypotheses are made:

H3: There are two types of government attitudes towards environmental regulation: environmental regulation and no environmental regulation.

According to the value chain theory, Figure 1 shows the flow chart of enterprise value, and Table 1 shows some variables and their symbolic representations based on the assumptions and flow chart of value presented in this paper.

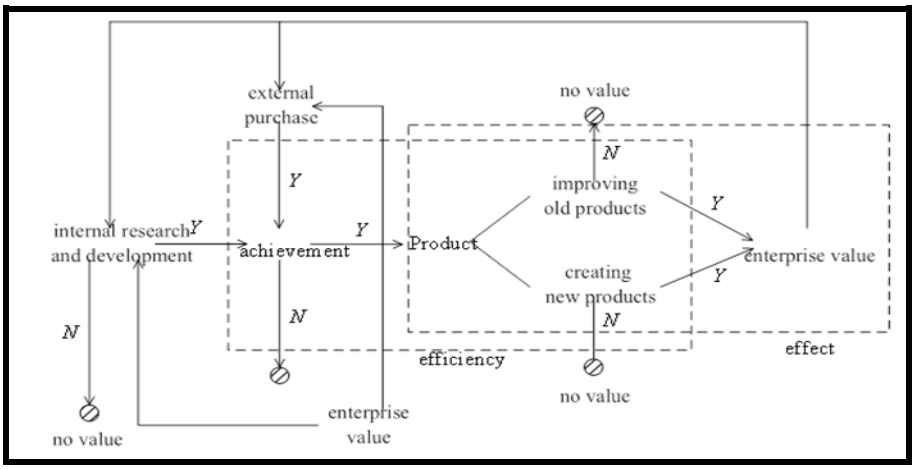

Figure 1The flow chart of the enterprise value

Table 1
The Meaning of Correlation Variables and Symbolic Representations

The meaning of Correlation Variables	Symbolic representation
The probability of choosing internal research and development innovation results	X
Investment amount of internal research and development innovation achievements	A
The probability of external purchase of innovation results	1-X
Amount of external purchase of innovation achievements	B
The probability of internal research and development to produce innovative results	Y
The probability that internal research and development does not result in innovation	1-Y
The probability of innovation results from internal research and development being transformed into products	P
The probability that innovation results from internal research and development are not translated into products	1-P
The innovation results formed by internal research and development that have not been transformed into products are sold to gain profits	L_1
The probability of innovation results from internal research and development to improve old products	Q
The probability of creating new products from the innovation results of internal research and development	1-Q
The probability that the old product with perfect innovation results does not get sales revenue	1-W
The probability of sales revenue of the old product with perfect innovation achievements	W
Revenue from sales of old products that are innovative and perfect	L_2
The probability that the new product created by the innovation result does not get sales revenue	1-V
The probability that the new product created by the innovation results will get sales revenue	V
The revenue from sales of new products created by innovation	L_3
The failure of enterprises to innovate will lead to the destruction of the ecological environment, which will result in environmental losses and the government's investment of resources needed for environmental governance	K
The innovation achievements of enterprises are transformed into increased resource input in product process	C_1
Enterprises adopt traditional technology to deal negatively with the reputation loss caused by environmental regulation	H
Government subsidies for research and development to make up for a lack of investment in innovation	E
An additional fine that an enterprise has to pay for discharging pollutants in violation of environmental regulations	F
The investment needed by the government to implement environmental regulation policies	S_1
The revenue from environmental regulation by the government	T
The probability that the government does not implement environmental regulations	$1-\alpha$
The probability of government implementing environmental regulation	α
The probability that the new product generated by the innovation results will get sales revenue	β
The probability that the new product produced by the innovation result does not get sales revenue	$1-\beta$

Based on hypothesis H1, the two ways in which innovation results are generated: internal research and development and external purchase, the following calculations are made, Formula (1) and (2):

The value added by internal research and development

$$= YP[QWL_2 + (1-Q)VL_3] + Y(1-P)L_1\text{-A} \quad (1)$$

The value added by external purchase

$$= QWL_2 + (1-Q)VL_3 - B \quad (2)$$

If internal and external licensing are to be integrated, use both strategies together rather than relying too heavily on either. Calculate as follows, Formula (3):

The value added by the synergistic effect of internal research and development and external purchase

$$= XYP[QWL_2 + (1-Q)VL_3] + XY(1-P)L_1\}\text{-A} + (1-X)[QWL_2 + (1-Q)VL_3] - B \quad (3)$$

According to the hypothesis H2, there are two ways to generate innovative products: improving old products and creating new products, and the following calculations are made, Formula (4) and (5):

The value added by improving old products

$$= WL_2 \quad (4)$$

The value added by creating new products

$$= VL_3 \quad (5)$$

As for the relationship between the two, some studies put forward the concept of dual innovation, emphasizing that enterprises should adopt the two strategies at the same time in the actual operation process, so as to realize the complementarity of the two strategies and avoid the loss of operating benefits caused by excessive reliance on one strategy [16,17]. Make the following calculation, Formula (6):

The value added by dual innovation

$$= QWL_2 + (1-Q)VL_3 \quad (6)$$

It is hypothesis H3 that government has two types of attitudes towards environmental regulation, namely environmental regulation and no environmental regulation. According to the model established above, the payoff matrix under different strategy combinations can be obtained by combining relevant hypotheses.

(1) Transformation of innovation achievements (innovation efficiency), as shown in Table 2 and Table 3.

Table 2

Revenue Matrix When the Government does not Implement Environmental Regulation

	Enterprises	Government
Enterprises do implement the transformation of innovation achievements (P)	$QWL_2 + (1-Q)VL_3 - C_1$	$-K$
Enterprises do not implement the transformation of innovation achievements (1-P)	$L_1 - H$	0

Table 3

Revenue Matrix When the Government does Implement Environmental Regulation

	Enterprises	Government
Enterprises do implement the transformation of innovation achievements (P)	$QWL_2 + (1-Q)VL_3 - C_1 + E$	$-K - S_1 + T$
Enterprises do not implement the transformation of innovation achievements (1-P)	$L_1 - H - F$	0

In the process of dynamic game, with the evolution of the game, when the expected revenue reaches the maximum, the game of all parties reaches the equilibrium state.

Build a replicated dynamic equation

According to the game standard formula, we can get:

$$E_1 = E_{11}P + E_{12}(1-P) \quad (7)$$

Where, E1 is the average expected revenue of the enterprise, and E11 and E12 are the profit value obtained by the enterprise when it adopts two different innovation strategies.

The profit of the enterprise's innovation achievements transformation is E11

$$E_{11} = [QWL_2 + (1-Q)VL_3 - C_1](1-\alpha) + [QWL_2 + (1-Q)VL_3 - C_1 + E]\alpha$$

$$= QWL_2 + (1-Q)VL_3 - C_1 + E\alpha \quad (8)$$

The profit of the enterprise's not innovation achievements transformation is E12

$$E_{12} = (L_1 - H)(1-\alpha) + (L_1 - H - F)\alpha = L_1 - H - F\alpha \quad (9)$$

From the perspective of evolutionary game, the stability of the system in the game process can be analyzed according to the above replicated dynamic equation. According to the game standard formula and revenue calculation above, the replication dynamic equation as shown below can be obtained.

$$U_1(P) = \frac{dP}{dt} = (E_{11} - E_1)P$$
$$= [E_{11} - E_{11}P - E_{12}(1-P)]P$$
$$= (1-P)P(E_{11} - E_{12})$$
$$= (1-P)P[QWL_2 + (1-Q)VL_3 - C_1 + E\alpha - L_1 + H + F\alpha]$$
$$= (1-P)P[QWL_2 + (1-Q)VL_3 - C_1 + (E+F)\alpha - L_1 + H] \quad (10)$$

E2 is the average expected revenue of the government, then according to the game standard formula, we can get:

$$E_2 = E_{21}\alpha + E_{22}(1-\alpha) \quad (11)$$

Among them, E21 and E22 are the benefit under different government strategies.

The benefit of the government implementing environmental regulations is E21

$$E_{21} = (-K - S_1 + T)P \quad (12)$$

The benefit of the government not implementing environmental regulations is E22

$$E_{22} = -KP \quad (13)$$

Combined with the characteristics of the replicated dynamic equation and game evolution, the stability of the government in the game process will be analyzed in the following part. Based on Equations (11)-(13), the government replication dynamic equation as shown in Equation (14) below can be obtained.

$$U_2(\alpha) = \frac{d\alpha}{dt} = (E_{21} - E_2)\alpha$$
$$= [E_{21} - E_{21}\alpha - E_{22}(1-\alpha)]\alpha$$
$$= (1-\alpha)\alpha(E_{21} - E_{22})$$
$$= (1-\alpha)\alpha(-S_1 + T)P \quad (14)$$

(2) Sales (innovation effect) stage of innovative products, as shown in Table 4 and Table 5.

Table 4
Revenue Matrix When the Government does not Implement Environmental Regulation

	Enterprises	Government
The products produced by the innovation achievements get sales revenue (β)	$QWL_2 + (1-Q)VL_3$	$-K$
The products produced by the innovation achievements did not get sales revenue ($1-\beta$)	0	0

Table 5
Revenue Matrix When the Government does Implement Environmental Regulation

	Enterprises	Government
The products produced by the innovation achievements get sales revenue (β)	$QW(L_2+E)$ $+(1-Q)V(L_3+E)$	$-K-S_1+T$
The products produced by the innovation achievements did not get sales revenue ($1-\beta$)	$-F$	0

In the process of dynamic game, with the evolution of the game, when the expected revenue reaches the maximum, the game of all parties reaches the equilibrium state.

E3 is the average expected revenue of the enterprise, then according to the game standard formula, we can get:

$$E_3 = E_{31}\beta + E_{32}(1-\beta) \quad (15)$$

Among them, E31 and E32 are the benefit obtained by enterprises when they adopt two different innovation strategies.

That the products produced by the innovation achievements of the enterprise get selling profit is E31

$$E_{31} = [QWL_2 + (1-Q)VL_3](1-\alpha) + [QW(L_2+E) + (1-Q)V(L_3+E)]\alpha$$
$$= QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha \quad (16)$$

That the products produced by the innovation achievements of the enterprise did not get selling profit is E32

$$E_{32} = -F\alpha \quad (17)$$

Combined with the characteristics of the replicated dynamic equation and game evolution, the stability of the enterprise in the game process will be analyzed in the following part. Based on Equations (15)-(17), the enterprise replication dynamic equation as shown in Equation (18) below can be obtained.

$$U_3(\beta) = \frac{d\beta}{dt} = (E_{31}-E_3)\beta$$
$$= [E_{31} - E_{31}\beta - E_{32}(1-\beta)]\beta$$
$$= (1-\beta)\beta(E_{31}-E_{32})$$
$$= (1-\beta)\beta[QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha + F\alpha] \quad (18)$$

E4 is the average expected revenue of the government, then according to the game standard formula, we can get:

$$E_4 = E_{41}\alpha + E_{42}(1-\alpha) \quad (19)$$

Among them, E41 and E42 are the benefit under different government strategies.

The benefit of the government implementing environmental regulation is E41

$$E_{41} = (-K-S_1+T)\beta \quad (20)$$

The benefit of the government not implementing environmental regulations is E42

$$E_{42} = -K\beta \quad (21)$$

Combined with the characteristics of the replicated dynamic equation and game evolution, the stability of the government in the game process will be analyzed in the following part. Based on Equations (19)-(21), the government replication dynamic equation as shown in Equation (22) below can be obtained.

$$U_4(\alpha) = \frac{d\alpha}{dt} = (E_{41}-E_4)\alpha$$
$$= [E_{41} - E_{41}\alpha - E_{42}(1-\alpha)]\alpha$$
$$= (1-\alpha)\alpha(E_{41}-E_{42})$$
$$= (1-\alpha)\alpha(-S_1+T)\beta \quad (22)$$

MODEL SOLUTION AND STABILITY ANALYSIS

First, the selection of internal research and development and external purchase

To study the selection between internal research and development and external purchase, we only need to compare the relationship between enterprise value increased by the two strategies, which can be obtained from Equations (1) and (2):

Enterprise value added by internal research and development - enterprise value added by external purchase

$$=\Delta L1 = (1-YP)[QWL_2+(1-Q)VL_3] + Y(1-P)L_1 + A - B$$

$$= (1-YP)[QWL_2+(1-Q)VL_3-L_1] + (1-Y)L_1 + A - B \quad (23)$$

According to the meaning of parameters, its value range can be determined as follows:

$0<Y<1;\ 0<P<1;\ 0<Q<1;\ 0<W<1;\ 0<V<1;$

Therefore $0<1-YP<1;\ 0<1-Y<1$

$QWL_2 + (1-Q)VL_3 - L_1$, according to its denotation meaning, reflects the difference between the enterprise value increased by selling products and the enterprise value increased by directly selling innovation achievements. Under normal operation of the enterprise, the difference is greater than zero, unless the enterprise's main business is reselling innovation achievements. But that makes it moot to consider whether to develop in-house or buy from outside.

$A - B$, according to its meaning, it reflects the internal research and development innovation input amount and the external value of the difference between the purchase innovation achievements, due to internal research and development innovation investment amount may include the cost of failure, while the external purchases innovations will produce innovative products, enterprises will not buy the innovation achievement, so the balance is greater than zero.

In conclusion, the difference between the enterprise value increased by internal research and development and that increased by external purchase$\Delta L1$) must be greater than zero. So, the best choice between the internal research and development and external purchase is the internal research and development.

According to the above analysis, excessive reliance on external authorization or internal research and development will lead to poor innovation performance and problems in enterprise operation. Therefore, enterprises should adopt two innovation strategies at the same time to make full use of the synergistic effect. This paper will compare and study the synergistic effect between internal research and development and external purchase and the optimal choice of internal research and development in a single strategy to select the optimal strategy.

To study the selection between synergistic effect between internal research and development and external purchase and internal research and development, we only need to compare the relationship between enterprise value increased by the two strategies, which can be obtained from Formula (1) and (3):

Enterprise value increased by synergistic effect of internal research and development and external purchase

- enterprise value increased by internal research and development

$$= \Delta L_2 = XYP[QWL_2+(1-Q)VL_3] + XY(1-P)L_1\text{-A}+(1-X)[QWL_2+(1-Q)VL_3] - B - YP[QWL_2+(1-Q)VL_3] - Y(1-P)L_1 + \text{A} = (XYP+1-X-YP)[QWL_2+(1-Q)VL_3] + (X-1)Y(1-P)L_1 - B = (X-1)(YP-1)[QWL_2+(1-Q)VL_3] + (X-1)Y(1-P)L_1 - B = (X-1)\{YP[QWL_2+(1-Q)VL_3-L_1] - [QWL_2+(1-Q)VL_3-YL_1]\} - B$$

$$\frac{\partial \Delta L_2}{\partial Y} = (X-1)\{P[QWL_2+(1-Q)VL_3-L_1] + L_1\} = (X-1)\{P[QWL_2+(1-Q)VL_3] + (1-P)L_1\} \le 0 \quad (24)$$

It shows that $\Delta L2$ decreases with the increase of Y.

When Y=0, $\Delta L_2 = (1-X)[QWL_2 + 1-QVL3-B$

If $B<(1-X)[QWL_2+(1-Q)VL_3]$, $\Delta L_2>0$

When $\Delta L_2 = 0, Y_0 = \frac{B/(X-1)+QWL_2+(1-Q)VL_3}{P[QWL_2+(1-Q)VL_3-L_1]+L_1} > 0$, it can't tell how Y0 is related to 1.

When Y=1, $\Delta L_2 = (1-X)(1-P)[QWL_2 + (1-Q)VL_3 - L_1] - B$, it can't tell how ΔL_2 is related to 0.

So, when $B < (1-X)[QWL_2 + (1-Q)VL_3]$, the optimal strategy cannot be determined.

Since the optimal strategy cannot be determined in this case, the synergistic effect of internal research and development and external purchase as well as external purchase in a single strategy will be further verified to achieve the purpose of selecting the non-optional strategy. According to Equations (2) and (3), we can get:

Enterprise value increased by synergistic effect of internal research and development and external purchase - enterprise value increased by external purchase

$= \Delta L_3$

$= XYP[QWL_2 + (1-Q)VL_3] + XY(1-$
$PL1\text{-A}+1-XQWL2+1-QVL3$
$-B - QWL_2 - (1-Q)VL_3 + B$

$= XYP[QWL_2 + (1-Q)VL_3] + XY(1-$
$PL1\text{-A}-XQWL2+1-QVL3$

$$\frac{\partial \Delta L_3}{\partial Y} = XP[QWL_2 + (1-Q)VL_3] + X(1-P)L_1$$

$= XP[QWL_2 + (1-Q)VL_3 - L_1] + XL_1 > 0$(25)

When Y=0, $\Delta L_3 = -A - X[QWL_2 +$ 1−QVL3 < 0

When Y=1, $\Delta L_3 = XP[QWL_2 + (1-$ QVL3+X1−PL1-A−XQWL2+1−QVL3

$= X(1-P)[L_1 - QWL_2 - (1-Q)VL_3]\text{-A} < 0$

So, $0 < Y < 1, \Delta L_3 < 0$. At this time external purchase will increase less enterprise value for tobacco production enterprises.

If $B \geq (1-X)[QWL_2 + (1-Q)VL_3]$, $\Delta L_2 < 0$

When 0<Y<1, $\Delta L_2 < 0$. At this time, the synergy strategy of internal research and development and external purchase will increase more enterprise value.

Second, the selection of improving old products and creating new ones

To study the selection between improving old products and creating new products, we only need to compare the relationship between the enterprise value increased by the two strategies, which can be obtained from Formula (4) and (5):

Enterprise value increased by improving old products

- enterprise value increased by creating new products

$= \Delta L$

$= WL_2 - VL_3$ (26)

When $W > \frac{VL_3}{L_2}$, $\Delta L_4 > 0$. At this time improving old products will increase more enterprise value for tobacco production enterprises.

When $W < \frac{VL_3}{L_2}$, $\Delta L_4 < 0$. At this time creating new products will increase more enterprise value for tobacco production enterprises.

When $W = \frac{VL_3}{L_2}$, $\Delta L_4 = 0$. At this time improving old products and creating products will increase the same enterprise value for tobacco production enterprises.

As for the relationship between the two, some studies put forward the concept of dual innovation, which regards product development and exploration as complementary. Therefore, it is suggested that enterprises should adopt the two product innovation methods at the same time, instead of relying on one strategy only [16,17].

To study the selection between dual innovation and improving old products, we only need to compare the relationship between the enterprise value increased by the two strategies, which can be obtained from Formula (4) and (6):

Enterprise value increased by dual innovation -

enterprise value increased by improving old products

$$= \Delta L_5$$
$$= QWL_2 + (1-Q)VL_3 - WL_2$$
$$= -(1-Q)(WL_2 + VL_3) < 0 \quad (27)$$

At this time improving old products will increase more enterprise value for tobacco production enterprises.

To study the selection between dual innovation and creating new products, we only need to compare the relationship between the enterprise value increased by the two strategies, which can be obtained from Formula (5) and (6):

Enterprise value increased by dual innovation - enterprise value increased by creating new products

$$= \Delta L_6$$
$$= QWL_2 + (1-Q)VL_3 - VL_3$$
$$= Q(WL_2 - VL_3)(28)$$

When $W > \frac{VL_3}{L_2}$, $\Delta L_6 > 0$. At this time dual innovation will increase more enterprise value for tobacco production enterprises.

When $W < \frac{VL_3}{L_2}$, $\Delta L_6 < 0$. At this time creating new products will increase more enterprise value for tobacco production enterprises.

When $= \frac{VL_3}{L_2}$, $\Delta L_6 = 0$. At this time dual innovation and creating new products will increase the same enterprise value for tobacco production enterprises.

In summary, the selection results of the three strategies are as follows:

When $W > \frac{VL_3}{L_2}$, improving old products will increase more enterprise value for tobacco production enterprises.

When $W < \frac{VL_3}{L_2}$, creating new products will increase more enterprise value for tobacco production enterprises.

When $W = \frac{VL_3}{L_2}$, the three strategies will increase the same enterprise value for tobacco production enterprises.

Third, the equilibrium of environmental regulation and innovation efficiency and effect

The equilibrium of environmental regulation and innovation efficiency

Make the replicative dynamic equations of enterprises and governments (Formula (10) and (14)) zero, and the equations can be obtained as follows:

$$\begin{cases} U_1(P) = 0 \\ U_2(\alpha) = 0 \end{cases} (29)$$

Four special equilibrium points of the dynamic system evolutionary game can be obtained by solving equations (29), such as $M_1(0,0)$, $M_2(1,0)$, $M_3(0,1)$, $M_4(1,1)$.

$\{(P,\alpha) \mid P= 0, 1; \alpha= 0, 1\}$,: $\Omega = \{(P,\alpha) \mid 0 < P < 1; 0 < \alpha < 1\}$ constitutes the boundary of the solution domain of the evolutionary game.

For the above model equation and equilibrium point, the derivative of Equation (29) can be obtained in this paper, as shown in Equation (30), from which the stability of the corresponding equilibrium point can be determined.

$$U_1'(P) = (1-2P)[QWL_2 + (1-Q)VL_3 - C_1 + (E+F)\alpha - L_1 + H]$$
$$U_2'(\alpha) = (1-2\alpha)(-S_1 + T)P(30)$$

In the process of mutual game, the three parties of the game will constantly seek to achieve the equilibrium between each other. As the game evolves, according to the nature of the game, when $U_1'(P) < 0$ and $U_2'(\alpha) < 0$, P and α in Equation (30) respectively represent the stable strategies adopted by both parties in the game process, and the stable state at the corresponding moment can be calculated according to the equation.

When $P \in (0,1)$, $U_1(P) > 0$. The phase diagram of enterprise stability strategy evolution can be drawn according to Equation 1 in Equation (30), where the straight line $QWL_2 + (1-Q)VL_3 - C_1 + (E+F)\alpha - L_1 + H = 0$ forms the dividing line where enterprise strategy selection is in a stable state. If $QWL_2 + (1-Q)VL_3 - C_1 + (E+F)\alpha - L_1 + H > 0$, $U_1'(0) > 0$ and $U_1'(1) < 0$.

At this time enterprises put performance innovative achievements transformation activities as a stable strategy. If $QWL_2 + (1-Q)VL_3 - C_1 + (E+F)\alpha - L_1 + H < 0$, enterprises put nonperformance innovation achievements transformation activities as a stable strategy.

According to the "replication dynamics" method, the stability of the two parties in the game process can be analyzed to obtain the stability strategies adopted by different players in the game, which will provide an important reference for the game between enterprises and governments under environmental regulation.

(2) The equilibrium of environmental regulation and innovation effect

Make the replicative dynamic equations of enterprises and governments (Formula (18) and (22)) zero, and the equations can be obtained as follows:

$$\begin{cases} U_3(\beta) = 0 \\ U_4(\alpha) = 0 \end{cases} \quad (31)$$

Four special equilibrium points of the dynamic system evolutionary game can be obtained by solving equations (31), such as $M_1(0,0)$, $M_2(1,0)$, $M_3(0,1)$, $M_4(1,1)$.

$\{(P,\alpha) \mid P=0, 1; \alpha=0, 1\}$,: $\Omega = \{(P,\alpha) \mid 0 < P < 1; 0 < \alpha < 1\}$ constitutes the boundary of the solution domain of the evolutionary game.

For the above model equation and equilibrium point, the derivative of Equation (31) can be obtained in this paper, as shown in Equation (32), from which the stability of the corresponding equilibrium point can be determined.

$$U_3'(\beta) = (1-2\beta)[QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha + F\alpha]$$

$$U_4'(\alpha) = (1-2\alpha)(-S_1 + T)\beta \quad (32)$$

In the process of mutual game, the three parties of the game will constantly seek to achieve the equilibrium between each other. As the game evolves, according to the nature of the game, when $U_3'(\beta) < 0$ and $U_4'(\alpha) < 0$, β and α in Equation (32) respectively represent the stable strategies adopted by both parties in the game process, and the stable state at the corresponding moment can be calculated according to the equation.

When $\beta \in (0,1)$, $U_3(\beta) > 0$. The phase diagram of enterprise stability strategy evolution can be drawn according to Equation 1 in Equation (32), where the straight line $QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha + F\alpha = 0$ forms the dividing line where enterprise strategy selection is in a stable state. If $QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha + F\alpha > 0$, $U_3'(0) > 0$ and $U_3'(1) < 0$. At this time enterprises put performance innovative achievements transformation activities as a stable strategy. If $QWL_2 + (1-Q)VL_3 + QWE\alpha + (1-Q)VE\alpha + F\alpha < 0$, enterprises put nonperformance innovation achievements transformation activities as a stable strategy.

According to the "replication dynamics" method, the stability of the two parties in the game process can be analyzed to obtain the stability strategies adopted by different players in the game, which will provide an important reference for the game between tobacco production enterprises and governments under environmental regulation.

THE RESEARCH CONCLUSION

Tobacco production enterprises innovation activities play an important role in promoting enterprise value, improving ecological environment and increasing social welfare, which will be conducive to promoting the construction of ecological civilization in China and have a positive significance to realizing sustainable development. However, it is difficult for the market mechanism to play an effective role in promoting enterprises' ecological innovation. Therefore, the government needs to restrict it through environmental regulations to promote enterprises' innovation in environmental protection. In this paper, the following research is carried out by establishing the model of the game process between tobacco control city government and tobacco production enterprises.

(1) According to the process of value creation, the source of innovation achievements and the selection of strategies are studied to provide theoretical support for the primary link of tobacco production enterprises innovation activities. There are two sources of innovation achievements: internal research and development and external purchase. However, there are three kinds of selection strategies: internal research and development, external purchase and synergistic effect between the two. This paper quantifies the influence of the first link of the value chain on the enterprise value to make the optimal strategy. The results show that the selection of the three strategies is related to the cost of external purchase. When the cost of external purchase is less than a certain value, the optimal choice strategy cannot be determined. When the cost of external purchase is greater than a certain value, the optimal selection strategy is the synergistic effect of internal research and development and external purchase for tobacco production enterprise. This shows that in the process of tobacco production enterprise value creation, internal research and development costs play a crucial role.

(2) The application product types of the innovation achievements are studied to provide the basis for the selection of the important links of tobacco production enterprise innovation activities. There are three application strategies for innovation achievements: improving old products, creating new products and dual innovation. This paper quantifies the influence of the key link in the value chain on the enterprise value to make the optimal strategy. The results show that the selection of the three strategies is related to the probability that improving old products can increase more enterprise value. When the probability is greater than a certain value, the optimal strategy is to improve old products for tobacco production enterprise. When the probability is less than a certain value, the optimal strategy is to create new products for tobacco production enterprise. When the probability is equal to a certain value, the three strategies increase the same enterprise value. This shows that in the process of enterprise value creation, the probability that improving old products can increase more enterprise value plays a crucial role.

(3) From the perspective of evolutionary economics, the equilibrium dynamic evolutionary game process between tobacco control city government environmental regulation and enterprise innovation efficiency and innovation effect is discussed. Based on the model hypothesis, the corresponding evolution law is selected, and the evolution of the game process between government and enterprise is deduced, and the stability strategy under various conditions is demonstrated.

The weakness of this paper is that only the game theory method is used to conduct correlation analysis, but the relationship between environmental regulation, choice strategy of innovation activities and enterprise value can still be theoretically confirmed. The follow-up research will be conducted by empirical test method.

Conflict of Interest Disclosure Statement

The authors have no conflicts of interest, financial or otherwise.

Author Declaration

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