



Research on Innovation-Synergy Driven Model for Improving Ecological Competitiveness in Resource-Based City

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ABSTRACT

The issue of ecological environment deterioration is the main challenge of resource-based cities. The optimal innovation investment proportion and tendency of ecological protection behaviours of government and enterprise, can be analysed by means of establishing the innovation synergy driven interpretation model and the game model of innovation factors in the process of improving ecological competitiveness, and the research shows that the decrease of innovation cost, improvement of innovation benefit and perfection of cash deposit and innovation favour system can promote the innovation behaviour effectively. The related countermeasures and suggestions are put forward by means of analysing the result, which offers reference for eco-development of resource-based city.

INTRODUCTION

The ecological competitiveness of resource-based city reflects the capacity of sustainable development, and its promotional target is establishing the perfect environment protection system with low carbon, green and circulation, which is the standard of measuring the harmonious development of economics and environment, and the promotion progress should depend on the drive of technology innovation and institution innovation. The technology innovation can operate the realization of green and low-carbon production and implementation of ecological management, while the institution innovation can regulate the behaviors of principal agent involving resource development and environmental management, thus ensuring the accomplishment of ecological construction, and the synergetic evolution of them provides the continual innovation impetus. This thesis applies the game method to discuss the game relationship of innovation factors between the government and enterprise, and analyse the behaviour disposition of each principle agent, and then put forward the countermeasure and suggestion of promoting ecological competitiveness.

ECOLOGICAL PROBLEMS AND THEIR CAUSE OF RESOURCE-BASED CITY

The resource and zoology are an organic whole with interrelation, and the extensive mining of resource causes the austere ecological and environmental issues, which shows the rapid loss of resource and continuous deterioration of environment; the former derives from the "high yield drive" of resource and deficiency of innovative impetus, and the latter

derives from negative externality of resource development.

Resource loss-interest-driven and innovation extrusion:

The high yield of resource makes a large number of enterprises and production factors flow to resources department, thus accelerating the over-exploitation and extensive exploitation. Since the resource should depend on the ecological environment carrier, the exploitation process of resource brings the destruction of zoology inevitably. And because of the chase for high resource benefits, the scale resource industry is enlarged, but the power of technological innovation is lacking, then leading to the continuous extrusion of innovation activities, low level of resources utilization, thus aggravating the depletion rate of resource and deterioration of ecological environment (Sun 2012).

Environment pollution-negative externality of resource development:

The resource development has the remarkable negative externality because of the dependent relationship between the resource and zoology, which includes the destruction to the groundwater environment, occupation of land resources, pollution of the air, and damage to ecological environment, such as surface collapse, vegetation deterioration, water and soil loss, etc. The initiatives of agents involving in the resource benefits are also weak to ecological management because of the chase for revenue maximizing, and meanwhile, the separation and fuzzification on resource benefit right and property right of ecological environment, aggravates the occurrence of ecological problems (Lv et al. 2012).

Decline of ecological carrying capacity-economic development effect:

In resource-based cities, the carrying capacity

ity of total resources and ecological environment is limited. At the initial stage of city development, the emphasis of economic activities is promoting the rapid growth of economy by means of resource exploitation, and the demand of economic development is greater than the demand of ecological environment (Sun 2012). Continuous input of resource exploitation and imperfection of resources pricing system caused the low level of resources utilization, and aggravated consumption of resources, constantly devoured ecological capital and destroyed the carrying capacity of ecosystem as well.

EXPLANATION OF INNOVATION COOPERATION AND THE ECOLOGICAL COMPETITIVENESS

The innovation cooperation driven process is a combination process of technological innovation and institutional innovation in the development of resource based cities, which makes the urban ecological competitive potential gradually improve and support the dynamic evolution process of urban sustainable development. Its core content is to enhance the competitiveness of ecological competition through innovation cooperation (Du 2013). In this model, the mathematical model is used to explain the relationship between innovation cooperation and the improvement of urban ecological competitiveness.

It is assumed that resource-based city is a state variable, which is influenced by many factors in the urban ecosystem, expressed in C_t , as shown in formula (1):

$$C_t = f(R, S, D, K, E) \dots(1)$$

Where, R indicates the potential of resource exploitation, S is the use of resources, D is the ecological environment competitive potential, K is the ecological industry competitive potential, E is the ecological cultural competitive potential.

Assume that at some point in time t of the urban development, because of the technological innovation and institutional innovation, the city's ecological competitiveness is affected or disturbed, and the disturbance variables can be expressed as shown in formula (2):

$$I_t = f(X_t, Y_t) = f(X_t)f(Y_t) = KtX_t^\alpha Y_t^\beta \dots(2)$$

Where, X_t is the degree of ecological technology innovation at t time point, Y_t is the degree of the ecological institutional innovation at t time point, I_t is the combination of technology and institutions to interfere with the urban ecological competitiveness. K, α , β for the three parameters, represent the importance of technological innovation and institutional innovation, $0 < \alpha, \beta < 1$.

Competitive state variables: Through interference factors to achieve the change of competitive, factor is obvious, and the characteristic value of the state variable C_t represented as shown in formula (3):

$$C_t = f(R, S, D, K, E) \wedge I_t \dots(3)$$

When the influence of technology and institutions on the ecological competitiveness continued to the point t , the competitiveness to achieve a stable stage, the interference to normal factors, the C_t value can be expressed as shown in formula (4):

$$C_t = f(R, S, D, K, E, I_t) \dots(4)$$

In the following discussion, the disturbance factors were significant, changes in characteristic variables of C_t , we get the differential equation of the formula 4:

$$dC_t = (\partial C_t / \partial R)dR + (\partial C_t / \partial S)dS + (\partial C_t / \partial D)dD + (\partial C_t / \partial K)dK + (\partial C_t / \partial E)dE + (\partial C_t / \partial I_t)dI_t \dots(5)$$

Type $dC_t > 0$ indicates the stable development of ecological competitiveness, and $dC_t < 0$ indicates the ecological competitiveness in pathology, that is the state declined or promotion is blocked. Typically, due to the destruction of resources, exploitation, the low utilization rate of urban resources, the destruction of the ecological environment, the lagging of ecological industry, and the importance of ecological culture, each factor is different:

$$(\partial C_t / \partial R) < 0, (\partial C_t / \partial S) < 0, (\partial C_t / \partial D) < 0, (\partial C_t / \partial K) < 0, (\partial C_t / \partial E) < 0, (\partial C_t / \partial I_t) < 0$$

Therefore, as a result of the existence of block, if there is no reverse driven, will inevitably lead to the lack of urban ecological competitiveness. Even if the transformation, long-term development is still slow, the city's sustainable development again into a difficult situation, that is, $dC_t < 0$. To improve the competitiveness of the city, we must set up the following inequality:

$$(\partial C_t / \partial R)dR + (\partial C_t / \partial S)dS + (\partial C_t / \partial D)dD + (\partial C_t / \partial K)dK + (\partial C_t / \partial E)dE < |(\partial C_t / \partial I_t)dI_t|$$

Through the comprehensive effect of technological innovation and institutional innovation in resource-based cities, to offset the effects of the decline of urban development on the ecological competitiveness,

$$\begin{aligned} &\text{or to make, } |(\partial C_t / \partial I_t)dI_t| > (\partial C_t / \partial D)dD, \\ &\text{or to make, } |(\partial C_t / \partial I_t)dI_t| > (\partial C_t / \partial K)dK, \\ &\text{or to make, } |(\partial C_t / \partial I_t)dI_t| > (\partial C_t / \partial E)dE, \end{aligned}$$

These methods can be considered as the combination of the technology and the institutional innovation in the role of the ecological environment decline, or the ecological industry decline, or the ecological cultural decline etc.

Technical and institutional investment combination: Fig. 1, explains in different periods of ecological competitive-

ness in resource-based city, the optimal investment portfolio of the ecological technology innovation and the ecological institutional innovation. The x-axis is the investment in the ecological technology innovation, the y-axis is the investment in the ecological institutional innovation, EF and GH are the investment combination of the technological and institutional innovation in different periods, curve AB is the possibility of boundary of the ecological competitiveness, and ejection fraction EF and GH line respectively, tangent with C and D.

Assumption, along with the time change, the AB from the left to the right bottom of the C point, which is the best combination of technology innovation and institutional innovation, this time the ecological technology innovation investment is OJ, the ecological institutional is OI, with the change of EF. D point is the optimal combination of the second competitive state, which the ecological technology is ON, and the ecological institutional is OM. Observation found that the institutional of C point OI greater than the D point OM, and the technology of C point investment OJ less than the D point ON, which is due to the different stages of eco competitiveness development, technological innovation and institutional innovation ability. From the first state to the second state, the increase of ecological competitiveness is more dependent on technological innovation, the investment of ecological technology innovation to keep the lowest cost. In the same way, assuming that the curve of AB is changed from the right direction to the upper left, the investment equilibrium point of the second state stage is the C point, which has the advantage of the institutional innovation, so it will increase the investment of the ecological institutional and realize the comparative advantage.

Through the analysis, in the different periods of the development of the ecological competitiveness, the investment of the ecological technological innovation and the ecological institutional innovation of the resource based cities have the optimal equilibrium point. And the optimal proportion of investment will change, in order to ensure the optimal condition, and put the innovation resources into the one with the comparative advantage, and then achieve the best competitive level.

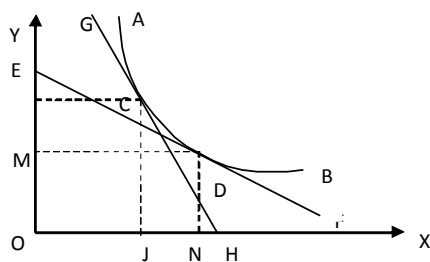


Fig. 1: The combination of technology and institutional.

GAME ANALYSIS ON INNOVATION-DRIVEN FACTORS

Interactive relationship of innovation-driven factors: In the improvement process of the ecological competitiveness, technology innovation and institution innovation are both wings which can't be ignored, and they depend on each other, evolve synergistically (Dan 2014). On the one hand, the institution innovation ensures the institutional environment of ecological technology innovation, determines the power source of ecological technology innovation agents, and it is the effective mean to intervene the ecological technology innovation activities (Murauskait 2012). The government can reduce the ecological management cost, increase the ecological benefits, and make the enterprise to trend towards the ecological technology innovation behaviors by means of system design to encouraging the technology innovation activities, including the research and development expenditure, innovation incentive, cooperative arrangement, etc. On the other hand, the ecological technology innovation can make the ecological output to realize the progressive increase of scale within limits, which can increase the potential ecological environment benefits of the government after institution innovation, and reduce the cost for part of the institution arrangement, promote the new institution innovation activities as well. By means of continuous technology innovation and institution innovation activities, the cumulative effect on protection and control of ecological environment will be obvious. The enterprise and city obtain the potential ecological benefits, and sequentially strengthen the technology innovation and institution innovation (Wang 2012).

Establishment of game model: In the improvement of ecological competitiveness in resource-based cities, the principle agent of ecological institution innovation is local government, and the principle agent of ecological technology innovation is enterprise. The relationship between the ecological technology innovation and ecological institution innovation interactional, on the one hand, the ecological institution innovation creates the favourable environment for ecological technology innovation of enterprise and encourages the enthusiasm of innovation. On the other hand, ecological technology innovation of enterprise can change benefits of institution innovation, and reduce the operating cost of institution arrangement (Lv 2012). This paper, uses the game model to analyse the trend, whether the government and enterprise choose the innovation or not, it is optional for the government, to conduct the ecological institution innovation or don't conduct the ecological institution innovation, and it is optional for the enterprise, to conduct the ecological technology innovation or don't conduct the ecological technology innovation.

Table 1: Innovation game matrix between local government and enterprise.

		Enterprise	
		Conduct ecological technology innovation	Don't conduct ecological technology innovation
Local government	Conduct ecological institution innovation	$Rg - Cg - Dg, Re - Ce + Dg$	$K - Cg, -K$
	Don't conduct ecological institution innovation	$Rg, Re - Ce$	0,0

Model Assumption: 1. The enterprise doesn't know what action will be taken by the government when making decision, and the government also doesn't know whether the enterprise will take the technology innovation when making decision, so the game between them is a static game.

2. The government considers the maximizing of economic benefit and environmental benefit when making decisions, while the ultimate goal of enterprise's decision-making is realizing the maximization of economic benefit.

Suppose Dg is the favourable support given by the government when the enterprise conducts the ecological technology innovation, Cg is the expenditure when the government conducts the ecological institution innovation, excluding the benefit to the enterprise from ecological technology innovation of Dg . Re, Rg is the benefit to the government when the enterprise conducts the ecological technology innovation, Ce is the expenditure when the enterprise conducts the ecological technology innovation, K is the ecological security when the ecological technology of enterprise is substandard. This paper assumes the ecological technology will be substandard if the enterprise doesn't conduct the ecological technology innovation, and the enterprise doesn't need to pay the ecological security when the government doesn't conduct the ecological institution innovation. The game relationship matrix between government and enterprise is shown in Table 1.

Equilibrium solution of game model: This paper assumes that $K > Cg + Dg, K > Ce$, meaning the expected revenue of the ecological security of government is larger than the expenditure sum between the ecological institution innovation and preferential support of government, and the expected ecological security expenditure of enterprise is larger than the expenditure on ecological technology innovation of government. On the basis of this prerequisite of assumption, given that the government conducts the ecological institution innovation, the optimal strategy of enterprise is conducting the ecological technology innovation. Given that the government does not conduct the ecological institution innovation, the optimal strategy of enterprise is without innovation, hence, there is no pure strategy. Nash Equilibrium is

based on this prerequisite of assumption. Suppose the probability of ecological institution innovation conducted by the government is $P1$, while the probability without innovation is $1 - P1$, the probability of ecological technology innovation conducted by the enterprise is $P2$, while the probability without innovation is $1 - P2$, determine the mixed strategy Nash Equilibrium of this model.

The expected revenue of government which conducts the ecological institution innovation or doesn't conduct the ecological institution innovation respectively as shown in formula (6) and (7):

$$S1 = P2(Rg - Cg - Dg) + (1 - P2)(K - Cg) \quad \dots(6)$$

$$S2 = P2 * Rg + (1 - P2) * 0 \quad \dots(7)$$

Get $P2^* = (K - Cg)/(K + Dg)$, by now, the government can choose randomly whether conducting the ecological institution innovation or not.

The expected revenue of enterprise which conducts the ecological technology innovation or doesn't conduct the ecological technology innovation respectively as shown in formula (8) and (9):

$$U1 = P1(Re - Ce + Dg) + (1 - P1)(Re - Ce) \quad \dots(8)$$

$$U2 = P1 * (-K) + (1 - P1) * 0 \quad \dots(9)$$

Get $P1^* = -(Re - Ce)/(K + Dg)$, by now, the enterprise can choose randomly whether conducting the ecological technology innovation or not.

Result analysis: When the probability range of the ecological institution innovation conducted by the government is $P1 \in (-(Re - Ce)/(K + Dg), 1]$, the expected revenue of ecological technology innovation conducted by the enterprise will be larger than the expected revenue without ecological technology innovation, so the enterprise will choose to conduct innovation. Similarly, when $P1$ range is $P1 \in [0, -(Re - Ce)/(K + Dg))$, the enterprise will not conduct innovation.

When the probability $P2$ range of the ecological technology innovation conducted by the enterprise is $P2 \in ((K - Cg)/(K + Dg), 1]$, the expected revenue of the eco-

logical institution innovation conducted by the government will be smaller than the expected revenue without ecological institution innovation, so the government will not choose to conduct innovation. Similarly, P_2 when range is $P_2 \in [0, (K - C_g)/(K + D_g))$, the government will choose to conduct innovation.

When the government conducts the ecological institution innovation with probability P_1^* , the enterprise conducts the ecological technology innovation with probability P_2^* , the game between the government and enterprise reaches to the mixed strategy Nash Equilibrium. The equilibrium value of government P_1^* in the game presents the negative correlation with the net earnings of the enterprise which conducts the ecological technology innovation $Re - Ce$, and presents the positive correlation with the ecological security K paid by the enterprise when its ecological technology is substandard and the favorable privilege of innovation to the enterprise from government D_g . The equilibrium value of enterprise in the game P_2 has the positive correlation with the benefit $K - C_g$ when the government conducts the ecological institution innovation but the enterprise doesn't conduct innovation, and has the positive correlation with the ecological security K paid by the enterprise when its ecological technology is substandard and favorable privilege of innovation to the enterprise from government D_g .

The analysis of results shows that the reduction on ecological institution innovation cost of government, improvement on ecological technology innovation benefit of enterprise, effective implementation on ecological security system, implementation on preferential support system of technology innovation, etc., will be helpful for the enterprise to carry out the ecological technology innovation actively, thus guaranteeing the ecological environment of city, and improving the ecological competitiveness of city.

COUNTERMEASURES AND SUGGESTIONS ON IMPROVING ECOLOGICAL COMPETITIVENESS OF RESOURCE-BASED CITY

The development problem of innovation development in resource-based city reflects that the crowding-out effect of technology innovation and institution innovation from resource-based economics and the shortage of innovation capacity restrict the improvement of competitiveness of resource-based city (Wang 2008). This paper discusses the innovation behaviour tendency between the government and enterprise by means of game analysis on technology innovation and institution innovation in the improvement of ecological competitiveness in resource-based city, and the paper puts forward the following countermeasures and suggestions based on the result analysis.

Promote green technology innovation, improve innovation benefit of the enterprise: The green technology innovation of resource-based cities relies on the innovation agents, including enterprises, universities and scientific research institution, etc., to carry out and implement effectively in the enterprise at the end. Each innovation agent should be encouraged to cooperate, and establish the strategy alliance of green technology innovation, integrate the innovation resource, guide the innovation factors to gather to enterprise, promote the green transition of resource-based enterprise and develop the modern and green innovation enterprise, reduce the cost of green production, pollution prevention and control of enterprise by means of implementation of green innovation technology in enterprise (Wu et al. 2012) and then improving the added economic benefits of enterprise from innovation activities, encouraging the enthusiasm of enterprise who conducts the research and development and implementation of green technology innovation unceasingly.

Develop cyclic technology innovation, reduce the innovation cost of the enterprise: The method of developing the cyclic resource economics also can reduce the implementation cost of technology innovation of enterprise. The development of cyclic economics can guarantee the reasonable request from ecological system, and excavate the economical value of resource and environment with highest possible. The improvement of cyclic technology level can remit the degree of dependence to the ecological environment from economic development, reduce the resource loss, "emission reduction" and "loss reduction" can be realized effectively through the extension of industrial chain and recycle of waste resource; and the innovation implementation cost of enterprise in ecological control will be decreased, according with the gold of enterprise which chases the maximization of economic benefit.

Optimize innovation environment of ecological technology, promote innovation behaviour tendency of ecological technology of enterprise: At the aspect of optimizing the innovation environment of ecological technology, the government should take efforts energetically, which mainly includes strengthening the import and training of talents, improve the gathering ability of talents by establishing scientific management system and income distribution of talents, enlarge the public investment on platform of sci-tech innovation, such as promoting the construction on service platform of ecological technology transfer, perfecting the construction of sci-tech innovation park, etc. The improvement of ecological innovation environment in city should be given priority to consider at the fund balance, when the government rewards the ecological technology innovation activities, meanwhile, strengthen the publicity of innovation culture, commend and reward the innovation-based enterprises,

improve the attention of enterprise to innovation, and promote the behaviour tendency of enterprise conducting the ecological technology innovation.

Perfect ecological simulation and compensation system, increase favorable support for innovation: The resource-based city faces the increasingly intense resource environment constraint, the government should perfect the ecological simulation and compensation system, strengthen the application of innovation activities in enterprise, in order to remit the serious ecological pressure (Wang 2011). The reward and policy privilege should be given to the enterprise that are conducting the ecological technology innovation, for example, establish the reward fund of ecological technology innovation, build the ecological assessment system, realize the land, tax privilege, and at the same time, perfect the ecological compensation system, balance the interest of resource beneficiaries, resource protectors and losers, and increase the support on ecological compensation and ecological environment protection by establishing the special fund of ecological construction.

Perfect ecological security system: The ecological security is the guarantee fee for the damage of ecological environment caused potentially, before the enterprise conducts the resource mining and product production, so it is the restriction mechanism of prevention in advance. From the result of game analysis, the probability of ecological technology innovation conducted by the enterprise has the positive correlation with the ecological security, meaning the ecological security system can effectively promote the enterprise to implement the behaviors of ecological technology protection and environment control, in the implementation progress of ecological security. The scientific ecological assessment standard should be formulated in order to ensure the implementation effect of system. The implementation of security system can effectively decrease the ecological management cost of government, improve the ecological control behaviors of enterprise, and thus improving the ecological competitiveness of city.

Definitude ecological responsibility system, dispose responsible enterprise according to law: The enterprise that implements the ecological protection and control can adopt the encouraging measures by responsibility supervision of government to enterprise, including financial contribution, fiscal, etc. The enterprise that doesn't perform responsibility should be disposed gravely according to the law, for example, in order to promote the engineering of blue sky and water, Shanxi province closed 6000 coal mine places, banned 2771 enterprise that discharge pollution illegally, imposed the sewage charge with 1.55 billion, only the displacement of sulphur dioxide and chemical oxygen demand decreased

3.56% and 2.77% respectively. Meanwhile, the government also needs to establish the operation mechanism of ecological responsibility, including formulating the programme of ecological construction, strengthening the management of property rights of resource, providing the financial support, improve the implementation system of system, etc. (Zhang & Sun 2011). The constraint organization of the third party, such as public, environmental protection organizations, also can be imported to supervise the implementation situation on ecological responsibility of government and enterprise, and improve the supervision efficiency, guarantee the implementation of ecological responsibility system as well.

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