



A Study on the Coupling Rules between Ecological Environment and Urban Competitiveness

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Abstract

The relation between city and ecological environment forms in the coupling process of urban systems and environmental factors, in which there is a definite rule. Urban competitiveness embodies the evolvement and development of the city, using the dissipative structure principle and mathematical analysis, this paper probes into the coupling rule between urban competitiveness and ecological environment. It is indicated that the amicability degree of human environmental behavior determines the shape of environmental Kuznets curve, the human amicable behavior and technological progress are significant for coordinating the city development and improving the urban competitiveness.

Keywords: Urban competitiveness, Ecological environment, Coupling rule

1. Introduction

At present, many scholars divide the stage of city according to the changing rule between the extrinsic landscape changing and economic growth or the proportion of the investment in environmental protection to urban economy. Urban competitiveness is an important symbol to evaluate the development of the city; the coupling state between urban competitiveness and ecological environment thoroughly embodies the harmony degree of the city, and is an objective method to evaluate the ecological construction in the city. This paper probes into the coupling rule between urban competitiveness and ecological environment, so as to judge the harmony degree of urban environment development and provide rational reference for the harmonious development of city.

2. Interactive coercing and restricting effect between ecological environment and city

Urban system and ecological environment system are the two subsystems of the huge human-earth system. The environmental quality of certain urban region is determined by the quantity of contaminations; the units of the city will continuously divide, proliferate, develop, consume energy and discharge wastes that will influence the environmental quality, after getting the information about pollution degree, the decision-making department will regulate the human activity and pollution control through policy and market mechanism, accordingly realize the balance between city and ecological environment.

Urban economic development menaces the environment: more resources and energy were consumed to increase economic aggregate, which will lead to the change of industrial structure and the manner to act on ecological environment; the change of enterprise scale and land occupation will increase the spatial pressure of ecological environment. In the process mentioned above, there is behavior that will increase the pressure of ecological environment; also there is regulation that will reduce the pressure. The economic development will introduce more environmental protection investment, while the policy interference and the popularization of cleaning technology will reduce the total amount of environmental pollutant and the environmental pressure. The menace of economic development on ecological environment is the result of the mutual interaction of the above two reverse forces.

The comfort degree of the city influences the float of human resource. In the modern world, people are paying more and

more attention to the ecological environment around their house. The residents' pursuit of beautiful environment is the main driving power for the large city to extend to the circumjacent region. The deterioration of ecological environment will lead to the effect of "bad money drives out good money" (Huang, et al., 2003), the high-quality residents will be "banished" out of the city, accordingly the lost of technology and capital will induce the recession of the city and change the spatial structure of urban area.

3. Probing into the coupling rule between ecological environment and urban competitiveness basing on the dissipative structure principle

There is certain evolvement rule between the city development and environment development. According to the ergodic hypothesis, in a sufficiently large space, the development of the same region at different periods of time (time series) can be identified by the development of different regions at the same period of time (spatial spectrum) (Yang, et al., 2003). If the time is long enough and the space is large enough, the mutual interaction between city and ecological environment will show a dynamic alternant time and space variation. Hence, the mutual interaction rule between ecological environment and urban competitiveness could theoretically be revealed through the relationship between city evolvement and ecological environment and the relationship between economic development and ecological environment (Yang, et al., 2003).

The development of urban competitiveness and the evolvement track of ecological environment could be characterized by dissipative structure entropy change equation. "Dissipation" is a common concept in physics, which means the process of energy transformation from high efficacy energy to low efficacy energy. Dissipative structure is an ordered structure status of system in the nonlinear balance: an open system far from equilibrium state exchanges substance, energy and information with the external world, the various factors in the system form a ordered status in the aspect of time, space and function when there is complex nonlinear effect between the factors. "Entropy" indicates the chaotic degree of system, if the entropy is larger, the system will be more chaotic. Urban ecological system satisfies condition of dissipative structure: firstly, urban ecological system is an open large system, the city is based on the environment and exchange substance, energy, information, capital and population with the environment; secondly, urban ecological system is far from equilibrium state, in which various factors are equal, single, chaotic and are in unordered state, it is obviously that urban ecological system keeps orderly in the aspects of time, space and function, the relationship between the internal factors of urban ecological system and the subsystems is nonlinear, for example, the population grows nonlinearly, there are nonlinear feed forward multiplier effect and feed back saturation effect among the industries and departments of the city; thirdly, the urban ecological system is continuously influenced by the external world and produces numerable "small fluctuation", which will make the urban ecological system deviate from equilibrium state, when the influence of fluctuation accumulates to a certain degree, urban ecological system will produce "giant fluctuation", city will transit from the present state to more ordered state, and form a new dissipative structure, and accordingly promote the development of urban ecological system. It can be seen that as a typical dissipative structure, ecological system will surely keep to the rules of dissipative structure; the development trend of urban system will be essentially understood if the urban development rule is studied in accordance with the characteristic of dissipative structure.

The entropy change of the city includes two parts: $ds = d_i s + d_e s$ (1)

$d_e s$ means the entropy change induced by the inflow and outflow of substance and energy when the urban ecological system communicates with the external world, it is termed as systematic entropy change; $d_i s$ is the entropy change in the inner process of system, it is termed as entropy production. According the dissipative structure principle, $d_i s$ must be greater than zero, while $d_e s$ can be positive or negative. For an open system, if the ds is to be less than zero, $d_e s$ should be less than zero, and satisfies the condition: $|d_e s| > |d_i s|$, the system will be more ordered when the entropy decreases. The entropy of system is alterable (Cao, 1998), which can be ratiocinated by the following methods: firstly, the entropy production $d_i s$ and entropy flow $d_e s$ should be calculated, then the entropy change of system ds can be calculated according to the formula (1), if $ds < 0$, the entropy flow into the ecological system is larger than the entropy production of the ecological system itself, the urban ecological system will develop toward the ordered direction and be in a "growing" state; if $ds > 0$, the entropy flow into the ecological system is smaller than the entropy production of the ecological system itself, the urban ecological system will develop toward the chaotic equilibrium state and decline; if $ds = 0$, the entropy production equals to the entropy flow of the system, the system is in temporal "equilibrium" state. Different measures can be taken according to the different states of the system to make the system develop toward the direction that is propitious to the human society.

According to the characteristic of urban system, the industry, finance, insurance, foreign trade and architecture are the entropy flow of urban ecological system. The city mainly communicates with the external world through those channels. City takes in the raw material and labor force that contain much low quality energy and produces products that contain

much high-quality energy, and discharges waste that contain low quality energy to the environment, there is a entropy flow between the system and external environment, the function of which is to lower the entropy of the system. Entropy flow means the input and output of ecosystem, it embodies the exchange capacity between the system and the external world. If the absolute value of entropy flow is larger, the output of system will be larger when the inputs are the same, and the function of system will be stronger. Other industries, such as road, city planning, infrastructure, education and environmental protection, are to maintain the normal running of system, they have no direct profits and are entropy increase processes, so investment should be carried out in these projects to counteract the entropy production, and the investment can be taken as the reference to calculate the entropy production of the system, larger investment ratio means larger entropy production of the system (Wu, et al., 2000).

4. Classification of the coupling models between urban competitiveness and ecological environment

Urban competitiveness, ecological environment development and the coupling system between urban competitiveness and ecological environment are set as $d_{c,s}$, $d_{s,s}$, and $d_{c-s,s}$. According to the definition and characteristic of d_s , both $d_{c,s}$ and $d_{s,s}$ have three entropy change trajectories, by combining the evolvement trajectories of city and ecological environment, five kinds of coupling model are put forward, and each kind contains several similar ones as shown in table 1.

4.1 Coupling coordination model

It includes type B, if $d_{c,s} < 0$ and $d_{s,s} < 0$, the $d_{c-s,s} < 0$, that is to say, urbanization and ecological environment development bring out the best in each other, they will become more and more ordered. Coupling coordination model is the ideal model for the development of urbanization and ecological environment.

4.2 Basic coordinating model

It includes type A, C and type M, J. Type A, C means that the urbanization or ecological environment develops orderly and both of them are in equilibrium state, the coupling system between urbanization and ecological environment tends to become ordered. Type M, J means that the urbanization or ecological environment degenerated to a certain extent, but they develop orderly and the coupling system between urbanization and ecological environment still tends to become ordered.

4.3 Conflicting model

It includes type H and K. When $d_{s,s} > 0$, $d_{c,s} < 0$ or $d_{s,s} > 0$, $d_{c,s} > 0$, the $d_{c-s,s} > 0$, indicating that the urbanization develops orderly but the ecological environment tends to become chaotically, or the urbanization tends to become chaotically but the ecological environment develops orderly, generally, the coupling system tends to recession. This kind of coupling model can only exist for a short period of time, or else, the urbanization and ecological environment system will break down.

4.4 Coupling recession model

In this model, $d_{c-s,s} > 0$, and it includes type E, F and G. The type G ($d_{c,s} > 0$, $d_{s,s} > 0$) shows strongest conflict, in which the urbanization develops chaotically and the ecological environment tends to become chaotically. This kind of model leads to the breakdown of system easily.

4.5 Critical model

In this model, $d_{c-s,s} = 0$, and it includes type D, I and L. This is the "threshold" for the coordination or conflict of coupling. It includes positive mutation (from conflict to coordination, usually happens at the high-level stage of urbanization) and negative mutation (from coordination to conflict, usually happens at the preliminary stage of urbanization).

5. Mathematical analysis on the coupling between ecological environment and urban competitiveness

Commoner (1991), an economist, put forward the famous environmental quality equation (IPAT), he thinks that the population scale, economy scale and technological progress determine the contaminations produced by human, to reduce the contaminations or keep the total amount constant, the broad sense technological progress should be equal to or exceed the economic growth speed (Wu, et al., 2000). The relationship between economy and ecological environment development can be shown with environment Kuznets curve in inverse "U" (EKC), which exhibits the characteristic of mutual development of economy and environment. At the beginning of modern economy, resource-intensive industry that severely polluted the environment took the dominant position, people paid little attention to the environment, and there was little cleaning technology, the environmental pollution became more and more severe with the development of economy; after a period of time, knowledge intensive industry and cleaning technology were developed and popularized, environmental pollution was gradually alleviated. Basing on the data from 157 countries in 1977, Zhou Yixing, a Chinese scholar, put forward that the relationship between urbanization and economic growth could be expressed with logarithmic curve, on the basis that proportion of urban population

represented the urbanization level, and the per capita GDP represented the economic development level (Zhou, 1995; Xu and Zhu 1988).

The coupling relation curve between urbanization and ecological environment is the logic combination of environment Kuznets curve and logarithmic curve (Huang, et al., 2003). According to algebra and geometry, the formula $z = m - a[10^{\frac{y+b}{a}} - p]^2$ (2) can be deduced, in which z is the ecological environment index, Y is the urbanization level, m is the ecological environment threshold, a , b , P are non negative parameters. The coupling rule between urbanization and ecological environment can be qualitatively analyzed in accordance with the formula (2): when $10^{\frac{y+b}{a}} < p$, ecological environment will gradually deteriorate with the development of urbanization; when $10^{\frac{y+b}{a}} = p$, the deterioration of ecological environment will achieve critical threshold; when $10^{\frac{y+b}{a}} > p$, ecological environment will gradually improve with the development of urbanization.

With the development of urbanization, more contaminations will be discharged, the change of pollutant quantity can be reflected with exponential function $z = \alpha e^{\delta t}$, and the GDP growth in a period of time can be expressed with exponential function $x = \beta e^{\theta t}$ (α , β , δ , θ are constants, t is time), the environmental pressure function will be $p = \alpha \beta e^{(\delta+\theta)t}$ ($\delta < 0, \theta > 0$), δ means the enhancement of people's consciousness to protect the environment, the optimization of industrial structure and the improvement of technology, so it is negative; θ is positive. If $\delta + \theta > 0$, the environmental pollutant quantity will increase with the high-speed development of economy, and the environmental pressure will be increased; if $\delta + \theta = 0$, environmental pollutant quantity will keep constant, and the environmental pressure will be stable; if $\delta + \theta < 0$, environmental pollutant quantity will decrease with the development of economy, and the environmental pressure will be decreased (Liu and Li, 2006). Hence, the precondition to realize the environment Kuznets curve in inverse "U" is $\delta + \theta < 0$, δ and θ can be controlled, the shape of environment Kuznets curve in a short period of time depends on the influence of human activities, if the human activity is friendly to environment, the turning point of environment Kuznets curve will present itself early.

6. Conclusion

There is a certain rule in the development of urban environment, the coordinated development of city demands that subsystems of the city don't damage each other. The shape of environment Kuznets curve depends on the amicability degree of human activity to a great extent, man-made amicable environmental behavior and the implicit technological progress are of great significance for coordinating the urban development, accelerating urbanization and improving the urban competitiveness.

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Table 1. The coupling models between city and ecological environment

coupling models	$d_{c-s} > 0$	$d_{c-s} = 0$	$d_{c-s} < 0$
$d_s > 0$	$G(d_{c-s} > 0)$	$F(d_{c-s} > 0)$	H, I, J
$d_s = 0$	$E(d_{c-s} > 0)$	$D(d_{c-s} > 0)$	$A(d_{c-s} < 0)$
$d_s < 0$	K, L, M	$C(d_{c-s} < 0)$	$B(d_{c-s} < 0)$

H, K: $d_{c-s} > 0$; I, L: $d_{c-s} = 0$; M, J: $d_{c-s} < 0$