Research on the Relationship of Symbiotic Subject in Urban Energy Saving Innovation Ecosystem

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Abstract: As an important space carrier of sustainable development of human settlements, cities are the basic regional units to promote energy saving innovation, improve energy efficiency and reduce emissions. It is very important to promote the process of urban sustainable development. On the basis of literature review, the government and energy saving enterprises are identified as the symbiotic subjects of urban energy saving innovation ecosystem. Based on logistic equation, this paper constructs a dual agent symbiosis model of urban energy saving innovation ecosystem. The simulation results show that the positive and negative of the symbiosis coefficient is an important parameter affecting the results of symbiosis equilibrium on urban energy saving innovation ecosystem. When the symbiosis coefficient is negative, the coordination and promotion between symbiotic subjects is greater than competition and competition, which makes the existing resources meet the needs of more symbiotic subjects to participate in urban energy saving.

1. Introduction
The essence of the development of urban energy saving innovation ecosystem is the symbiotic relationship between the symbiotic subjects. Symbiosis is the relationship between symbiotic units in a certain symbiotic environment in accordance with a certain symbiotic model. Therefore, the government and energy saving enterprises are the symbiotic unit of urban energy saving innovation ecosystem, that is, the symbiotic subject of urban energy saving innovation ecosystem, and the basic unit of energy saving activities or behaviors and energy saving information resource exchange. There is obvious complementary resources between government and energy-saving enterprises, which is the premise and foundation of symbiosis relationship [1].

The symbiotic relationship between the symbiotic units of government and energy-saving enterprises is the symbiotic mode of urban energy saving innovation ecosystem [2]. It reflects the way that the government and energy-saving enterprises combine each other, and also reflects the characteristics of their energy saving activities or behaviors and the exchange of energy saving information resources [3]. From the purpose of energy saving, government and energy-saving enterprises is to serve the symbiotic relationship of urban energy saving innovation ecosystem.
2. Literature Review
Symbiotic relationship expresses a certain degree of biological permanence [4]. Symbiosis research mainly focuses on the government and enterprises, mainly manifested in the increasingly close relationship marketing between business and politics [5], which stimulates, promotes and cultivates the symbiotic relationship environment [6]. Enterprises can achieve coexistence and symbiosis through the relationships of cooperation and competition [7]. The industrial cluster centered on large enterprises promotes the formation of symbiotic relationship between large and small enterprises [8]. Industrial symbiosis is an innovative way to sustainable development, while the long-term prosperous enterprises with flexibility and sustainability are in symbiosis [9]. Information ecology applies the ecological principles of balance, opportunism, symbiosis and ecological inheritance to information economy [10]. There is knowledge symbiosis between social economics and institutional economics, which makes their advantages and disadvantages complementary [11]. Various symbiotic processes in biology can guide actions in the social environment, which makes them applicable to the social stage [12].

Throughout the existing research results, it is found that the research on innovation ecosystem symbiosis involves many scenarios, and each scenario has both commonness and difference. At present, the urban energy saving innovation ecosystem has a significant impact on promoting urban energy conservation and improving environmental protection, which has also been widely concerned by scholars and industry. Therefore, it is of great theoretical value and practical significance to carry out the symbiosis research of urban energy saving innovation ecosystem.

3. Construction of Dual Agent Development Model of Urban Energy Saving Innovation Ecosystem
The growth and development of symbiotic agents in innovation ecosystem is consistent with the development model of symbiotic agents determined by ecological population logistic equation. As shown in equation (1).

\[
\begin{align*}
\frac{dx}{dt} &= rx \left(1 - \frac{x}{x_m}\right) = f(x, r) \\
x(0) &= x_0
\end{align*}
\]

(1)

It is assumed that there are only two symbiotic subjects in the urban energy saving innovation ecosystem, and their growth and development follow the logistic equation.

\(x_1(t)\) and \(x_2(t)\) are the current actual scale of two symbiotic subjects in the urban energy saving innovation ecosystem. \(r_1\) and \(r_2\) are the inherent growth rates of two symbiotic subjects in the urban energy saving innovation ecosystem. \(N_1\) and \(N_2\) are the maximum potential scale of growth and development of two symbiotic subjects alone in the urban energy saving innovation ecosystem.

For symbiotic subject 1, as shown in equation (2).

\[
\frac{dx_1}{dt} = r_1 x_1 \left(1 - \frac{x_1}{N_1}\right)
\]

(2)

\(1 - x_1 / N_1\) refers to the blocking effect on consumption of limited energy saving resources by symbiotic subject 1 in the urban energy saving innovation ecosystem for its own scale growth in energy-saving. \(x_1 / N_1\) represents the percentage of energy saving resources consumed by the symbiosis subject 1 in the urban energy saving innovation ecosystem.

For symbiotic subject 2, as shown in equation (2).

\[
\frac{dx_2}{dt} = r_2 x_2 \left(1 - \frac{x_2}{N_2}\right)
\]

(3)
\( \left(1 - \frac{x_2}{N_2}\right) \) refers to the blocking effect on consumption of limited energy saving resources by symbiotic subject 2 in the urban energy saving innovation ecosystem for its own scale growth in energy-saving. \( \frac{x_2}{N_2} \) represents the percentage of energy saving resources consumed by the symbiosis subject 2 in the urban energy saving innovation ecosystem.

Therefore, the symbiosis effect \( b_1 \) of urban energy saving innovation ecosystem symbiosis subject 1 is obviously directly proportional to the current actual scale number and inversely proportional to the maximum potential scale number of symbiosis subject 2. The development model equation of symbiosis subject 1 of urban energy saving innovation ecosystem is shown in equation (4).

\[
\frac{dx_1}{dt} = r_1 x_1 \left(1 - \frac{x_1}{N_1} - b_1 \frac{x_2}{N_2}\right) = f_1(x_1, x_2)
\]  

(4)

Similarly, the symbiosis effect \( b_2 \) of urban energy saving innovation ecosystem symbiosis subject 2 is obviously directly proportional to the current actual scale number and inversely proportional to the maximum potential scale number of symbiosis subject 2. The development model equation of symbiosis subject 2 of urban energy saving innovation ecosystem is shown in equation (5).

\[
\frac{dx_2}{dt} = r_2 x_2 \left(1 - \frac{x_2}{N_2} - b_2 \frac{x_1}{N_1}\right) = f_2(x_1, x_2)
\]

(5)

The interaction and symbiosis mechanism relationship between the symbiotic agents of urban energy saving innovation ecosystem, that is, the symbiotic development model of urban energy saving innovation ecosystem with the purpose of energy saving is shown in equation (6).

\[
\begin{align*}
\frac{dx_1}{dt} &= r_1 x_1 \left(1 - \frac{x_1}{N_1} - b_1 \frac{x_2}{N_2}\right) = f_1(x_1, x_2) \\
\frac{dx_2}{dt} &= r_2 x_2 \left(1 - \frac{x_2}{N_2} - b_2 \frac{x_1}{N_1}\right) = f_2(x_1, x_2)
\end{align*}
\]

(6)

If \( f_1(x_1, x_2) = 0 \) and \( f_2(x_1, x_2) = 0 \), the four equilibrium states of equation (6) can be obtained. The results are as follows.

\[
\begin{align*}
E_1 &= \left(\frac{N_1 (1-b_1)}{1-b_1b_2}, \frac{N_2 (1-b_2)}{1-b_1b_2}\right), \quad E_2 = (0, 0), \quad E_3 = (N_1, 0), \quad E_4 = (0, N_2).
\end{align*}
\]

4. Simulation of Dual Agent Development Model of Urban Energy Saving Innovation Ecosystem

In the absence of a large number of time series data, numerical simulation becomes the most effective method. Generally speaking, there is no definite relationship between \( b_1 \) and \( b_2 \). For the convenience of discussion, we only discuss the case that \( b_1 \) and \( b_2 \) are independent of each other. Through the simulation of equation (4), the general law of symbiosis relationship between energy saving enterprises and government departments in urban energy saving innovation ecosystem is gained.

Suppose that \( x_1 \) and \( x_2 \) represent the current actual scale of energy saving enterprises and government departments in the urban energy saving innovation ecosystem. Suppose that \( N_1 \) and \( N_2 \) represent the largest potential scale of energy saving enterprises and government departments in the
urban energy saving innovation ecosystem. Suppose that \( r_1 = 0.04 \) and \( r_2 = 0.03 \) are the inherent growth rates of two symbiotic subjects in the urban energy saving innovation ecosystem. 400 and 2000 iterations were performed for observation and analysis, as shown in Figure 1.

If \( b_1 = -0.2 \) and \( b_2 = -0.4 \), figure 1 shows the simulation results of 400 and 2000 iterations for energy saving enterprises and government departments in the urban energy saving innovation ecosystem. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 1200 after 200 iterations. The scale numbers of government departments continued to rise, reaching a peak of 130 after 200 iterations.

If \( b_1 = 0.2 \) and \( b_2 = 0.4 \), figure 2 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 520 after 400 iterations. The scale numbers of government departments continued to rise, reaching a peak of 90 after 150 iterations.
If $b_1 = -0.2$ and $b_2 = 0.4$, figure 3 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 450 after 400 iterations. The scale numbers of government departments continued to rise, reaching a peak of 110 after 150 iterations.

If $b_1 = 0.2$ and $b_2 = -0.4$, figure 4 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 1100 after 200 iterations. The scale numbers of government departments continued to rise, reaching a peak of 80 after 100 iterations.
If $b_1 = 0$ and $b_2 = 0$, figure 5 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 800 after 250 iterations. The scale numbers of government departments continued to rise, reaching a peak of 100 after 180 iterations.

If $b_1 = 0$ and $b_2 = -0.4$, figure 6 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 1120 after 250 iterations. The scale numbers of government departments continued to rise, reaching a peak of 100 after 150 iterations.

If $b_1 = 0.2$ and $b_2 = 0$, figure 7 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises continued to rise, reaching a peak of 800 after 250 iterations. The scale numbers of government departments continued to rise, reaching a peak of 90 after 100 iterations.
Fig 8 Iterative simulation diagram of government and enterprise

If $b_1 = 1.2$ and $b_2 = 1.4$, figure 8 shows the simulation results of 400 and 2000 iterations. The scale numbers of energy saving enterprises increased first, reached a peak of 135 at 50 iterations, and then continued to decline, reaching 0 after 600 iterations. The scale numbers of government departments continued to rise, reaching a peak of 100 after 600 iterations.

5. Conclusion

Firstly, if $b_1 = b_2 = 0$, the dual symbiotic subjects of urban energy saving innovation ecosystem do not affect each other and coexist independently. Each of the dual symbiotic subjects reaches the maximum potential scale in energy saving development. The speed of energy saving development varies with its own growth rate in energy saving.

Secondly, if $b_1 = 0$ and $b_2 < 0$ (or $b_2 > 0$), $b_2 = 0$ and $b_1 < 0$ (or $b_1 > 0$), one of the symbiotic subjects of urban energy saving innovation ecosystem has reached its maximum potential scale in energy saving development. The scale of the other symbiotic subject of urban energy saving innovation ecosystem depends on the positive and negative of symbiosis coefficient $b$. When the coefficient $b$ is positive, the other symbiosis subject of urban energy saving innovation ecosystem will not reach its large potential scale. When the coefficient $b$ is negative, the other symbiosis subject of urban energy saving innovation ecosystem will exceed its large potential scale.

Thirdly, if $b_1 > 0$ and $b_2 < 0$ (or $b_1 < 0$ and $b_2 > 0$), one of the symbiotic subjects of urban energy saving innovation ecosystem will slightly break through its maximum potential scale in energy saving development. For the other symbiosis subject of urban energy saving innovation ecosystem, there will be a certain gap between the actual scale and its maximum potential scale.

Fourthly, if $b_1 < 0$ and $b_2 < 0$, the double symbiosis subject of urban energy saving innovation ecosystem will break through its maximum potential scale in energy saving development.

Fifthly, if $b_1 > 0$ and $b_2 > 0$, the double symbiosis subject of urban energy saving innovation ecosystem have failed to reach its maximum potential scale. If $b_1 > 1$ and $b_2 > 1$, one of the symbiotic subjects of the urban energy-saving innovation ecosystem will disappear first because the other one consumes more energy saving resources, while the other symbiotic subject can reach its maximum potential scale in energy saving development.

In a word, for the urban energy saving innovation ecosystem, if its symbiosis coefficient $b$ is zero, the symbiotic subject will lose its significance in the urban energy saving innovation ecosystem. Therefore, for urban energy saving innovation ecosystem, the positive and negative of symbiosis coefficient $b$ should be considered.
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