

Study on the Classification and Stability of Industry-University-Research Symbiosis Phenomenon: Based on the Logistic Model

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Abstract

The cooperation among industries, universities and research institutions is similar to the symbiotic cooperation of the individual organisms. This paper discussed the symbiotic relationship of the enterprises and the research institutions, constructed a logistic growth model of the symbiotic relationships, and divided the symbiotic relationships into equal-symbiosis, rely-symbiosis, dependence-symbiosis, and one-way-symbiosis. We found that different symbiotic relationships should be treated by different methods. The stable conditions of these four types of symbiotic relationship were proposed, and the results provided a theoretical guidance to choose the reasonable symbiosis models

Keywords: symbiosis phenomenon, industry-university-research cooperation, classification, stability, logistic model

INTRODUCTION

The cooperation of Industry-University-Research (Referred to as I.U.R.) refers to the economic and social activities that enterprises, universities and research institutions cooperate with each other by their complementary resources in the process of technological innovation (Feng et al., 2009). The cooperation in the Industry-University-Research becomes more and more important in the economic and social development (Fontana et al., 2006). Therefore, studying the way to promote the cooperation also becomes significant. Si Shangqi proposed that there was a symbiotic relationship between the research institutions and the enterprises in the cooperation of Industry-University-Research, and the Symbiotic Theory is a good perspective to study on the cooperation of Industry-University-Research (Si et al., 2009). Obviously, it gives us a new way of thinking of the relationship of the universities, the enterprises and the research institutions. In this paper we focused on the needs for the classification of the Industry-University-Research symbiosis phenomenon, and we also focused on the stability of each category. Firstly, elaborated how the universities, enterprises and the research institutions symbiose with each other. Secondly based on the Logistic Model, we divided the relationships into

three categories and analyzed the stability of each category. Finally, the results provided a theoretical guidance to choose the reasonable symbiosis models.

The Symbiotic Relationship of I.U.R. Cooperation

The concept of symbiosis first appeared in the field of biology which was proposed by a Germany biologist Anion De Bary in 1947. The symbiosis means two or more organisms form a symbiotic relationship of co-existence and co-evolution. The cooperation of the enterprises, the universities and the research institutions are strongly similar to the symbiotic relationship between the organisms. Kumar, N. first proposes that symbiotic relationship existed in the cooperation of universities and enterprises (Kumar, 1994). This paper argued that the cooperation relationship of I.U.R. was essentially symbiotic relationship. The universities and the research institutions show strong similarity in the cooperation with the enterprises, so this paper treated them as the same type called them the Research Institutions. In the cooperation, the enterprises can obtain technology or knowledge from the research institutions with which the enterprises can develop new products or improve productivity (Giuliania et al., 2009), and get more profits (Crespo, 2007). The research institutions can obtain funds from the

enterprises to develop more studies and promote self development. Additional, the talents cultured by the research institutions are just what the enterprises need, so the research institutions can culture more practical talents through joint training. The exchange of the talents and the funds (we can treat them as substance, information, and energy) form a symbiosis between the enterprises and the research institutions. The Figure 1 described the symbiotic relationship of the enterprises and the research institutions.

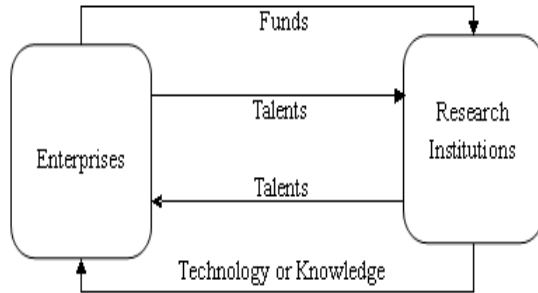


Figure 1 The Symbiotic Relationship of Enterprises and Research Institutions

Source: (SI Shangqi et al., 2009)

The Logistic Model

Logistic model was used to describe the discipline of population growth in the field of biology, and it also was used to describe the symbiotic relationship between populations. The cooperation of I.U.R is the symbiotic relationship, so we can use the Logistic model to describe the characteristics of the relationship of I.U.R.. In this model, we can simplify the change of the enterprises or the research institutions to the revenue and because of the symbiosis, the enterprises and the research institutions can obtain additional revenue.

We just consider one enterprise and one research institution. And we call the enterprise e , and the research institution r . $R_e(t)$ and $R_r(t)$ are the revenue of e and r at the time of t . N_e and N_r are the maximum of the revenue of the e and the r without the symbiotic relationship. We assume that they are constants, and the growth of the independent state obeys the law of Logistic model. η_e and η_r are the average growth rate of all the enterprises and all the research institutions and we also assume them to be constants. R/N represents the revenue ratio of the maximum in the independent state. We call it the natural growth saturation rate. So $(1 - R/N)$ represents the blocking effect to the revenue of the natural growth saturation rate under the given constraints. G_e is the contribution of the research institution's natural growth saturation rate to the growth of enterprise and G_r represents the contribution of the enterprise's natural growth

saturation rate to the growth of research institution. $Ge > 0$, $Gr > 0$. If $Ge > 1$, it means that the promotion of the research institution to the enterprise is bigger than the block effects of itself.

Through the Logistic Model, we can get the equation of the growth of the enterprise (1) and the equation of the growth of the research institution (2) in independent state (Guo et al., 2005).

$$\frac{dR_e(t)}{dt} = \eta_e R_e (1 - R_e / N_e) \quad (1)$$

$$\frac{dR_r(t)}{dt} = \eta_r R_r (1 - R_r / N_r) \quad (2)$$

Classifications and Stability Analysis of the I.U.R. Symbiosis

Based on the beneficial relationship and the dependent degree of the enterprise and the research institution, we can divide the relationship of symbiotic into four types called equal-symbiosis, rely-symbiosis, dependence-symbiosis and one-way-symbiosis. We analyzed the conditions of the steady state of each type of symbiotic relationship in the following paragraphs.

The Type of Equal-Symbiosis

The equal-symbiosis means that the enterprise and the research institution in the symbiotic relationship can obtain revenue from the cooperation but either of them can be alive itself. This model is an ideal model of symbiosis, and it can relatively easy to form a stable state. As describe it in Figure 2, the white circle means the enterprise and the black circle means the research institution.



Figure 2 The equal-symbiosis relationship

Based on the discussion above, we can establish the model. We assume that the revenue growth of enterprise and the research institution obey the Logistic Model. When they reached a symbiotic relationship, they can both obtain additional revenue from the symbiosis, so we can add one formula in the factor of $(1 - R/N)$, and the formula is proportional to the revenue natural growth saturation. The equations of symbiotic state are like these: (Wang et al., 2007).

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e R_e \left(1 - \frac{R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) \\ \frac{dR_r(t)}{dt} = \eta_r R_r \left(1 - \frac{R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right) \end{cases} \quad (3)$$

The equation (3) is autonomous nonlinear, so we used the linear approach to discuss the stability of the equilibrium point. Assumed that:

$$\begin{cases} f(R_e, R_r) \equiv \frac{dR_e(t)}{dt} = \eta_e R_e \left(1 - \frac{R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) = 0 \\ g(R_e, R_r) \equiv \frac{dR_r(t)}{dt} = \eta_r R_r \left(1 - \frac{R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right) = 0 \end{cases} \quad (4)$$

The solution of equation (4) is the equilibrium point of (3). We can find the solution of (4) is $Q_1\left(\frac{N_e(1+\varphi_e)}{1-\varphi_e\varphi_r}, \frac{N_r(1+\varphi_r)}{1-\varphi_e\varphi_r}\right), Q_2(0,0)$. Then we

unfold the equation (3) at the point $P(R_e^0, R_r^0)$ for the Taylor Progression and omitted the second power and the above items, then we can get:

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e \left(1 - \frac{2R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) (R_e - R_e^0) + \eta_e \varphi_e \frac{R_e}{N_r} (R_r - R_r^0) \\ \frac{dR_r(t)}{dt} = \eta_r \left(1 - \frac{2R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right) (R_r - R_r^0) + \eta_r \varphi_r \frac{R_r}{N_e} (R_e - R_e^0) \end{cases} \quad (5)$$

So the coefficient matrix is like this:

$$M = \begin{bmatrix} \eta_e \left(1 - \frac{2R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right), & \eta_e \varphi_e \frac{R_e}{N_r} \\ \eta_r \left(1 - \frac{2R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right), & \eta_r \varphi_r \frac{R_r}{N_e} \end{bmatrix}$$

We put Q_1 and Q_2 into M , we find that $Q_2(0,0)$ is unstable equilibrium point. The condition of Q_1 to be stable equilibrium is $\varphi_e\varphi_r < 1$. Since that the enterprise and the research institution in the cooperation are symmetric, so the stable condition can be change into $\varphi_e < 1, \varphi_r < 1$. In the state of stable equilibrium, the revenue of the enterprise and the research institution are $\frac{N_e(1+\varphi_e)}{1-\varphi_e\varphi_r} > N_e, \frac{N_r(1+\varphi_r)}{1-\varphi_e\varphi_r} > N_r$. And it shows that both of the enterprise and the research institution can achieve more revenue than operating themselves.

The Type of Rely-Symbiosis

The rely-symbiosis means that the enterprise and the research institution in the symbiotic relationship rely on each other. If the symbiotic relationship is interrupted, the revenue of other one will reduce and close to 0. So we can describe the relationship in Figure 3. The revenue of the enterprise can be list as

$$\frac{dR_e(t)}{dt} = -\eta_e R_e, \text{ and the revenue for the research}$$

institution can be list as $\frac{dR_r(t)}{dt} = -\eta_r R_r$. They both

obtain the symbiotic revenue and is hindered by themselves. So we must add one item and subtract one item, which have relationships with the natural saturation of the enterprise and the research institution.

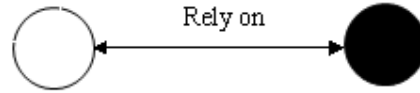


Figure 3 The rely-symbiosis relationship
We can list:

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e R_e \left(-1 - \frac{R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) \\ \frac{dR_r(t)}{dt} = \eta_r R_r \left(-1 - \frac{R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right) \end{cases} \quad (6)$$

We can solve it similar to the way of 4.1. and the equilibrium point are

$$Q_1\left(\frac{N_e(1+\varphi_e)}{\varphi_e\varphi_r-1}, \frac{N_r(1+\varphi_r)}{\varphi_e\varphi_r-1}\right), Q_2(0,0). \text{ Then we}$$

unfold the equation(6) at the point $P(R_e^0, R_r^0)$ for the Taylor Progression and omitted the second power and the above items, then we can get:

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e \left(-1 - \frac{2R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) (R_e - R_e^0) + \eta_e \varphi_e \frac{R_e}{N_r} (R_r - R_r^0) \\ \frac{dR_r(t)}{dt} = \eta_r \left(-1 - \frac{2R_r}{N_r} + \varphi_r \frac{R_e}{N_e}\right) (R_r - R_r^0) + \eta_r \varphi_r \frac{R_r}{N_e} (R_e - R_e^0) \end{cases} \quad (7)$$

According to the Stability theory of differential equations (Jiang, 1993), we know that Q_1 is unstable equilibrium point, and the Q_2 is always stable equilibrium point in any case.

The Type of Dependence-Symbiosis

If the symbiotic relationship has a core unit, and other units rely on the core one, then we call the model dependence-symbiosis. The core unit can be an enterprise or a research institution. In general, the size of the core unit is much larger than the satellite unit. The core units always have a function of management and coordination, and the satellite units are normally subjected to the core unit. We assumed that the enterprise was the core unit, and the research institution is the satellite unit. If the research institution is the core unit, the analysis is similar. Then we can use Figure 4 to describe it.



Figure 4: The dependence-symbiosis relationship

Before the symbiotic relationship appears, the revenue of the enterprise obeys the Logistic Model. When the symbiotic relationship has formed, the research institution will promote the growth of the enterprise. So we have:

$$\frac{dR_e(t)}{dt} = \eta_e R_e \left(1 - \frac{R_e}{N_e} + \varphi_e \frac{R_r}{N_r}\right) \quad (8)$$

To the research institution relied on the core unit, it operates independently, and has declining revenue and the revenue is close to 0. So the revenue for the research institution can be described as

$$\frac{dR_r(t)}{dt} = -\eta_2 R_2. \text{The enterprise will also promote}$$

the revenue of the research institution, and the research institution has impediment to itself. So we have the revenue of the research institution:

$$\frac{dR_r(t)}{dt} = \eta_r R_r \left(-1 - \frac{R_r}{N_r} + \varphi_r \frac{R_e}{N_e} \right) \quad (9)$$

We can solve it similar to the way of 4.1., and we will get the equilibrium point are

$$Q_1 \left(\frac{N_e(1-\varphi_e)}{1-\varphi_e\varphi_r}, \frac{N_r(-1+\varphi_r)}{1-\varphi_e\varphi_r} \right), Q_2(0,0). \text{Then we}$$

unfold the equation (8) and (9) at the point $P(R_e^0, R_r^0)$ for the Taylor Progression and omitted the second power and the above items. Then we can get:

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e \left(1 - \frac{2R_e}{N_e} + \varphi_e \frac{R_r}{N_r} \right) (R_e - R_e^0) + \eta_e \varphi_e \frac{R_e}{N_r} (R_r - R_r^0) \\ \frac{dR_r(t)}{dt} = \eta_r \left(-1 - \frac{2R_r}{N_r} + \varphi_r \frac{R_e}{N_e} \right) (R_r - R_r^0) + \eta_r \varphi_r \frac{R_r}{N_e} (R_e - R_e^0) \end{cases} \quad (10)$$

According to the Stability theory of differential equations (Jiang, 1993), we know that Q_2 is unstable equilibrium point, and the condition of Q_2 to be stable equilibrium point is $\varphi_e < 1, \varphi_r > 1, \varphi_e\varphi_r < 1$, which means no matter how the initial condition is, if the promotion to the enterprise of the research institution is not large ($\varphi_e < 1$), the promotion to the research institution of the enterprise is quite large ($\varphi_r > 1$), and φ_e is quite small and φ_r is quite big ($\varphi_e\varphi_r < 1$), then the symbiotic relationship is stable.

The Type of One-Way-Symbiosis

The one-way-symbiosis means that only one unit can obtain revenue from the symbiotic relationship. It can be the enterprise or the research institution. This is relatively rare. We can use Figure 5 to describe the situation.



Figure 5 The one-way-symbiosis relationship

We assume that the research institution can obtain additional revenue from the enterprise but the enterprise cannot obtain additional revenue from the symbiotic relationship. If the profitable unit is the enterprise, the method is similar. So we can list the revenue of the enterprise:

$$\frac{dR_e(t)}{dt} = \eta_e R_e \left(1 - \frac{R_e}{N_e} \right) \quad (11)$$

The revenue of the research institution is:

$$\frac{dR_r(t)}{dt} = \eta_r R_r \left(1 - \frac{R_r}{N_r} + \varphi_r \frac{R_e}{N_e} \right) \quad (12)$$

We can solve it similar to the way of 4.1. and get the equilibrium point are

$$Q_1(N_e, N_r(1+\varphi_r)), Q_2(0,0). \text{Then we unfold the}$$

equation (11) and (12) at the point $P(R_e^0, R_r^0)$ for the Taylor Progression and omitted the second power and the above items. Then we can get:

$$\begin{cases} \frac{dR_e(t)}{dt} = \eta_e \left(1 - \frac{2R_e}{N_e} \right) (R_e - R_e^0) \\ \frac{dR_r(t)}{dt} = \eta_r \left(1 - \frac{2R_r}{N_r} + \varphi_r \frac{R_e}{N_e} \right) (R_r - R_r^0) + \eta_r \varphi_r \frac{R_r}{N_e} (R_e - R_e^0) \end{cases}$$

According to the Stability theory of differential equations (Jiang, 1993), we know that Q_2 is unstable equilibrium point. The condition of Q_2 to be stable equilibrium point is $\varphi_r > 0$. That means if $\varphi_r > 0$, then the symbiotic relationship is stable, and the revenue of the enterprise and the research institution is N_e and $(1+\varphi_r)N_r$.

CONCLUSIONS

The relationship of symbiosis can be divided into four types. The conditions of each type are different. The stable condition of the equal-symbiosis is that both the enterprise and the research institution do not contribute too much to the other side. The stable condition of the rely-symbiosis is very severe. So we do not recommend the enterprise and the research institution to form the rely-symbiosis relationship. The stable condition of the dependence-symbiosis needs the enterprise and the research institution must have a wide gap in size. The stable state is easy to reach in the one-way-symbiosis. The conclusions can guide cooperation among the industries, universities, research institutions to better promote the transformation and technology transfer.

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