Technology Transfer from MNCs to Host Country Enterprises: An In-depth Analysis Based on Game Theories

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The problem of MNCs' technology transfer is virtually the dynamic game problem between MNCs and host country enterprises. The paper introduces evolutionary game theory to the field of technology transfer. For the problem of technology transfer between MNCs and host country enterprises, Evolutionary game theory sets up the model of an evolutionary game according to host country enterprises whether they have research and development capability or not, and comparatively analyzes the equilibrium results. Finally, the paper draws a useful and enlightening conclusion.

INTRODUCTION

The problem of MNCs' technology transfer is virtually the game problem between MNCs and host country enterprises. Some experts have realized this point and have done some research: Das(1987) set up a game model between MNCs and host country enterprises in the 1980s. Wang and Blomstrom(1992) also created their game models to discuss the game problem between MNCs and host country enterprises. However, the methods that these experts used was the traditional game theory, which paid attention to the technology spillover effect. Chinese experts such as Longying Hu(2000) used the model of a cooperative game to prove that, under certain restrictions of the policy system environment, both sides of MNCs and host country enterprises who were in information asymmetry can establish the cooperation mechanism; and Yixun Zhang(2002) also used the same method to prove that both the MNCs and host country enterprises can gain maximum profits with cooperation between them.

Nevertheless, these experts hadn't paid attention to a more microcosmic, specific and realistic problem: both MNCs and host country enterprises had easy success and earned maximum profits, as long as they made sure which kind of host country enterprises with whom they should cooperate (viz: the MNCs should cooperate with which kind of host country enterprises, and host country enterprises should cooperate with which kind of MNCs).

THE BASIC HYPOTHESES OF THE EVOLUTIONARY GAME MODEL

The MNCs have two strategies to select on technology transfer after they enter the host country One is that the MNCs cooperate with host country enterprises and transfer the technology to them; another is that the MNCs establish their own companies, do not cooperate with host country enterprises, and, of course, do not transfer the technology to them. At the same time, the host enterprises also have two strategies to select. One is that the host country enterprises cooperate with MNCs and receive the technology; another is that the host country enterprises do not cooperate with MNCs and develop by themselves. When the MNCs decide whether to transfer the technology to host country enterprises or not, and the host country enterprises decide whether to cooperate with MNCs or not, wing to the fact that information is not complete, and that both sides (MNCs and host country enterprises) are all bounded rationally, both are playing a game which is a learning process and a dynamic process that is adjusted continually. This paper analyzes the initiative and evolutionary process and the evolutionarily stable strategy (ESS) of the MNCs and host country enterprises when they cooperate with each other. To analyze this process, the paper makes the following hypotheses concerning the evolutionary model:

Hypothesis 1. Pair wise game. Although one individual of two groups (MNCs and host enterprises) will face all other enterprises when he makes a decision, we can assume that the game is taking place between MNCs and host country enterprises.

Hypothesis 2. Approximate eye. When one of the MNCs changes its strategy, it always takes the distribution of recent strategy as a known condition, then transforms to one type of the best strategies corresponding to the recent strategy. Despite that large numbers of MNCs change strategies, it will make the strategy space and payoff function different from the original ones .

Hypothesis 3. Cooperative condition. In order to facilitate the following theoretical analysis, this paper assumes that the cooperation between host country enterprises and MNCs is based on technology transfer. That is, if the MNCs want to cooperate with host country enterprises, MNCs must transfer their technology to host country enterprises, otherwise, it is deemed to be uncooperative.

Hypothesis 4. Always find the cooperator. If only one group (MNCs or host country enterprises) wants to, it can find his cooperator in another group (MNCs or host country enterprises). According to different aspects such as technology level and profitability of different enterprises (MNCs or host country enterprises), we assume that MNCs can find the cooperators only if they are willing to transfer their technologies; meanwhile, host country enterprises can find the cooperators only if they are willing to cooperate with MNCs and receive their technologies.

Hypothesis 5. We assume that MNCs have not entered the host country and established companies, but is only ready to do, or, we assume that MNCs are not allowed to enter the host country using a sole proprietorship form of business organization.

THE EVOLUTIONARY GAME MODEL AND EVOLUTIONARILY STABLE STRATEGY ANALYSIS

When the MNCs and host country enterprises repeatedly play a dynamic game, the MNCs have two strategies to select (namely N=2): Strategy 1 The MNCs transfer their technologies to the host country (cooperate with host country enterprises), Strategy 2 The MNCs do not transfer their technologies to the host country (not cooperate with host country enterprises). The host country enterprises also have two strategies to select (namely N=2): Strategy 1 The host country enterprises cooperate with the MNCs, Strategy 2 The host country enterprises do not cooperate with the MNCs. We assume that the loss caused by technology spillover during technology transfer is $L_{1,}$ the cost needed by technology transfer is C_1 ; the cost needed by cooperation between host country enterprises and MNCs is C_2, the loss caused by decrease of market share in cooperation is L_2. We assume that the gross profits gained by cooperation between host country enterprises and MNCs is R, in which, the profits gained by the MNCs is βR (namely the proportion of both return on equity is β ： （1－β）), the profits gained by host country enterprises after cooperation with MNCs is （$1-\beta$）R. Moreover, the profits of the technology improvement caused by the host country enterprises' cooperation is R. These elements always directly impact the game payoff function.

When all of the MNCs have not entered the host countries but are ready to do, or the MNCs cannot enter the host countries using a sole proprietorship form of business organization, a situation is created which we will discuss accordingly.

The Host Country Enterprises Without Research and Development Capability

When the industry that the MNCs want to set up is a new one for a host country, and the host country has no related basic technologies and is indifferent to carry on independent research and development, the game payoff matrix is shown in table 1.

TABLE 1
THE GAME PAYOFF MATRIX BETWEEN HOST COUNTRY ENTERPRISES AND MNCS WITHOUT ENTRY(ENTERPRISES WITH NO R&D CAPABILITY)

1 \ 2		Host country enterprises	
		Cooperation	non- cooperation
MNCs	transfer	$\beta R-L_1-C_1$, $(1-\beta)R+r-C_2$	$\beta R-L_1-C_1$, 0
	Non-transfer	0, $(1-\beta)R+r-C_2$	0, 0

This paper assumes that P denotes the proportion of strategy 1 (transfer), and is adopted by MNCs, and q denotes strategy 1 (cooperation), and is adopted by host country enterprises. Therefore, one point (p, q) in the area of $S=[0, 1]\times[0, 1]$ is used to describe the state $s=\{(s_1^1, s_2^1), (s_1^2, s_2^2)\}=\{(p, 1-p), (q, 1-q)\}$, in which, $s_1^1=p$, $s_1^2=q$, thus, $s_2^1=1-p$, $s_2^2=1-q$. $r^1=(1, 0)$ denotes the strategy 1 (transfer) that MNCs select with probability 1, $r^2=(0, 1)$ denotes the strategy 2 (transfer) that MNCs select with probability 2. For MNCs, we can know from table 1:

The strategy 1 (transfer) is adopted by MNCs, which fitness is:

$$f^1(r^1, s)=q(\beta R-L_1-C_1)+(1-q)(\beta R-L_1-C_1)$$

The fitness of adopting strategy 2 (non-transfer) is:

$$f^1(r^2,s)=q\times 0+(1-q)\times 0=0$$

Its average fitness is:

$$f^1(p,s)=pf^1(r^1,s)+(1-p)f^1(r^2,s)=p[q(\beta R-L_1-C_1)+(1-q)(\beta R-L_1-C_1)]$$

Similarly, for the host country enterprises, the strategy 1 (cooperation) is adopted by host country enterprises, whose fitness is:

$$f^2(r^1,s)=p[(1-\beta)R+r-C_2]+(1-p)[(1-\beta)R+r-C_2]$$

The fitness of adopting strategy 2 (non-transfer) is:

$$f^2(r^2,s)=p\times 0+(1-p)\times 0=0$$

Its average fitness is：

$$f^2(q,s)=qf^2(r^1,s)+(1-q)f^2(r^2,s)=q\{p[(1-\beta)R+r-C_2]+(1-p)[(1-\beta)R+r-C_2]\}$$

In evolutionary game theory, duplicators of populations are dynamically assumed to be : the growth rate of one strategy depends on its fitness, and the strategies that produce higher profits have higher growth rate. Therefore, according to Malthusian equation, the strategy 1 (transfer) is adopted by the MNCs, whose fitness $f^1(r^1, s)$ minus the average fitness $f^1(p, s)$ equals its growth rate $\dot{p}/p$, that is,

$$\dot{p}/p = f^1(r^1, s) - f^1(p, s)$$

thus, $$\dot{p} = p(1-p)(\beta R - L_1 - C_1) \qquad (1)$$

Similarly, we can know, the strategy 1 (transfer) is adopted by host country enterprises, whose growth rate is:

$$\dot{q}/q = f^2(r^1,s) - f^2(q,s)$$

That is, $$\dot{q} = q(1-q)[(1-\beta)R + r - C_2] \qquad (2)$$

A two-dimensional, dynamic and autonomous (not containing time *t*) system is made up of (1) and (2). According to the theory of differential equations, if (p_0, q_0) makes the right side of (1) and (2) be zero, so then we have equations

$$\begin{cases} p_0(1-p_0)(\beta R - L_1 - C_1)=0 \\ q_0(1-q_0)((1-\beta)R + r - C_2)=0 \end{cases}$$

Then (p_0, q_0) is the equilibrium point or singular point. Therefore, this autonomous system has four equilibrium points (singular point):

$E_1(0, 0)$、$E_2(0, 1)$、$E_3(1, 0)$、$E_4(1, 1)$

According to the method proposed by Friedman, if there is a population dynamic systematically described by the differential equation, its stability at the equilibrium point is obtained through a local stability analysis of the Jacobian matrix. The system is composed by equation (1) and (2), whose Jacobian matrix is:

$$J=\begin{bmatrix} \partial \dot{p}/\partial p & \partial \dot{p}/\partial q \\ \partial \dot{q}/\partial p & \partial \dot{q}/\partial q \end{bmatrix} = \begin{bmatrix} (1-2p)(\beta R - L_1 - C_1) & 0 \\ 0 & (1-2q)[(1-\beta)R + r - C_2) \end{bmatrix}$$

The determinant of the Jacobian matrix is:

$$\det J = (1-2p)(\beta R - L_1 - C_1)\,(1-2q)[(1-\beta)R + r - C_2]$$

The trace of the Jacobian matrix is:

$$\mathrm{tr}J = (1-2p)(\beta R - L_1 - C_1) + (1-2q)[(1-\beta)R + r - C_2]$$

TABLE 2
THE LOCAL STABILITY ANALYSIS OF THE EQUILIBRIUM POINT

equilibrium point	The determinant of Jacobian matrix: det*J*	The trace of Jacobian matrix: tr*J*
$E_1(0, 0)$	$(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2]$	$(\beta R - L_1 - C_1)+[(1-\beta)R + r - C_2]$
$E_2(0, 1)$	$-(\beta R - L_1 - C_1)(1-\beta)R + r - C_2]$	$(\beta R - L_1 - C_1)-[(1-\beta)R + r - C_2]$
$E_3(1, 0)$	$-(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2]$	$-(\beta R - L_1 - C_1)+[(1-\beta)R + r - C_2]$
$E_4(1, 1)$	$(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2]$	$-[\beta R - L_1 - C_1 + (1-\beta)R + r - C_2]$

Proposition 1 When $\beta R < L_1 + C_1$, $(1-\beta)R + r < C_2$, E_1（0，0）is a locally and asymptotically stable point, its evolutionary stable strategy (ESS) is (non-transfer, non-cooperation).

Proof: When $\beta R < L_1 + C_1$, $(1-\beta)R + r < C_2$, $(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2]>0$, and $(\beta R - L_1 - C_1) + [(1-\beta)R + r - C_2]<0$, that is, we can know from table 2 that det$J$>0, tr$J$<0, in the equilibrium point E_1（0，0）, now, the E_1（0，0）is the evolutionary stable strategy (ESS) of the system. And, when $\beta R < L_1 + C_1$, $(1-\beta)R + r < C_2$, we can know from the table 2 that E_4（1，1）is an unstable point of the system, and E_2（0，1）、E_3（1，0）are the saddle points of the system (table 3), thus, E_1（0，0）is the only ESS of system. (Completion of proof)

TABLE 3
THE LOCAL STABILITY ANALYSIS' RESULT SHOWING THE EQUILIBRIUM POINT OF PROPOSITION 1

equilibrium point	det$J$'s sign	tr$J$' sign	local stability
E_1（0，0）	+	—	ESS
E_2（0，1）	—	±	saddle point
E_3（1，0）	—	±	saddle point
E_4（1，1）	+	+	unstable point

The proposition shows that: When all the profits that the MNCs and host country enterprises gain through cooperation with each other do not reach a certain value（$\beta R < L_1 + C_1$, $(1-\beta)R + r < C_2$）, the MNCs and host country enterprises all trend to cooperate: the MNCs do not transfer the technologies to host country enterprises, and the host country enterprises do not cooperate with them.

Proposition 2 When $\beta R < L_1 + C_1$, $(1-\beta)R + r > C_2$, E_2（0，1）is locally and asymptotically stable point, so the evolutionary stable strategy (ESS) of the system is (transfer, non-transfer).

Proof: When $\beta R < L_1 + C_1$, $(1-\beta)R + r > C_2$, $-(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2]>0$, and $(\beta R - L_1 - C_1) - [(1-\beta)R + r - C_2]<0$, that is, we can know from table 2 that in equilibrium point E_2（0，1）, det$J$>0, tr$J$<0, through analyzing the stability of the equilibrium point, now, E_2（0，1）is the evolutionary stable strategy (ESS) of the system. In addition, we can know from Table 2 that E_3（1，0）is an unstable point of system, and E_1（0，0）, E_4（1，1）are the saddle points of system (table 4), so E_2（0，1）is the only ESS of system. (Completion of proof)

TABLE 4
THE LOCAL STABILITY ANALYSIS'S RESULT OF THE EQUILIBRIUM POINT OF PROPOSITION 2

equilibrium point	det*J*'s sign	tr*J*' sign	local stability
E_1（0，0）	—	±	saddle point
E_2（0，1）	+	—	ESS
E_3（1，0）	+	+	unstable point
E_4（1，1）	—	±	saddle point

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises is less than a certain value （$\beta R<L_1+C_1$）, the MNCs tend to not transfer the technologies; when the profits that the host country enterprises gain through cooperation with MNCs exceed the cost （（1－β）$R+r>C_2$）, the host country enterprises tend to cooperate with MNCs.

Proposition 3 when $\beta R>L_1+C_1$，（1－β）$R+r<C_2$， E_3（1，0）is the locally and asymptotically stable point, the evolutionary stable strategy (ESS) of system is (transfer, non-cooperation).

Proof: When $\beta R>L_1+C_1$，（1－β）$R+r<C_2$， －（$\beta R-L_1-C_1$）$[(1-\beta)R+r-C_2]>0$，and－（$\beta R-L_1-C_1$）$+[(1-\beta)R+r-C_2]<0$，that is, through stable analysis to the equilibrium point, we can know from table 2 that det$J$>0，tr$J$<0 in the equilibrium point E_3（1，0）. At this time, E_3（1，0）is the evolutionary stable strategy (ESS) of system. And this time, we can know from table 2 that E_2（0，1）is the unstable point of system, and E_1（0，0）、E_4（1，1）are the saddle points (table 5), so E_3（1，0）is the only evolutionary stable strategy (ESS) of the system. (Completion of proof)

TABLE 5
THE LOCAL STABILITY ANALYSIS' RESULT SHOWING THE EQUILIBRIUM POINT OF PROPOSITION 3

equilibrium point	det*J*'s sign	tr*J*' sign	local stability
E_1（0，0）	—	±	saddle point
E_2（0，1）	+	+	unstable point
E_3（1，0）	+	—	ESS
E_4（1，1）	—	±	saddle point

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises exceed a certain value （$\beta R<L_1+C_1$）, the MNCs tend to transfer the technologies; when the profits that the host country enterprises gain through cooperation with MNCs cannot reach the cost （（1－β）$R+r>C_2$）, the host country enterprises tend to not cooperate with MNCs.

Proposition 4: when $\beta R > L_1 + C_1$, $(1-\beta)R + r < C_2$, that is, when $R > L_1 + C_1 + C_2 - r$, $(L_1 + C_1)/R < \beta < (R + r - C_2)/R$, E_4 (1, 1) is locally and asymptotically stable, the evolutionary stable strategy (ESS) of system is (transfer, cooperation).

Proof: When $\beta R > L_1 + C_1$, $(1-\beta)R + r < C_2$, $(\beta R - L_1 - C_1)[(1-\beta)R + r - C_2] > 0$, and $-(\beta R - L_1 - C_1) + [(1-\beta)R + r - C_2] < 0$, that is, through stable analysis at the equilibrium point, we can know from table 2 that det$J$>0, tr$J$<0 in the equilibrium point E_3 (1, 0). At this time, E_4 (1, 1) is the evolutionary stable strategy (ESS) of the system. And this time, we can know from Table 2 that E_1 (0, 0) is the unstable point of the system, and E_2 (0, 1) 、E_3 (1, 0) are the saddle points (table 6), so E_4 (1, 1) is the only the evolutionary stable strategy (ESS) of the system. (Completion of proof)

TABLE 6
THE LOCAL STABILITY ANALYSIS' RESULT OF THE EQUILIBRIUM POINT OF PROPOSITION 4

equilibrium point	det$J$'s sign	tr$J$' sign	local stability
E_1 (0, 0)		+	unstable point
E_2 (0, 1)	—	±	saddle point
E_3 (1, 0)	—	±	saddle point
E_4 (1, 1)	+	—	ESS

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises exceed a certain value ($\beta R < L_1 + C_1$), the MNCs tend to transfer the technologies; when the profits that the host country enterprises gain through cooperation with MNCs exceed the cost ($(1-\beta)R + r > C_2$), the host country enterprises tend to cooperate with MNCs. Then they cooperate successfully; that is, they come to comprehensive co-operation.

The Host Country Enterprises with Research Capability

We now consider the situation when the industry that the MNCs want to set up is not a new one for the host country, and the host country has the related basic technologies, research and development capability and is ready or has been ready to carry on the independent research and development. We assume that profits are gained by host country enterprises that have research and development capability, and who do not cooperate with MNCs but whose activities are shown by R_{02}. The loss caused by decrease of market share in cooperation is L2.The host country enterprises cooperate with the MNCs that affect their independent research and development and lead to loss, and we assume this loss to be L_{21}, so the game payoff matrix is shown in table 7.

TABLE 7
THE GAME PAYOFF MATRIX OF HOST COUNTRY ENTERPRISES AND MNCS WHO DO NOT ENTER

1 \ 2		Host country enterprises: Cooperation	Host country enterprises: non- cooperation
MNCs	transfer	$\beta R - L_1 - C_1$, $R_{02} + (1-\beta)R + r - L_2 - L_{21} - C_2$	$\beta R - L_1 - C_1$, $R_{02} - L_2$
	non-transfer	0, $R_{02} + (1-\beta)R + r - L_2 - L_{21} - C_2$	0, R_{02}

At this time, the same to 2.1, we can know from the Malthusian's system of equations:

$$\dot{p} = p(1-p)\left(\beta R - L_1 - C_1\right) \quad (3)$$

$$\dot{q} = q(1-q)\left\{L_2 p + [(1-\beta)R + r - L_2 - L_{21} - C_2]\right\} \quad (4)$$

So there are four equilibrium points (singular point) in an automatic system:
E_1（0，0）、E_2（0，1）、E_3（1，0）、E_4（1，1）

And the corresponding Jacobian matrix is:

$$J=\begin{bmatrix} \partial \dot{p}/\partial p & \partial \dot{p}/\partial q \\ \partial \dot{q}/\partial p & \partial \dot{q}/\partial q \end{bmatrix}$$

$$=\begin{bmatrix} (1-2p)(\beta R - L_1 - C_1) & 0 \\ q(1-q)L_2 & (1-2q)\left\{ L_2 p + \left[(1-\beta)R + r - L_2 - L_{21} - C_2 \right] \right\} \end{bmatrix}$$

The determinant of the Jacobian matrix：

$$\det J = (1-2p)(\beta R - L_1 - C_1)\,(1-2q)[L_2 p + (1-\beta)R + r - L_2 - L_{21} - C_2]$$

The trace of the Jacobian matrix：

$$\mathrm{tr} J = (1-2p)(\beta R - L_1 - C_1) + (1-2q)[L_2 p + (1-\beta)R + r - L_2 - L_{21} - C_2]$$

TABLE 8
THE LOCAL STABILITY ANALYSIS OF THE EQUILIBRIUM POINT

equilibrium points	determinant of Jacobian matrix:detJ	trace of Jacobian matrix: trJ
E_1（0，0）	$(\beta R-L_1-C_1)\times(1-\beta)R+r-L_2-L_{21}-C_2$	$(\beta R-L_1-C_1)+(1-\beta)R+r-L_2-L_{21}-C_2$
E_2（0，1）	$-(\beta R-L_1-C_1)\times(1-\beta)R+r-L_2-L_{21}-C$	$(\beta R-L_1-C_1)-(1-\beta)R+r-L_2-L_{21}-C_2$
E_3（1，0）	$-(\beta R-L_1-C_1)\times(1-\beta)R+r-L_{21}-C_2$	$-(\beta R-L_1-C_1)+(1-\beta)R+r-L_{21}-C_2$
E_4（1，1）	$(\beta R-L_1-C_1)\times(1-\beta)R+r-L_{21}-C_2$	$-\{(\beta R-L_1-C_1)\times(1-\beta)R+r-L_{21}-C_2\}$

Proposition 5: When $\beta R>L_1+C_1$，（$1-\beta$）$R+r<C_2$, E_1（0，0）is locally and asymptotically stable, the evolutionary stable strategy (ESS) of the system is (non-transfer, non-cooperation).

Proof:

When $\beta R<L_1+C_1$，（$1-\beta$）$R+r<L_{21}+C_2$,（$\beta R-L_1-C_1$）$[(1-\beta)R+r-L_2-L_{21}-C_2]>0$, and（$\beta R-L_1-C_1$）+ $[(1-\beta)R+r-L_2-L_{21}-C_2]<0$，that is, $\det J>0$，$trJ<0$ in the equilibrium point E_1（0，0）. At this time, through stable analysis to the equilibrium point, we can know from table 8 that E_1（0，0）is the evolutionary stable strategy (ESS) of the system. And when $\beta R<L_1+C_1$，（$1-\beta$）$R+r<L_{21}+C_2$, we can know from table 8 that E_4（1，1）is the unstable point of the system, and E_2（0，1）、E_3（1，0）are the saddle points (table 9), so E_1（0，0）is the only the evolutionary stable strategy (ESS) of system. (Completion of proof)

TABLE 9
THE LOCAL STABILITY ANALYSIS RESULT SHOWING THE EQUILIBRIUM POINT OF PROPOSITION 5

equilibrium points	det$J$'s sign	tr$J$' sign	local stability
E_1（0，0）	+	－	ESS
E_2（0，1）	－	±	saddle point
E_3（1，0）	－	±	saddle point
E_4（1，1）	+	+	unstable point

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises cannot reach a certain value（$\beta R<L_1+C_1$,（$1-\beta$）$R+r>L_2+L_{21}+C_2$, no matter whether it is the MNCs or host country enterprises, they both tend to not cooperate: the MNCs do not transfer their technologies, and the host country enterprises do not cooperate with them.

Proposition 6 When $\beta R< L_1 + C_1$，（1－β）$R+r> L_2 + L_{21} + C_2$，E_2（0，1）is locally and asymptotically stable, the evolutionary stable strategy (ESS) of system is (non-transfer, non-cooperation).

Proof: When $\beta R< L_1 + C_1$，（1－β）$R+r > L_2 + L_{21} + C_2$， －（$\beta R - L_1 - C_1$）[$(1-\beta)R + r - L_2 - L_{21} - C_2$]>0, and（$\beta R - L_1 - C_1$）[$(1-\beta)R + r - L_2 - L_{21} - C_2$]<0，that is, det$J$>0，tr$J$<0 in the equilibrium point E_2（0，1）. At this time, through stable analysis to the equilibrium point, we can know from table 8 that E_2（0，1）is the evolutionary stable strategy (ESS) of the system. And when $\beta R< L_1 + C_1$，（1－β）$R+r< L_{21} + C_2$, we can know from table 8 that E_3（1，0）is the unstable point of the system, and E_1（0，0）、E_4（1，1）are the saddle points (table 10), so E_2（0，1）is the only evolutionary stable strategy (ESS) of the system. (Completion of proof)

TABLE 10
THE LOCAL STABILITY ANALYSIS RESULT OF THE EQUILIBRIUM POINT

equilibrium points	det$J$'s sign	tr$J$' sign	local stability
E_1（0，0）	－	±	saddle point
E_2（0，1）	+	－	ESS
E_3（1，0）	+	+	unstable point
E_4（1，1）	－	±	saddle point

The proposition shows that: When the profits that the MNCs gain through cooperation with host country enterprises is less than a certain value $\beta R< L_1 + C_1$, they tend to not transfer their technologies; when the profits that the host country enterprises gain through cooperation with MNCs exceed a certain value（1－β）$R+r> L_2 + L_{21} + C_2$, the host country enterprises tend to cooperate with the MNCs.

Proposition 7 when $\beta R< L_1 + C_1$，（1－β）$R+r> L_2 + L_{21} + C_2$，E_3（1，0）is locally and asymptotically stable, the evolutionary stable strategy (ESS) of the system is (transfer, non-cooperation).

Proof:When $\beta R > L_1 - C_1, (1-\beta)R + r < L_{21} + C_2, -(\beta R - L_1 - C_1) \times [(1-\beta)R + r - L_{21} - C_2] > 0$, and －（$\beta R - L_1 - C_1$）+[$(1-\beta)R + r - L_{21} - C_2$]<0，that is, det$J$>0，tr$J$<0 in the equilibrium point E_3（1，0）. At this time, through stable analysis to the equilibrium point, we can know from table 8 that E_3（1，0）is the evolutionary stable strategy *(ESS)* of the system. And when $\beta R< L_1 + C_1$，（1－β）$R+r< L_{21} + C_2$, we can know from table 8 that E_2（0，1）is the unstable point of the system, and E_1（0，0）、E_4（1，1）are the saddle points (table 11), so E_3（1，0）is the only the evolutionary stable strategy (ESS) of the system. (Completion of proof)

TABLE 11
THE LOCAL STABILITY ANALYSIS' RESULT SHOWING THE EQUILIBRIUM POINT OF PROPOSITION 7

equilibrium points	det*J*'s sign	tr*J*' sign	local stability
E_1（0，0）	−	±	saddle point
E_2（0，1）	+	+	unstable point
E_3（1，0）	+	−	ESS
E_4（1，1）	−	±	saddle point

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises exceed a certain value $\beta R<L_1+C_1$, they tend to transfer their technologies; when the profits that the host country enterprises gain through cooperation with the MNCs is less than a certain value（$1-\beta$）$R+r>L_2+L_{21}+C_2$, host country enterprises tend to cooperate with the MNCs.

Proposition 8 when $\beta R<L_1+C_1$，（$1-\beta$）$R+r>L_2+L_{21}+C_2$， that is, when $R>L_1+L_{21}+C_1+C_2-r$，$(L_1+C_1)/R<\beta<(R+r-L_{21}-C_2)/R$， E_4（1，1）is locally and asymptotically stable, the evolutionary stable strategy (ESS) of the system is (transfer, cooperation).

Proof: (1) When $\beta R>L_1+C_1$，$L_{21}+C_2<$（$1-\beta$）$R+r<L_2+L_{21}+C_2$，（$\beta R-L_1-C_1$）$[(1-\beta)R+r-L_{21}-C_2]>0$，and $-\{(\beta R-L_1-C_1)+[(1-\beta)R+r-L_{21}-C_2]\}<0$，that is, *detJ>0，trJ<0* in the equilibrium point E_4（1，1）. At this time, through stable analysis to the equilibrium point, we can know from table 8 that E_4（1，1）is the evolutionary stable strategy (ESS) of the system. And we can know from table 8 that E_2（0，1）is the unstable point of the system, and E_1（0，0）、E_3（1，0）are the saddle points (table 12), so E_4（1，1）is the only the evolutionary stable strategy (ESS) of system.

TABLE 12
THE LOCAL STABILITY ANALYSIS'S RESULT OF THE EQUILIBRIUM POINT OF PROPOSITION 8(1)

equilibrium points	det*J*'s sign	tr*J*' sign	local stability
E_1（0，0）	−	±	saddle point
E_2（0，1）	+	+	unstable point
E_3（1，0）	−	±	saddle point
E_4（1，1）	+	−	ESS

(2) when $\beta R < L_1 + C_1$，（1－β）$R+r > L_2 + L_{21} + C_2$， －（$\beta R - L_1 - C_1$）$[(1-\beta)R + r - L_2 - L_{21} - C_2]$>0，and（$\beta R - L_1 - C_1$）$[(1-\beta)R + r - L_2 - L_{21} - C_2]$<0, that is, *detJ>0，trJ<0* in the equilibrium point E_4（1，1）. At this time, we can know from table 8 that E_4（1，1） is the evolutionary stable strategy (ESS) of the system. And when $\beta R < L_1 + C_1$，（1－β）$R+r > L_{21} + C_2$, we can know from table 8 that E_4（1，1）is the unstable point of the system, and E_2（0，1）、E_3（1，0）are the saddle points (table 13), so E_4（1，1）is the only the evolutionary stable strategy (ESS) of the system. (Completion of proof)

TABLE 13
THE LOCAL STABILITY ANALYSIS' RESULT CONCERNING THE EQUILIBRIUM POINT OF PROPOSITION 8(2)

equilibrium points	det*J*'s sign	tr*J*' sign	local stability
E_1（0，0）	+	+	unstable point saddle
E_2（0，1）	－	±	point
E_3（1，0）	－	±	saddle point
E_4（1，1）	+	－	ESS

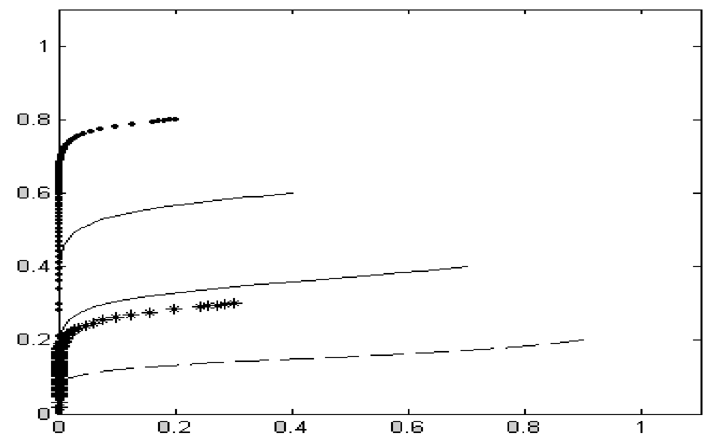
The proposition 8 was proved through summing up of (1) and (2).

The proposition shows that: When the profits that the MNCs gain through technology transfer with host country enterprises exceed a certain value $\beta R < L_1 + C_1$, they tend to transfer their technologies; when the profits that the host country enterprises gain through cooperation with the MNCs exceed a certain value（1－β）$R+r > L_2 + L_{21} + C_2$, the host country enterprises tend to cooperate with the MNCs. Then the MNCs cooperate with the host country enterprises successfully, namely, they come to Comprehensive cooperation.

THE DYNAMIC AND EVOLUTIONARY DIAGRAM OF GAMES BETWEEN MNCS AND HOST COUNTRY ENTERPRISES

The following is to further confirm the equilibrium point which has been confirmed and to show the evolutionary track from the different initial value point to the equilibrium point with the method of numerical simulation. This paper uses the MATLAB 7.0 software to make a numerical simulation analysis. The initial value is taken from [0.2，0.8]，[0.4，0.6]，[0.3，0.3]，[0.7，0.4]and [0.9，0.2]，time quantum is [0,100], Lateral Axis and longitudinal axis separately represents *p* and *q*, and in the space of [0，1]×[0，1], the dynamic evolutionary process is described from five different initial points to each equilibrium point.

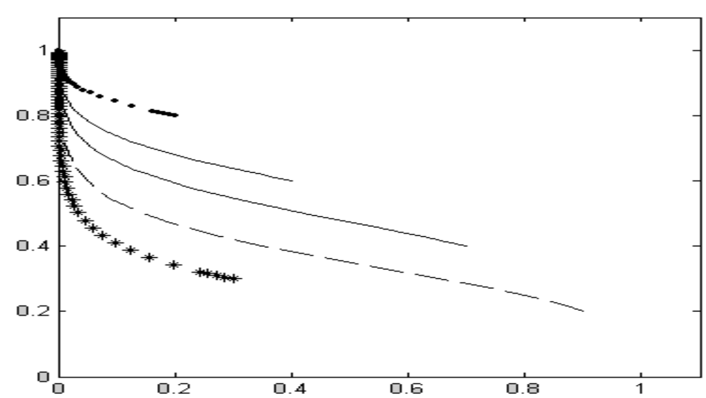
FIGURE 1
PROPOSITION 1 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 55；R=2. 1；r=0. 3；L_1=2；C_1=1；C_2=1. 5

The figure shows that, given the proportion *p* of technology transfer strategy that is adopted by the MNCs and given the proportion *q* of cooperation strategy that is adopted by the host country enterprises, their different initial value point[*p*，*q*] trends toward the path of equilibrium point(0，0): when the *p* of the initial value point[*p*，*q*] is too large, its evolutionary path is that, first, decreasing the value *p* quickly (that is, the proportion of technology transfer strategy that is adopted by MNCs decreases quickly), then decreasing the collective value *q* (that is, the proportion of cooperation strategy that is adopted by the host country enterprises decreases), so it tends to the equilibrium point(0，0).

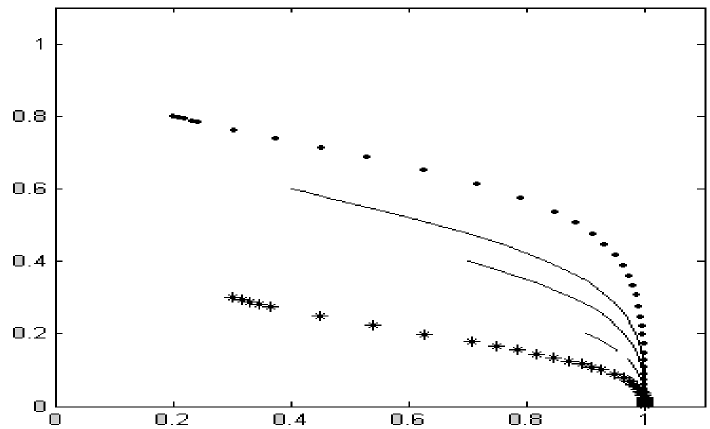
FIGURE 2
PROPOSITION 2 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 55；R=2. 1；r=0. 3；L_1=2；C_1=1；C_2=1. 5

The figure shows that, different initial value points[*p*，*q*] trend toward the path of the equilibrium point(1，0): when the *p* of the initial value point[*p*，*q*] is too large, its evolutionary path is that, first, decreasing the value *p* quickly (that is, the proportion of technology transfer strategy that is adopted by MNCs decreases quickly), then increasing the collective value *q* (that is, the proportion of cooperation strategy that is adopted by the host country enterprises increases), so it tends to the equilibrium point(0，1).

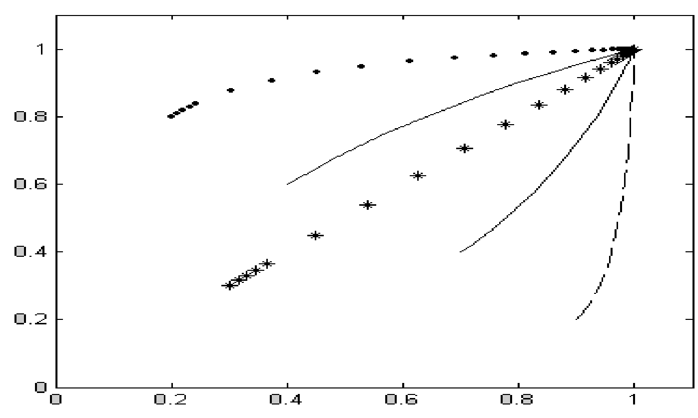
FIGURE 3
PROPOSITION 3 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 7；R=5；r=0. 3；L_1=2；C_1=1；C_2=2

The figure shows that, different initial value points[*p*，*q*] trend toward the path of equilibrium point(1，0): when the *p* of the initial value point[*p*，*q*] is too small, its evolutionary path is that, first, increasing the value *p* quickly (that is, the proportion of technology transfer strategy that is adopted by MNCs increases quickly), then decreasing the collective value *q* (that is, the proportion of cooperation strategy that is adopted by the host country enterprises decreases), so it tends to the equilibrium point(1，0).

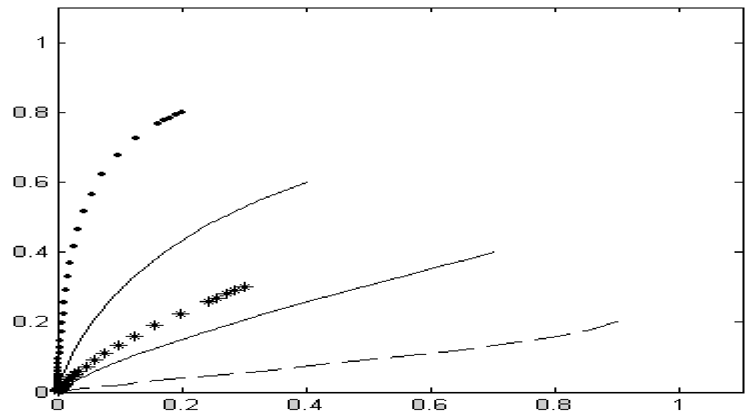
FIGURE 4
PROPOSITION 4 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 7；R=4. 5；r=0. 3；L_1=2；C_1=1；C_2=1. 5

The figure shows that, the different initial value point[*p*，*q*] trends toward the path of the equilibrium point(1，1): If the initial value point[*p*，*q*] is close to the equilibrium point(1，1), it will approach the value of the equilibrium point quickly(such as p or q is 0.7, 0.8, 0.9, so the value will be increased up to 1 quickly) ; Contrarily, if it is far from the corresponding value's point of equilibrium point(1, 1), it become slow to approach the value of equilibrium point(such as p or q is 0.2, 0.3, so the value will be increased up to 1 slowly).

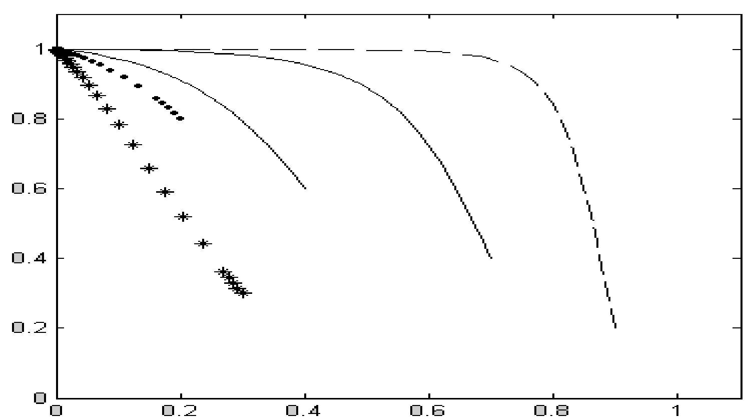
FIGURE 5
PROPOSITION 5 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 55; R=3; r=0. 3; L_1=2; L_{21}=0. 5; L_2=0. 8; C_1=1; C_2=1. 5

The figure shows that, different initial value points [p, q] all trend toward the path of equilibrium point(0, 0) slowly.

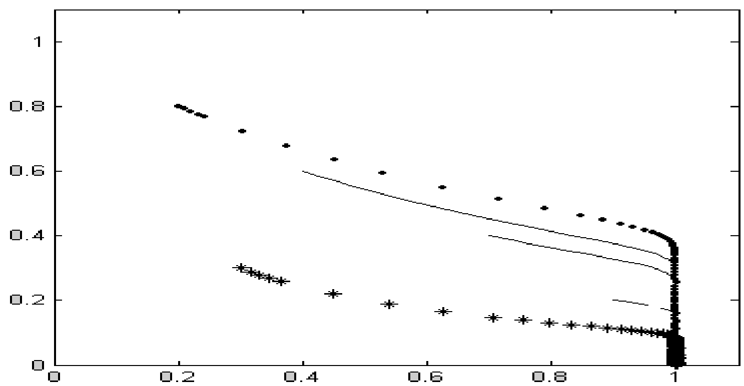
FIGURE 6
PROPOSITION 6 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 5; R=5. 5; r=0. 3; L_1=2; L_{21}=0. 5; L_2=0. 8; C_1=1; C_2=1. 5

The figure shows that, the different initial value point[p, q] trends toward the path of equilibrium point(0, 1): when the q of initial value point[p, q] is too small, its evolutionary path is that, first, increasing the value q quickly (that is, the proportion of cooperation strategy that is adopted by host country enterprises increases quickly), then decreasing the collective value p (that is, the proportion of technology transfer's strategy that is adopted by the MNCs decreases), so it tends to the equilibrium point(0，1).

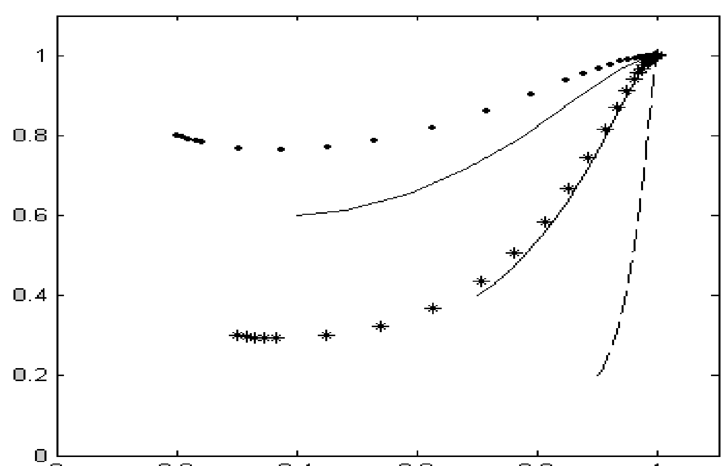
FIGURE 7
PROPOSITION 7 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 7；R=5. 5；r=0. 3；L_1=2；L_{21}=0. 5；L_2=0. 8；C_1=1；C_2=1. 5

The figure shows that, different initial value point[p，q] trends toward the path of equilibrium point(1，0): when the p of initial value point[p，q] is too small, its evolutionary path is that, first, increasing the value p quickly (that is, the proportion of strategy that is adopted by MNCs increases quickly), then decreasing the collective value q (that is, the proportion of cooperation strategy that is adopted by the host country enterprises decreases), so it tends to the equilibrium point(1，0).

FIGURE 8
PROPOSITION 8 DYNAMIC EVOLUTIONARY FIGURE OF DIFFERENT INITIAL VALUE



Hypothesize parameter β=0. 6；R=5. 5；r=0. 3；L_1=2；L_{21}=0. 5；L_2=0. 8；C_1=1；C_2=1. 5

The figure shows that, different initial value points [p，q] all trend toward the path of the equilibrium point(1，1) slowly.

COMPARATIVE ANALYSES AND CONCLUSION

On the issue of technology transfer between MNCs and host country enterprises, this paper has established the evolutionary game model and has discussed separate issues based on two situations: the host country enterprises had research and development capacity or they had not. We make a comparative analysis to the equilibrium result of the two situations, and as a result, we drew useful conclusions and implications, as follows:

1. The host country enterprises have research and development capacity. Their unwillingness to cooperate is stronger than before when they did not this capacity, and the conditions are better than before. Such MNCs have not entered the host country. If the host country enterprises had no research and development capacity, their willingness to cooperate was poor; if the host country enterprises had this capacity, their willingness to cooperate would be strengthened.

2. Before MNCs and host country enterprises cooperate, their profitability is not related directly to the later cooperation between the two sides and their successful cooperation.

3. Because the last evolutionary stable strategy that this paper discusses is based on cooperation between the two sides, as long as one side of the MNCs or host country enterprises select not to cooperate the end result is that the cooperation cannot be realized. Therefore, the cooperation can be realized only when the host country enterprises are lack of research and development capacity, and at same time the condition of proposition 4 is satisfied, namely, the profits that MNCs gain through technology transfer with host country enterprises exceed the total costs. It is necessary to indicate that the cost of technology transfer and the loss caused by technology spillover should be included in the total costs. When the profits that host country enterprises gain through cooperation with MNCs exceed the needed cost, both MNCs and host country enterprises select the cooperation strategy, then they come to cooperate. If the host country enterprises have research and development capacity, the condition of proposition 8 should be satisfied: the profits that MNCs gain through technology transfer with host country enterprises (cooperation) exceed the total costs, which contain the cost of technology transfer and the loss caused by technology spillover. In addition, when the profits that host country enterprises gain through cooperation with MNCs exceed the total costs, which contain the needed cost and loss caused by their cooperation but affecting independent innovation, both MNCs and host country enterprises select the cooperation strategy, and then successful cooperation comes true.

4. Comparing proposition 4 with proposition 8, we discover that, given comprehensive cooperation between MNCs and host country enterprises, if the host country enterprises have research and development capacity, the conditions for cooperation will be improved. We can state clearly, according to numerical modeling, that if the host country enterprises have research and development capacity, a successful cooperation should meet the following conditions: 1) After cooperation, the total profits are more than before, namely, the cooperative scale becomes bigger or the technology becomes more advanced; 2) through cooperation with MNCs, the host country enterprises' profits caused by improvement of technology capacity become more; 3) (And this is a very important point) There will be a change of equity structure. The host country enterprises have research and development capacity, so the proportion of host country enterprises' return on equity will be decreased, the corresponding proportion of host country enterprises' return on equity will be increased.

REFERENCES

Das, S. (1987). Externalities and technology transfer through multinational corporations. *Journal of International Economics*, 90：1142-1165.

Magnus, B. & Jianye Wang (1992). Foreign investment and technology transfer：a simple model. *European Economic Review*, 36(1)：137-155.

Longying Hu, Zhixin Tang (2000). Research on cooperative game model of international technology transfer' behaviour. *Journal of Harbin Institute of Technology*, 32(2): 70-73.

Yiyun Zhang (2002). Analysis on both sides' cooperative game of the MNCs' technology transfer. *Journal of Northwestern Polytechnic University (Social Sciences)*, 22(2): 22-25.

Webull, J. (1995). Evolutionary game theory. *Princeton: Princeton Press*.

Friedman, D.(1998). On Economic Applications of Evolutionary Game Theory. *Journal of Evolutionary Economics* ,8,15-43.

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