The Research on the Benefit of Telemedicine to Human Based on Evolutionary Game Theory

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Abstract. For situation that inadequate and overly expensive medical service as a result of medical and health resources are scarce and the distribution is not reasonable in our country, the paper uses evolutionary game theory to establish the evolutionary game model of the general hospital and patient based on telemedicine system, analyze the evolutionary process and the result of the two sides, and come to the conclusion that people can get the most benefit when choosing telemedicine. What's more, the paper use MATLAB to simulate the model, to further verify the benefits brought by telemedicine.

Keywords: Telemedicine · Evolutionary game theory · MATLAB

1 Introduction

The investigation found that the United States spends the annual cost of medical services is the largest in developed countries, while the per capita annual medical expenses in China is only 0.27% of that in the United States, indicating that the medical resources in China are extremely scarce. The medical and health resources in China are so serious shortage and are not evenly distributed, the city with a population of only 20% of the population has 80% of the country's medical and health resources, while the rural population is 80% of the total population but the medical and health resources account for only 20% of the country's total [1]. As a result, it is difficult for people to see a doctor, and telemedicine play an important role in improving the situation. As a new medical system, telemedicine connects the central hospital and the general hospital through the network, so that the patients can get the treatment from the central hospital in the general hospital, and it can improve health care resource utilization and patient flow issues better, to a large extent, the problem that people is difficult to see a doctor is greatly improved.

At present, telemedicine has been widely used both at home and abroad. The earliest application model of telemedicine is a two-way television system applied in radiology in the early 1950s [2]. From then on, more and more medical activities have

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begun to integrate with technology. In order to promote the development of telemedicine, developed countries in the West have successively developed some valuable projects. As a pioneer in developed countries, the United States has strong technological and economic strength and therefore has access to most areas of telemedicine, including pediatric far-reaching medical care and the UWGSP9 telemedicine project [3]. Since last century, China's economy has just started, the study of telemedicine far less than the developed countries in the West. At the end of the 20th century, telemedicine activities were carried out by General Hospital of PLA and Huashan Hospital, which enabled the start and breakthrough of telemedicine [4]. In addition, the Ministry of Health also created a telemedicine consultation system. Later, the People's Liberation Army General Hospital conducted a telemedicine consultation with a hospital in Jinan Military Region using E-mail, Videophone and ISDN, and established a "telemedicine center".

Telemedicine technology has broken borders and has a significant impact on the reform of the health care system. This article uses evolutionary game theory to analyze the benefits brought by telemedicine.

2 Model Establishment

2.1 Model Assumptions

Suppose general hospitals and patients is limited rationality during the game process; assuming that the patient must have a medical treatment, when the patient does not choose the general hospital treatment, he will choose the central hospital for treatment.

2.2 Model Factors

(1) Game sides

This paper studies the game of general hospital and patient under the telemedicine system, so the two sides of the game are general hospital and patient respectively.

(2) Strategy

General hospitals choose whether or not to carry out telemedicine cooperation with the central hospital. Therefore, the general hospital's strategy set is {cooperative, uncooperative}, and patients choose whether to go to a general hospital for treatment. Therefore, the patient's strategy set is {choose, no choose}.

(3) Income matrix

For hospitals, suppose that the ratio of general hospitals choose to cooperate with the central hospital with telemedicine is y ($0 < y < 1$) [5]. The benefits of general hospital choose to cooperate with central hospital are π_1, the benefits of general hospitals do not cooperate with the central hospital are π_2, As patients can get more trust from telemedicine, so $\pi_1 > \pi_2$; the cost to be paid that general hospital cooperates with central hospital (advocacy costs, operating costs and other fixed costs) is C_1, the cost to be paid when not cooperating with the central hospital (hospital fixed costs) is $C_2 (C_1 > C_2)$, in addition regardless of the general hospital how to choose, the cost in doctor when patients choose general hospital (bonus and salary of doctor) is C_3; the financial support provided by the government when the general hospital cooperate with the central hospital is W_1, and the financial support provided by the government which does not cooperate with the central hospital is W_2, now China is strongly supporting and promoting telemedicine, so $W_1 > W_2$. For patients, suppose the ratio that patients choose to visit a general hospital is $x(0 < x < 1)$ [6]. When the general hospital cooperate with the central hospital, the utility that patients choose the general hospital is V_1, when the general hospital cooperate with the central hospital for telemedicine, the utility obtained by the patients choosing general hospitals was V_1. When the general hospital do not carry out the telemedicine cooperation with the central hospital, the utility obtained by the patients choosing general hospitals was $V_2(V_1 > V_2)$; when the general hospital chooses to cooperate with the central hospital, the cost to be paid by the patient is P_1. When the general hospital does not choose to cooperate with the central hospital, the cost to be paid by the patient is P_2; the proportion of reimbursement of medical insurance in general hospital is σ, because the utility will reduce significantly when general hospitals do not cooperate with central hospitals, the patient will complain about the general hospital, and the cost is C_4, which result in the loss of the general hospital is L. Taking into account the patient must be medical treatment, this paper assumes that when the patient does not choose a general hospital for medical treatment, that is, choose the center of the hospital for medical treatment, the utility of the patient to the central hospital for treatment is V', the medical expense paid is P', and the reimbursement ratio of the central hospital is σ'. Additional costs paid such as transportation costs, time cost, and accommodation cost are E [7].

According to the above assumptions analysis: The actual expenses paid by patients when they choose to visit a general hospital are $P_1(1 - \sigma)$ and $P_2(1 - \sigma)$ respectively; when general hospital cooperate with central hospital, the patient's satisfaction with the general hospital increased, and the extra cost was saved, so the utility of the patient was $V_1 > (1 - \sigma)P_1$; when general hospitals do not cooperate with central hospitals, the patients are in doubt about the medical standards of general hospital doctors, so the patients may not be satisfied with the general hospital medical services, so the utility obtained by the patients is $V_2 < (1 - \sigma)P_2$ [8].

Based on the above assumptions and analysis, we can get the return matrix of both sides of the game, as shown in Table 1.

Table 1. The game income matrix of general hospitals and patients

		General hospital	
		合作 (y)	不合作 $(1-y)$
患	选择 (x)	$V_1 - (1-\sigma)P_1$, $\pi_1 - C_1 - C_3 + W_1$	$V_2 - (1-\sigma)P_2 - C_4$, $\pi_2 - C_2 - C_3 + W_2 - L$
者	不选择 $(1-x)$	$V' - (1-\sigma')P' - E, -C_1 + W_1$	$V' - (1-\sigma')P' - E, -C_2 + W_2$

Based on Table 1, the income matrix of patients is:

$$A = \begin{bmatrix} V_1 - (1-\sigma)P_1 & V_2 - (1-\sigma)P_2 - C_4 \\ V' - (1-\sigma')P' - E & V' - (1-\sigma')P' - E \end{bmatrix} \quad (1)$$

The income matrix of general hospital is:

$$B = \begin{bmatrix} \pi_1 - C_1 - C_3 + W_1 & \pi_2 - C_2 - C_3 + W_2 - L \\ -C_1 + W_1 & -C_2 + W_2 \end{bmatrix} \quad (2)$$

3 Model Analysis

Based on the above assumptions and analysis, the expected benefits of adopting two strategies of "selecting" and "not selecting" for a single patient are U_{11}, U_{12}, and the average income of patients are $\overline{U}_1$, respectively:

$$U_{11} = y[V_1 - (1-\sigma)P_1] + (1-y)[V_2 - (1-\sigma)P_2 - C_4 \quad (3)$$

$$U_{12} = y(V' - (1-\sigma')P' - E) + (1-y)[V' - (1-\sigma')P' - E] \quad (4)$$

$$\overline{U}_1 = xU_{11} + (1-x)U_{12} \quad (5)$$

The dynamic equation for constructing the imitator is:

$$\begin{aligned} F(x) &= \frac{dx}{dt} = x\left(U_{11} - \overline{U}_1\right) = x(1-x)(U_{11} - U_{12}) \\ &= x(1-x)\{y[V_1 - V_2 - (1-\sigma)(P_1 - P_2) + C_4] - [V' - (1-\sigma')P' - E]\} \end{aligned} \quad (6)$$

Similarly, the imitation of general hospitals dynamic equation is:

$$F(y) = \frac{dy}{dt} = y\left(U_{21} - \overline{U}_2\right) = y(1-y)[x(\pi_1 - \pi_2 + L) + W_1 - W_2 - (C_1 - C_2) \quad (7)$$

The evolvement behavior of the two sides in the process of game can be illustrated by the dynamic equation of imitators in both sides of the game. Let $F(x) = 0$, $F(y) = 0$, we can get five dynamic equilibrium point, respectively: O(0, 0), $A(0,1)$, $B(1,1)$, $C(1,0)$, $D(x^*, y^*)$, If and only if $0 < x^* < 1$ and $0 < y^* < 1$. Among them:

$$x^* = \frac{C_1 - C_2 - (W_1 - W_2)}{\pi_1 - \pi_2 + L}$$

$$y^* = \frac{V' - (1-\sigma')P' = -E - [V_2 - (1-\sigma)P_2 - C_4]}{V_1 - V_2 - (1-\sigma)(P_1 - P_2) + C_4}$$

According to the above assumptions and the actual situation, the benefits of patients will much than the cost paid when they see a doctor, otherwise the patient will not choose to see a doctor, and when general hospitals cooperate with central hospitals and patients choose general hospitals, because of the additional cost was saved, so the benefits of patients obtain are much than that they choose central hospitals, so $0 < y^* < 1$.

According to Jacobian matrix analysis, constructing Jacobian matrix J [9]:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial y} \end{bmatrix}$$

Among them, the formula (6) and (7) derived partial derivation:

$$\frac{\partial F(x)}{\partial x} = (1-2x)\{y[V_1 - V_2 - (1-\sigma)(P_1 - P_2) + C_4] + V_2 - (1-\sigma)P_2 - C_4 - [V' - (1-\sigma')P' - E]\}$$

$$\frac{\partial F(x)}{\partial y} = x(1-x)[V_1 - V_2 - (1-\sigma)(P_1 - P_2) + C_4]$$

$$\frac{\partial F(y)}{\partial x} = y(1-y)(\pi_1 - \pi_2 + L)$$

$$\frac{\partial F(y)}{\partial y} = (1-2y)[x(\pi_1 - \pi_2 + L) + W_1 - W_2 - (C_1 - C_2)]$$

The determinant of Jacobian matrix J is:

$$det(J) = |J| = \frac{\partial F(x)}{\partial x} \cdot \frac{\partial F(y)}{\partial y} - \frac{\partial F(x)}{\partial y} \cdot \frac{\partial F(y)}{\partial x}$$

The trace of the Jacobian matrix is:

$$tr(J) = \frac{\partial F(x)}{\partial x} + \frac{\partial F(y)}{\partial y} \tag{8}$$

It should be pointed out that in the process of solving the model, we need to find out the evolutionary stability strategy of the game model to analyze the model. The evolutionary stability strategy has the corresponding criterion, when a certain equilibrium point of the game model makes the determinant of the Jacobian matrix positive and makes the trace of the Jacobian matrix to be negative, then this equilibrium point is the evolutionary stabilization strategy.

According to the patient's imitator dynamic equation analysis, When $y = y^*$, $F(x)$ always is 0, so all x are stable. When $y > y^*$, $x^* = 1$ is the *ESS* equilibrium point; when $y < y^*$, $x^* = 0$ is the *ESS* equilibrium point [10].

From the above three cases are available, the patient's imitator dynamic phase diagram is shown in Fig. 1(a–c).

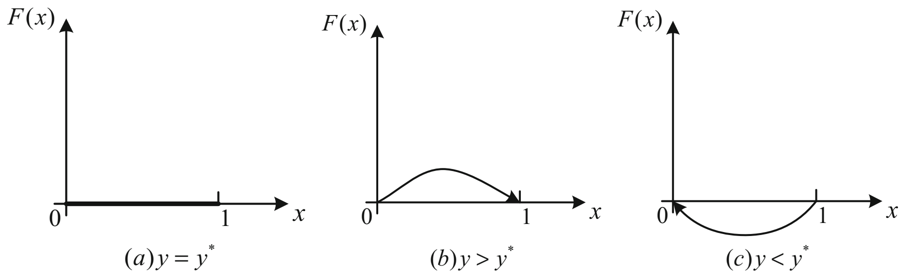

Fig. 1. The imitator dynamic phase diagram of patients

Similarly, we can obtain what through the dynamic equation analysis of imitators in general hospital strategy is: when $x = x^*$, $F(y)$ is always, that is, all y are stable; when $x > x^*$, $y^* = 1$ is the *ESS* equilibrium point; when $x < x^*$, $y^* = 0$ is the *ESS* equilibrium point [11].

From the above three cases are available, the general hospital's imitator dynamic phase diagram is shown in Fig. 2(a–c).

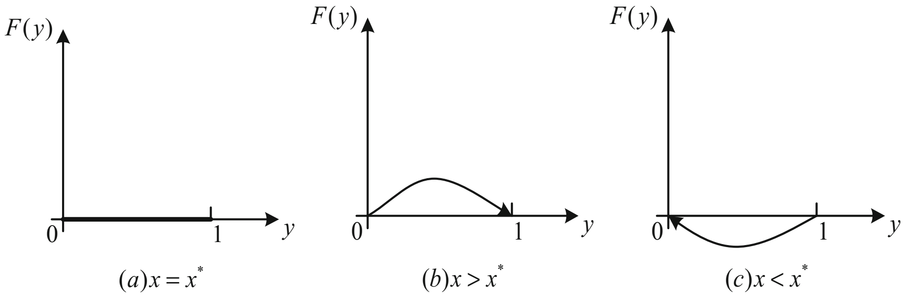

Fig. 2. The imitator dynamic phase diagram of general hospitals

According to the different values of x^*, there are three cases for analysis. According to the analysis, when the value of x^* is different, the general hospital and the patient's game strategy choice will be different. The dynamic phase diagram of the imitator is shown in the same coordinate system to obtain the dynamic evolution diagram of interaction between ordinary hospitals and patients under different x^* values, as shown in Fig. 3(a–c). It can be divided into three cases.

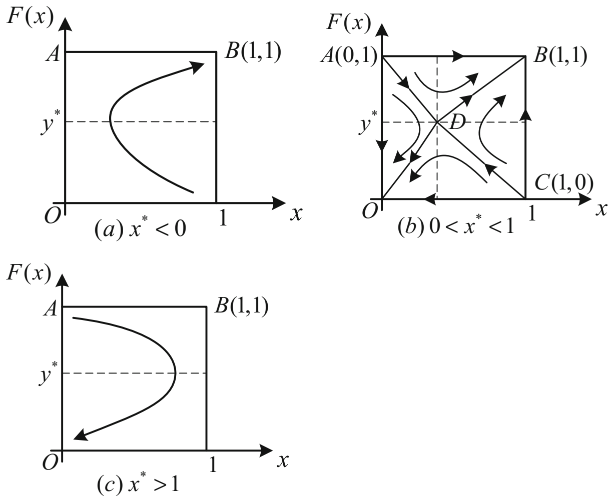

Fig. 3. Dynamic evolution of general hospital-patient interaction

Case 1. $x^* < 0$, that is $W_1 - W_2 > C_1 - C_2$
According to the above assumptions, in both cases whether general hospitals cooperate with central hospitals or not, the increase in the amount of money supported by the government to the general hospital can make up for the increase in the cost of the introduction of telemedicine in ordinary hospitals. That is to say, the general hospital benefit when cooperate with the central hospital. In this case, according to the Jacobian matrix determinant and trace symbol analysis corresponding to the equilibrium point of the dynamic system, $B(1,1)$ is the *ESS* equilibrium point of the system. That is, the evolutionary result is that the general hospital chooses cooperate with the central hospital, and the patients choose the general hospital for treatment, and at the same time, the maximum benefit of both is achieved [12]. The Jacobian matrix determinant and trace symbol analysis shown in Table 2, the dynamic evolution of general hospital interaction with patients as shown in Fig. 3(a).

Case 2. $0 < x^* < 1$, that is $W_1 - W_2 < C_1 - C_2$ and $(\pi_1 - \pi_2 + \mathrm{L}) + [(W_1 - W_2) - (C_1 - C_2)] > 0$
According to the above assumptions, in both cases whether general hospitals cooperate with central hospitals or not, the increase in the amount of money supported by the government to the general hospital can't make up for the increase in the cost of the introduction of telemedicine in ordinary hospitals. However, general hospitals have benefited in the long run by bringing increased benefits to general hospitals through telemedicine. In this case, according to the Jacobian matrix determinant and trace symbol analysis corresponding to the equilibrium point of the dynamic system, $O(0,0)$ and $B(1,1)$ is the *ESS* equilibrium point of the system. That is, the evolutionary result is that the general hospital does not choose cooperate with the central hospital, and the patients does not choose the general hospital for treatment, or the evolutionary result is that the general hospital chooses cooperate with the central hospital, and the patients

Table 2. Ranks and trace sign analysis of Jacobian matrix in case 1

Equilibrium	Determinant of J	Symbol	Trace of J	Symbol	Local stability
$O(0,0)$	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}\cdot W_1-W_2-(C_1-C_2)$	–	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}+W_1-W_2-(C_1-C_2)$	–	Saddle point
$A(0,1)$	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\cdot[C_1-C_2-(W_1-W_2)]$	–	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]+[C_1-C_2-(W_1-W_2)]$	+	Saddle point
$B(1,1)$	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}\cdot[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	+	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}+[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	–	*ESS*
$C(1,0)$	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}\cdot[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	+	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}+[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	+	Instability point

Notes: *ESS is evolutionary Stable Strategy*

Table 3. Ranks and trace sign analysis of Jacobian matrix in case 2

Equilibrium	Determinant of J	Symbol	Trace of J	Symbol	Local stability
$O(0,0)$	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}\cdot W_1-W_2-(C_1-C_2)$	+	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}+W_1-W_2-(C_1-C_2)$	–	*ESS*
$A(0,1)$	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\cdot[C_1-C_2-(W_1-W_2)]$	+	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]+[C_1-C_2-(W_1-W_2)]$	+	Instability point
$B(1,1)$	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}\cdot[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	+	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}+[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	–	*ESS*
$C(1,0)$	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}\cdot[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	+	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}+[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	+	Instability point
$D(x^*,y^*)$	$-u$	–	0	0	Saddle point

choose the general hospital for treatment [13]. The Jacobian matrix determinant and trace symbol analysis shown in Table 3, the dynamic evolution of general hospital interaction with patients as shown in Fig. 3(b).

In this case, the game model can evolve two evolutionary stability strategies, and the different initial states of each element in the model will cause the system to converge to different stable points, so as to obtain different evolutionary stabilization strategies. As can be seen from Fig. 3(b), when the initial state is in the area $AOCD$, the system will converge to $O(0,0)$, that is, general hospitals do not cooperate with central hospitals, patients do not choose general hospitals; when the initial state is in the area ABCD, the system will converge to point B (1, 1), that is, the general hospital cooperate with the central hospital for telemedicine, patients choose the general hospital for treatment. And the larger the area of $ABCD$, the greater the probability that the system converges to the stable point $B(1,1)$, and the smaller the probability of converging to $O(0,0)$. Therefore, the factors influencing the evolutionary path of the analysis system can be transformed into the factors that affect the size of the $ABCD$. The area of $ABCD$ can be expressed as:

$$\begin{aligned} S_{ABCD} &= \frac{1}{2}(2 - x^* - y^*) \\ &= \frac{1}{2}\left[2 - \frac{C_1 - C_2 - (W_1 - W_2)}{\pi_1 - \pi_2 + L} - \frac{V' - (1-\sigma')P' - E[V_2 - (1-\sigma)P - C_4]}{V_1 - V_2 - (1-\sigma)(P_1 - P_2) + C_4}\right] \end{aligned} \tag{9}$$

Next, we discuss the effect of the change of parameters on the overall evolutionary result [14]:

(1) The cost increment of cooperative telemedicine in general hospital: $C_1 - C_2$.
To the formula (9), through the derivative with respect to $C_1 - C_2$, $\frac{\partial S_{ABCD}}{(C_1 - C_2)} < 0$, that is, S_{ABCD} is a decreasing function of $C_1 - C_2$, increases with decreasing $C_1 - C_2$ and decreases with increasing $C_1 - C_2$. So when the cost that general hospitals choose central hospitals for telemedicine increasing, S_{ABCD} will be reduced, the probability of the system to $O(0,0)$ points will be increased.

(2) The increase in government subsidies when general hospitals cooperate with central hospitals: $W_1 - W_2$.
To the formula (9), through the derivative with respect to $W_1 - W_2$, $\frac{\partial S_{ABCD}}{(C_1 - C_2)} > 0$, that is, S_{ABCD} is a increasing function of $C_1 - C_2$, increases with increasing $C_1 - C_2$ and decreases with decreasing $C_1 - C_2$. So The increase in government subsidies when general hospitals cooperate with central hospitals increasing, S_{ABCD} will increase, the probability of system evolution to $B(1,1)$ points will increase.

Table 4. Ranks and trace sign analysis of Jacobian matrix in case 2

Equilibrium	Determinant of J	Symbol	Trace of J	Symbol	Local stability
$O(0,0)$	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}\cdot W_1-W_2-(C_1-C_2)$	+	$\{[V_2-(1-\sigma)P_2-C_4]-[V'-(1-\sigma)P'-E]\}+W_1-W_2-(C_1-C_2)$	–	*ESS*
$A(0,1)$	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\cdot[C_1-C_2-(W_1-W_2)]$	+	$[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]+[C_1-C_2-(W_1-W_2)]$	+	Instability point
$B(1,1)$	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}\cdot[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	–	$-\{[V_1-(1-\sigma)P_1]-[V'-(1-\sigma')P'-E]\}+[(C_1-C_2)-(W_1-W_2)-(\pi_1-\pi_2+L)]$	Unsure	Saddle point
$C(1,0)$	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}\cdot[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	–	$-\{[V_2-(1-\sigma)P_2+C_4]-[V'-(1-\sigma')P'-E]\}+[\pi_1-\pi_2+L+W_1-W_2-(C_1-C_2)]$	Unsure	Saddle point

(3) The increase of return when general hospitals cooperate with central hospitals: $\pi_1 - \pi_2$.
To the formula (9), through the derivative with respect to $\pi_1 - \pi_2$, $\frac{\partial S_{ABCD}}{(C_1 - C_2)} > 0$, that is, S_{ABCD} is a increasing function of $\pi_1 - \pi_2$, increases with increasing $\pi_1 - \pi_2$ and decreases with decreasing $C_1 - C_2$. So The increase of return when general hospitals cooperate with central hospitals increasing, S_{ABCD} will increase,

Table 5. Model initial parameter assignment table

Factors	Assignment
W_1, W_2	600, 200 (million)
C_1, C_2	800, 300 (million)
π_1, π_2	400, 200 (million)
P_1, P_2	1.2, 1
σ, σ'	0.4, 0.6
V_1, V_2	1, 0.2
L, E	2, 0.2
C_4, P', V'	1, 2, 1.2

the probability of system evolution to $B(1, 1)$ points will increase.

(4) General hospital medical claims ratio: σ
To the formula (9), through the derivative with respect to σ, $\frac{\partial S_{ABCD}}{(C_1 - C_2)} > 0$, that is, S_{ABCD} is a increasing function of σ, increases with increasing σ and decreases with decreasing σ. So General hospital medical claims ratio increasing, S_{ABCD} will increase, the probability of system evolution to $B(1, 1)$ points will increase.

(5) Central hospital medical claims ratio: σ'

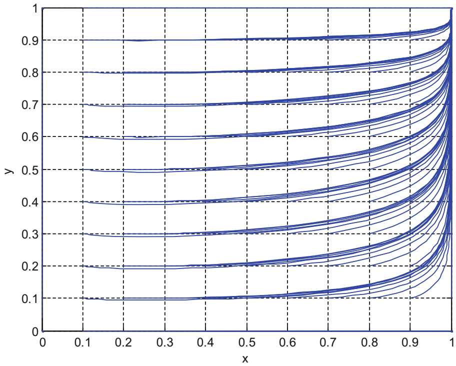

Fig. 4. Evolution trend simulation diagram of $x - y$ based on case 1.

To the formula (9), through the derivative with respect to σ', $\frac{\partial S_{ABCD}}{(C_1 - C_2)} < 0$, that is, S_{ABCD} is a decreasing function of σ', increases with decreasing σ' and decreases with increasing σ'. So when the cost that general hospitals choose central hospitals

Table 6. Changed parameter assignment table

Factors	Assignment
W_1, W_2	700, 200 (million)
C_1, C_2	700, 300 (million)
π_1, π_2	400, 200 (million)
P_1, P_2	1.2, 1
σ, σ'	0.4, 0.6
V_1, V_2	1, 0.2
L, E	2, 0.2
C_4, P', V'	1, 2, 1.2

for telemedicine increasing, S_{ABCD} will be reduced, the probability of the system to $O(0,0)$ points will be increased.

Case 3. $x^* > 1$, that is $W_1 - W_2 < C_1 - C_2$, and $(\pi_1 - \pi_2 + \mathrm{L}) + [(W_1 - W_2) - (C_1 - C_2)] < 0$.
According to the above assumptions, in both cases whether general hospitals cooperate with central hospitals or not, the increase in the amount of money supported by the government to the general hospital can't make up for the increase in the cost of the introduction of telemedicine in ordinary hospitals. And general hospitals don't have benefited in the long run by bringing increased benefits to general hospitals through

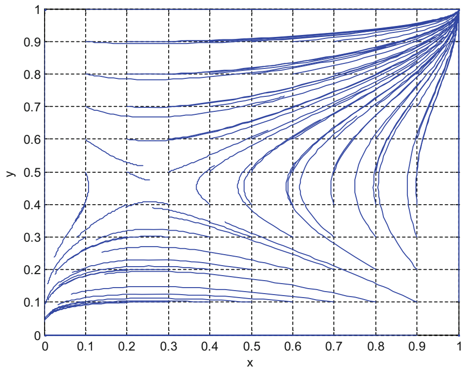

Fig. 5. Evolution trend simulation diagram of $x - y$ based on case 2.

telemedicine. In this case, according to the Jacobian matrix determinant and trace symbol analysis corresponding to the equilibrium point of the dynamic system, $O(0,0)$ is the *ESS* equilibrium point of the system. That is, when telemedicine can't make

Table 7. Changed parameter assignment table

Factors	Assignment
W_1, W_2	600, 200 (million)
C_1, C_2	1000, 300 (million)
π_1, π_2	400, 200 (million)
P_1, P_2	1.2, 1
σ, σ'	0.4, 0.6
V_1, V_2	1, 0.2
L, E	2, 0.2
C_4, P', V'	1, 2, 1.2

benefit for general hospitals, general hospitals will not cooperate with central hospitals and patients will not choose general hospitals for treatment. The Jacobian matrix determinant and trace symbol analysis shown in Table 4, the dynamic evolution of general hospital interaction with patients as shown in Fig. 3(c).

4 Simulation Analysis

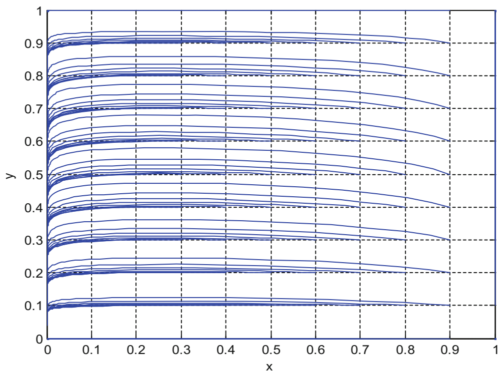

Fig. 6. Evolution trend simulation diagram of $x - y$ based on case 3.

From the above analysis we can see that when x^*, y^* have different values, the system will have different evolutionary path, resulting in different evolutionary results. In this paper, we use *MATLAB* to establish the model the about hospitals and patients. The paper simulate the model based on the three cases above, analyzing the impact of the initial state of the system on the game process of general hospitals and patients in different situations by graphics [15]. According to the evolution trend of the model in the graph, the factors that affecting the system evolution result will more clear.

Case 1. $x^* < 0$
In this case, the model initial parameter values are set to meet the situation 1, the specific assignment in Table 5.

Input the above model parameters into the *MATLAB* model, make the initial value of x, y is 0, In order to see the changing trend of the system clearly, make loop step is 0.05, running time is [0, 10] [16]. The $x - y$ chart of evolutionary game model of general hospital and patient running under the above conditions is shown in Fig. 4. The figure shows, when $x^* < 0$, all the points of x and y in the figure converge to (1, 1). That is, the final result of the evolution is that the general hospital chooses to cooperate with the central hospital and the patients choose to go to the general hospital for treatment. the system achieves a stable and balanced evolution at the (1, 1).

Case 2. $0 < x^* < 1$
In this case, the initial parameters of the model W_1, W_2, C_1, C_2 are changed so that the values of the model parameters meet the case 2 which is shown in Table 6.

Input the above model parameters into the *MATLAB* model, Same as case 1, make the initial value of x, y is 0, make loop step is 0.05, running time is [0, 10]. The $x - y$ chart of evolutionary game model of general hospital and patient running under the above conditions is shown in Fig. 5. The figure shows, when $0 < x^* < 1$, all the points of x and y in the figure converge to (0, 0) or (1, 1). That is, the final result of the evolution is that the general hospital chooses to cooperate with the central hospital and the patients choose to go to the general hospital for treatment or the general hospital does not choose to cooperate with the central hospital and patients do not choose to go to the general hospital [17]. the system achieves a stable and balanced evolution at the (0, 0) and (1, 1).

Case 3. $x^* > 1$
In this case, the initial parameters of the model W_1, W_2, C_1, C_2 are changed so that the values of the model parameters meet the case 3 which is shown in Table 7.

Input the above model parameters into the *MATLAB* model, Same as case 1 and case 2, make the initial value of x, y is 0, make loop step is 0.05, running time is [0, 10]. The $x - y$ chart of evolutionary game model of general hospital and patient running under the above conditions is shown in Fig. 6. The figure shows, when $x^* > 1$, all the points of x and y in the figure converge to (0, 0) [17]. That is, the final result of the evolution is that the general hospital does not choose to cooperate with the central hospital and patients do not choose to go to the general hospital. the system achieves a stable and balanced evolution at the (0, 0) [18].

From the simulation results, we can see that in the above three cases, when the general hospital chose to cooperate with the central hospital for telemedicine, both the patient and the general hospital can get the maximum return, that is, the model eventually evolves to (1, 1) point [19]. Therefore, it can be seen that the introduction of telemedicine technology can improve the current medical treatment in China.

5 Conclusion

Based on the serious shortage of medical and health resources and the extremely uneven distribution in China, this paper establishes an evolutionary game model of general hospitals and patients under the telemedicine system in order to improve people's problem of inadequate and overly expensive medical service [20]. According to the analysis of the game between the two sides, it can be concluded that when the general hospital chose to cooperate with the central hospital for telemedicine, patients can receive maximum benefit from their visit. This paper uses *MATLAB* to simulate the model, further illustrating that telemedicine technology can improve people's medical problems.

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