The Analysis of Evolutionary Game between Farmers and E-business Platform: A Perspective of Reducing Transaction Cost

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Abstract

Based on the assumption that the e-business sales model can reduce the transaction costs of the farmers trading in the e-business platform, the paper analyzes the influencing factors of e-business enterprises' invest strategy in e-business platform construction and farmers' strategy of trading in e-business platform, it also analyzes the evolutionary game between farmers and e- business enterprises. On the results of evolutionary game analysis, the paper puts forward the policy suggestion of developing e- business model in agricultural products transaction.

Keywords

Evolutionary Game, E-Business, Transaction Cost.

1. Introduction

In recent years, the use of e-business platform to sell agricultural products has become a popular way of selling farmers. E-business sales model has many advantages such as reducing farmers' transaction cost and reducing the risk of agricultural transaction default.

Before building an e-business platform, e-business company needs to measure the cost of investment and e-commerce platform after the benefits and benefits, the farmers also need to consider the cost and benefits when they trade the e-business platform.

This paper analyzes the factors influencing the investment of e-commerce enterprises and the adoption of e-commerce sales model by farmers, and the difference of evolution results caused by these factors.

2. Assumption and Model Parameters Definition

2.1 Assumption

Assumption 1: The proption of transaction defaults in e-business platform is less in non-e-business transaction enviroment because the transaction supervison and identity verification for both parties of transaction by the e-business, which means $p_e < p_{ne}$.

Assumption 2: The information cost for the farmers who search transaction in e-business platform is zero. c_z is the information cost for the farmers who search transaction in non-e-business environment.

Assumption 3: The supply and demand information services is free in e-business platform, and e-business platform charge the transaction fee from the completed transactions.

Assumption 4: Users of illegal credit management rules and trading rules will be punished in the e-business platform.

2.2 Model Parameters Definition

The parameters in the model is listed in Table 1.

Table 1. Model parameters

Parameter	Definition
r	r is the return rate of the total turnover in e-business platform given by farmers to the e-business platform
r_e	The ratio of transaction costs and turnover paid by farmers in e-business platform
r_{ne}	The ratio of transaction costs and turnover paid by farmers in non-e-business enviroment
p_e	The probability of dealing with a breach of contract to farmers in e-business platform
p_{ne}	The probability of dealing with a breach of contract to farmers in non-e-business enviroment
c_z	The information cost of finding transaction for the farmers in non-e-business enviroment
c_{fi}	The money paid by the farmers for preparing to join the transcation in the e-business platform
e_f	The total transaction value of agricultural products owned by farmers
c_e	The investment and operating costs of e-business platform under the investment strategy
e_b	The profit of e-business platform under the non-investment strategy
c_b	The cost of dealing with transaction defaults paid by e-business platform

Table 2. Evolution game payoff matrix of the Farmers and E-business Platform

Farmers	E-business Platform	
	Invest	Non-Invest
Join	$e_f \cdot (1-r_e-p_e)-c_{fi}$	$e_f \cdot (1-r_{ne}-p_{ne})-c_z-c_{fi}$
	$e_b+e_f \cdot r+e_f \cdot r_e-c_b-c_e$	e_b
Non-Join	$e_f \cdot (1-r_{ne}-p_{ne})-c_z$	$e_f \cdot (1-r_{ne}-p_{ne})-c_z$
	e_b-c_e	e_b

From the Table 2, we can know the results of evolutian game payoff matrix analysis:

When the farmers' strategy is not joning in the e-business platform, and e-business company take the non-investment strategy, the strategy combination of both sides is (non-join, non-investment), the returen of farmers is $e_f \cdot (1-r_{ne}-p_{ne})-c_z$ and the return of e-business company is e_b. When the farmers' strategy is joining the e-business platform, and e-business company take the non-investment strategy, the strategy combination of both sides is (join, non-investment), the returen of farmers $e_f \cdot (1-r_{ne}-p_{ne})-c_z-c_{fi}$ is and the return of e-business company is e_b. When the farmers' strategy is joining in the e-business platform, and e-business company take the investment strategy, the strategy combination of both sides is (join, investment), the returen of farmers is $e_f \cdot (1-r_e-p_e)-c_{fi}$ and the return of e-business company is $e_b+e_f \cdot r+e_f \cdot r_e-c_b-c_e$. When the farmers' strategy is not joining the e-business platform, and e-business company take the investment strategy, the strategy

combination of both sides is (non-join, investment), the returen of farmers is $e_f \cdot (1-r_{ne}-p_{ne})-c_z$ and the return of e-business company is $e_b - c_e$.

3. Analysis of Evolutionary stability strategy

Suppose the probability of choosing the "join" strategy is α (0≤α≤1) in the farmer group, and then the probability of choosing the "non- join" strategy is (1-α). Suppose the probability that the e-business platform chooses the "investment" strategy is β (0≤β≤1), then the probability of selecting the "non-investment" strategy is (1 - β).

3.1 Evolutionary stability strategy of farmers

Based on the analysis results of evolutian game payoff matrix in Table 2, we suppose the farmers' expected return of "join" strategy is $u_{1\alpha}$, and the expected return of "non-join" strategy is $u_{2\alpha}$. The calculation formula of $u_{1\alpha}$ and $u_{2\alpha}$is below:

$$u_{1\alpha} = \beta \cdot (e_f \cdot (1-r_e-p_e)-c_{fi}) + (1-\beta)\cdot(e_f \cdot (1-r_{ne}-p_{ne})-c_z-c_{fi}) \quad \text{Eq. 1}$$

$$u_{2\alpha} = \beta \cdot (e_f \cdot (1-r_{ne}-p_{ne})-c_z) + (1-\beta)\cdot(e_f \cdot (1-r_{ne}-p_{ne})-c_z) \quad \text{Eq. 2}$$

The average expected return of farmers is

$$\bar{u}_f = \alpha \cdot u_{1\alpha} + (1-\alpha)\cdot u_{2\alpha} \quad \text{Eq. 3}$$

Replicator dynamics equation of farmers is

$$F(\alpha) = \frac{d\alpha}{dt} = \alpha \cdot (1-\alpha)\cdot[(e_f \cdot (r_{ne}+p_{ne}-r_e-p_e)+c_z)\cdot\beta - c_{fi}] \quad \text{Eq. 4}$$

Let $F(\alpha)=0$, we can get the local equilibrium points of equation 4:

$$\alpha_1 = 0,\ \alpha_2 = 1,\ \beta_D = \frac{c_{fi}}{e_f \cdot (r_{ne}+p_{ne}-r_e-p_e)+c_z}$$

Derive the derivative of the equation 4,

$$F'(\alpha) = (1-2\alpha)\cdot[(e_f \cdot (r_{ne}+p_{ne}-r_e-p_e)+c_z)\cdot\beta - c_{fi}] \quad \text{Eq. 5}$$

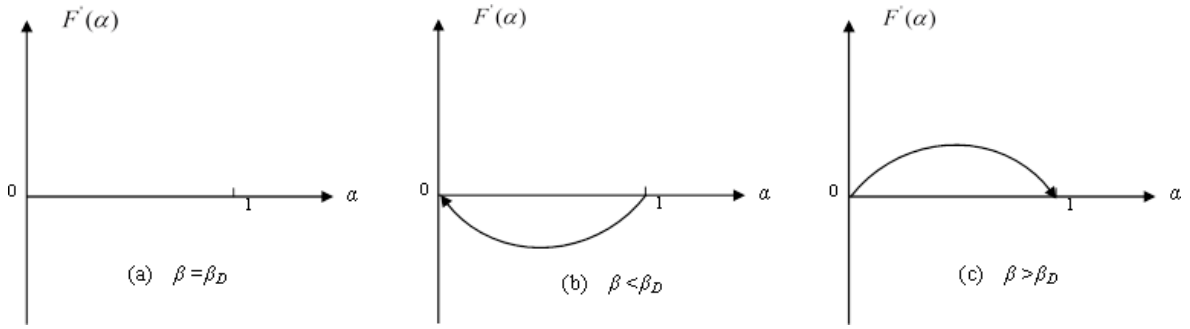

Fig. 1 Farmer strategy selection dynamic trend phase diagram

(1). if $\beta = \beta_D$, then $F(\alpha) \equiv 0$. For $\alpha \in [0,1]$, all α is the evolutionary stability points of farmers, which means when probability of choosing the investment strategy by e-business platform is $\frac{c_{fi}}{e_f \cdot (r_{ne}+p_{ne}-r_e-p_e)+c_z}$, farmers take any probability of joining the strategy is stable, as shown in Fig. 1 (a).

(2). if $\beta \neq \beta_D$, and $0 < \frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z} < 1$, the income of the farmer's joining the platform is greater than the cost of the input, the farmers tend to adopt the strategy of joining the platform. At this point to consider whether $\alpha_1 = 0$ and $\alpha_2 = 1$ are the evolutionary stability strategies.

If $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z} < \beta < 1$, $F'(\alpha_1) > 0$, $F'(\alpha_2) < 0$, $\alpha_2 = 1$ is the only evolutionary stability point. When probability of choosing the investment strategy by e-business platform is greater than $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$, farmers are gradually changed from non-joining to joining strategies, and finally choose to join the platform, as shown in Fig. 1 (c).

If $\beta < \frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z} < 1$, $F'(\alpha_1) < 0$, $F'(\alpha_2) > 0$, $\alpha_1 = 0$ is the only evolutionary stability point. When probability of choosing the investment strategy by e-business platform is less than $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$, farmers are gradually changed from joining to non-joining strategies, and finally choose to non-join the platform, as shown in Fig. 1 (b).

(3). If $\beta \neq \beta_D$ and $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z} > 1$, $F'(\alpha_1) < 0$, $F'(\alpha_2) > 0$, $\alpha_1 = 0$ is the only evolutionary stability point. The farmers tend to adopt the strategy of non-join the platform. , as shown in Fig. 1 (b).

3.2 Evolutionary stability strategy of E-business platform

Based on the analysis results of evolutian game payoff matrix in Table 2, we suppose the e-business platform' expected return of "invest" strategy is $u_{1\beta}$, and the expected return of "non-invest" strategy is $u_{2\beta}$. The calculation formula of $u_{1\beta}$ and $u_{2\beta}$ is below:

$$u_{1\beta} = \alpha \cdot (e_b + e_f \cdot r + e_f \cdot r_e - c_b - c_e) + (1-\alpha) \cdot (e_b - c_e) \quad \text{Eq. 6}$$

$$u_{2\beta} = \alpha \cdot (e_b - c_e) + (1-\alpha) \cdot e_b \quad \text{Eq. 7}$$

The average expected return of farmers is:

$$\bar{u}_b = \beta \cdot u_{1\beta} + (1-\beta) \cdot u_{2\beta} \quad \text{Eq. 8}$$

Replicator dynamics equation of farmers is

$$F(\beta) = \frac{d\beta}{dt} = \beta \cdot (1-\beta) \cdot (\alpha \cdot (e_f \cdot r + e_f \cdot r_e - c_b) - c_e) \quad \text{Eq. 9}$$

Let $F(\beta) = 0$, we can get the local equilibrium points of equation 9:

$$\beta_1 = 0,\ \beta_2 = 1,\ \alpha = \frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$$

Derive the derivative of the equation 9

$$F'(\beta) = (1-2\beta) \cdot (\alpha \cdot (e_f \cdot r + e_f \cdot r_e - c_b) - c_e) \quad \text{Eq. 10}$$

(1). If $\alpha = \alpha_D$, then $F(\beta) \equiv 0$. For $\beta \in [0,1]$, all β is the evolutionary stability points of e-business platform, which means when probability of joining the platform by farmers is $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, e-business platform take any probability of investing strategy is stable, as shown in Fig. 2(a).

(2). If $\beta \neq \beta_D$, and $0 < \frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b} < 1$, the income of the e-business platform's investing the platform is greater than the cost of the invest, the e-business platform tend to adopt the strategy of investing the platform. At this point to consider whether $\beta_1 = 0$ and $\beta_2 = 1$ are the evolutionary stability strategies.

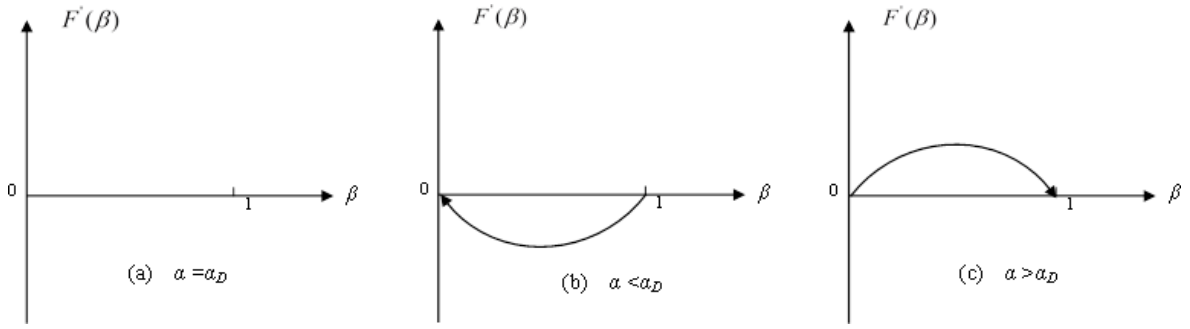

Fig. 2 E-business Platform strategy selection dynamic trend phase diagram

If $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b} < \alpha < 1$, $F'(\beta_1) > 0$, $F'(\beta_2) < 0$, $\beta_2 = 1$ is the only evolutionary stability point. When probability of joining the platform strategy by farmers is greater than $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, the e-business platform is gradually changed from investing to non-investing strategies, and finally choose to non-invest strategy, as shown in Fig. 2 (c).

If $\alpha < \frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b} < 1$, $F'(\beta_1) < 0$, $F'(\beta_2) > 0$, $\beta_1 = 0$ is the only evolutionary stability point. When probability of joining the platform strategy by farmers is less than $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, the e-business platform is gradually changed from non-invest to invest strategies, and finally choose to invest strategy, as shown in Fig. 2 (b).

(3). If $\beta \neq \beta_D$ and $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b} > 1$, $F'(\beta_1) < 0$, $F'(\beta_2) > 0$, $\beta_1 = 0$ the only evolutionary stability point. the e-business platform will choose the non-invest strategy, as shown in Fig. 2 (b).

4. Strategic Choice Evolutionary Stability Analysis of Farmers and E-business Platform"

Merging the Replicator dynamics of Fig. 1and Fig. 2 into a coordinate plane $R' = \{(\alpha, \beta) \mid 0 \leq \alpha, \beta \leq 1\}$, D is the saddle point, its coordinate value ($\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$), as shown in Fig. 3. Based on the analysis above, (0, 0) and (1, 1) are two evolutionary stable strategies of the game between farmers and e-business platform.

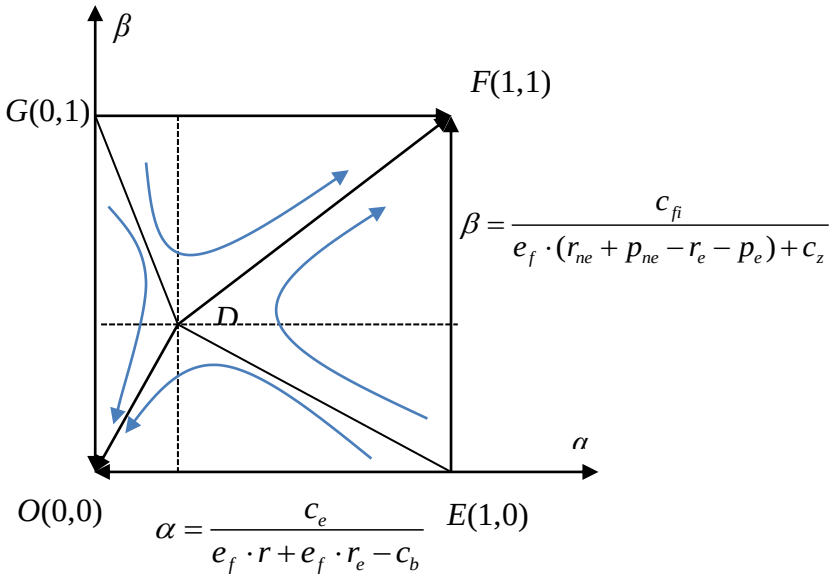

Fig. 3 Replicate the dynamic phase

When the initial state is in the quadrilateral *OEDG*, the system will converges to point *O*(0,0), at this moment, the farmers will choose non-join strategy and the e-business platform will non-invest strategy. There is at least one probability which should be met, $\beta < \frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$ or $\alpha < \frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, which means at least one of the both sides' expected income involved in the game is less than the cost of input.

When the initial state is in the quadrilateral *EFGD*, the system will converges to point *F*(1,1), at this moment, the farmers will choose join strategy and the e-business platform will choose invest strategy. There is at least one probability which should be met, $\beta > \frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$ or $\alpha > \frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$, which means at least one of the both sides' expected income involved in the game is greater than the cost of input, the farmers believe choosing the join strategy will benefit themselves, or e-business platform believe choosing invest strategy will benefit itself.

The polyline *EDG* is the boundary line where the whole system converges to the coordinate point *O* (0,0) or the coordinate point *E* (1,1). When the system initial state is located at the lower left of the polyline *EDG*, the system will eventually converge to the coordinate point *O* (0,0). When the initial state of the system is located at the upper right of the *EDG*, the system will eventually converge to the coordinate point *F* (1,1). The initial position of the system determines the evolutionary trend of the system.

Suppose the probability that the farmers chooses the join strategy is α, the probability that the e-business platform chooses the invest strategy is β, When α and β satisfy the relationship $\beta = 1 - \alpha$, the probability of converging to the coordinate point *F* or the coordinate point *O* is equal. When the relationship $\beta > 1 - \alpha$ is satisfied by α and β, the area of the quadrilateral *OEDG* is larger than the area of the quadrilateral *EFGD*, the probability of converging to the coordinate point *O*(0,0) is lager than the probability of converging to the coordinate point *F*(1,1); When $\beta < 1 - \alpha$ is satisfied by α and β, the area of the quadrilateral *OEDG* is smaller than the area of the quadrilateral *EFGD*, the

probability of converging to the coordinate point $F(1,1)$ is lager than the probability of converging to the coordinate point $O(0,0)$.

5. Interpretation of evolutionary game model

According to the analysis of evolutionary game above, we can conclude that:

The parameters of the game under the different strategy options can change the value of $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$ and $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$, the area of the quadrilateral *OEDG* and the quadrilateral *EFGD* will also change, and the evolution direction of the system will develop in the expected direction. The model is explained as follows:

5.1 Explanation of parameters of c_e and c_{fi}

c_e is the investment and operating costs of e-business platform under the investment strategy. c_{fi} is the money paid by the farmers for preparing to join the transcation in the e-business platform.

When c_e reduced, the value of $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$ become smaller. The position of point *D* moves to left. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral EFGD increases, the probability of the system evolving to point $F(1,1)$ is increasing.

When c_e reduced, the value of $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$ become smaller. The position of point *D* moves downwards. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point $F(1,1)$ is increasing.

From the analysis above, reducing the preparation cost of the farmers to join the platform transaction and reducing the investment and operating cost under the investment strategy of the e-business enterprises will be conducive to promoting the promotion and application of the "Internet +" model dominated by the e-business.

5.2 Explanation of parameters of c_z and c_b

c_z is the information cost of finding transaction for the farmers in non-e-business enviroment. c_b is the profit of e-business platform under the non-investment strategy.

In the case of other parameters unchanged, the value c_z of becomes bigger, the value of $\frac{c_{fi}}{e_f \cdot (r_{ne} + p_{ne} - r_e - p_e) + c_z}$ becomes smaller. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point $F(1,1)$ is increasing.

In the case of other parameters unchanged, the value c_b of becomes smaller, the value of $\frac{c_e}{e_f \cdot r + e_f \cdot r_e - c_b}$ becomes smaller. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point $F(1,1)$ is increasing.

From the analysis above, when the transaction is not conducted in the e-business platform, the higher the information cost of the farmer looking for the transaction opportunity, the easier it is for the farmer to join the e-business platform to trade. When the cost of dealing with transaction defaults is reduced, it means that the business platform is more comprehensive and effective in the transaction management of the transaction in the platform. It also shows that the soundness of the trading system

in the electric business platform, the sound trading system and the transaction default management are conducive to promoting the e-business trade mode.

5.3 Explanation of parameters of r_e, r_{ne}, p_{ne} and p_e

r_e is the ratio of transaction costs and turnover paid by farmers in e-business platform, r_{ne} is the ratio of transaction costs and turnover paid by farmers in non-e-business enviroment, $e_f(r_{ne}-r_e)$ represents the difference between the transaction costs that farmers need to bear in two different trading environments. The higher the value, the higher the transaction cost of the transaction without the use of the platform.

p_{ne} is the probability of dealing with a breach of contract to farmers in non-e-business enviroment, p_e is the probability of dealing with a breach of contract to farmers in e-business platform. The higher the value of $p_{ne}-p_e$, the higher the risk of a transaction which is not conducted in the e-business platform, the corresponding default loss $e_f\cdot(p_{ne}-p_e)$ will be greater.

In the case of other parameters unchanged, the value $r_{ne}-r_e$ of becomes bigger, the value of $\frac{c_{fi}}{e_f\cdot(r_{ne}+p_{ne}-r_e-p_e)+c_z}$ becomes smaller. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point *F*(1,1) is increasing.

In the case of other parameters unchanged, the value $p_{ne}-p_e$ of becomes bigger, the value of $\frac{c_{fi}}{e_f\cdot(r_{ne}+p_{ne}-r_e-p_e)+c_z}$ becomes smaller. In this case, the area of the quadrilateral *OEDG* becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point *F*(1,1) is increasing.

From the analysis above, the more farmers' transaction cost saved the more willingness they want to join the e-business platform. The more farmers' transaction risk reduced the more willingness they want to join the e-business platform.

5.4 Explanation of parameters of e_f and r

e_f is the total transaction value of agricultural products owned by farmers. r is the return rate of the total turnover in e-business platform given by farmers to the e-business platform.

In the case of other parameters unchanged, the value e_f becomes bigger, the value of $\frac{c_e}{e_f\cdot r+e_f\cdot r_e-c_b}$ and $\frac{c_{fi}}{e_f\cdot(r_{ne}+p_{ne}-r_e-p_e)+c_z}$ becomes smaller, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point *F*(1,1) is increasing.

In the case of other parameters unchanged, the value r becomes bigger, the value of $\frac{c_e}{e_f\cdot r+e_f\cdot r_e-c_b}$ becomes smaller, the value of $\frac{c_{fi}}{e_f\cdot(r_{ne}+p_{ne}-r_e-p_e)+c_z}$ does not change, the area of the quadrilateral *EFGD* becomes larger, and the chance of eventually falling on the quadrilateral *EFGD* increases, the probability of the system evolving to point *F*(1,1) is increasing.

From the analysis above, the more farmers' turnover of transaction the more profit the e-business platform make. It is conducive to promoting the promotion and application of the e-business model.

6. Conclusion

With the help of e-business platform, farmers can learn more about agricultural products market information and agricultural prices, and can promote agricultural products trading.

In order to promote the development of the e-business model, the government should increase investment in information infrastructure and reduce the cost of using e-commerce platform for farmers. The government should strengthen the construction of citizens' credit system and reduce the risk of default in transaction in e-business platform. In addition, the government should give e-business enterprises more preferential policies to encourage the platform serve the transaction of farmers'.

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