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Analysis of Multi-Farmers' Technology Adoption Behavior

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Abstract

Due to farmers' limited knowledge and judgment ability, obvious herding behavior during the process of technology innovation adoption is a common phenomenon. In this light of thinking, this paper constructs game model and spread model of technology innovation adoption of multi-farmers and then develops the empirical analysis. The empirical analysis shows that exchange earnings is an important factor to determine whether herding behavior happens in the process of multi-farmers' technology innovation adoption, and the exchange range and cost also have an effect on the farmers' decision-making behavior adoption.

Keywords*: technology innovation, farmers' behavior, adoption decision, game model*

1. Introduction

In the framework of behavioral economics, human behavior can be affected by psychological factors, such as risk appetite, mental accounting, loss aversion, *etc.* [1-2] these factors mainly depend on individual attitude to the risk. If farmers are completely insulated in the adoption process of new agricultural technology, the decision-making behavior can be analyzed from objective factors and psychological factors of single farmer [3-4].

However, in real life, farmers cannot be completely isolated, and they closely contact with other farmers around by means of exchanging information with each other. In addition, due to the limitation of their knowledge, farmers would pay much attention on decisions of other farmers around and then subconsciously imitate others' actions. In a manner of speaking, herding behaviors present to be widespread among farmers, and especially blindly following aggravates irrational behavior among farmers [5-7].

Therefore, in order to accurately depict farmers' technology innovation adoption behavior, mutual influence among multi-farmers and subsequent herd behavior must be taken into consideration. Also, it is necessary to construct the adoption model of multi-farmers technology innovation.

2. Model Construct of Multi-Farmers Technology Innovation Adoption

2.1 Game Model of Multi-Farmers Technology Innovation Adoption

Burke discusses that in the process of herd behavior analysis using game theory, analysis groups can be divided into two categories, one category is "insiders", and the other one is "outsiders" [8].The analysis of herding behavior can be actually transformed into game model between "insiders' and "outsiders", game model of "insiders" and "insiders", and "outsiders" and "outsiders" game model.

Specific to farmers' innovation technology adoption behavior, "insiders" are farmers who know well about agricultural technology, and can implement them precisely. We assume the decision of "insiders" not influenced by others in the process of innovation technology adoption. For "outsiders", who account for the majority of farmers, game

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model is needed to construct to explore the problem that whether "outsiders" make decisions on their own or just follow others impelled by group psychology.

In the process of generalization and application of agricultural technology innovation, all the farmers confront the problems in terms of whether to adopt new technology and which one to choose. Every farmer can generate one point of view m; in endeavor to make easy to the following up analysis, assume any point of views as $m \in [0,1]$. The finalized decision can be split into self-decision and following others, and indicate these two behaviors as A and B.

Every farmer can be regarded as one subject. The contact among farmers is random, and communications between two farmers compose game units. In the process of each farmer contacting with others, they can get partial information about whether others adopt new technology and what techs they choose, but it is not always the final decisions, and the information can affect farmers' final decisions. From the game theory, the communication behavior of farmers in the process of innovation technology adoption is an incomplete information game model.

From the further analysis we can get the information that farmers who choose A, must analyze relevant information of new technology in order to generate decisions approaching anticipation. Farmers who choose A, can receive exchange earnings ϑ and analytical earnings ψ in the process of communication with other types of farmers. However, this process has to cost certain amount of analytical expenditure c, such as time, money, *etc.* Farmers who choose behavior B have no analytical cost. Hence, they cannot receive analytical earnings, but they can get exchange earnings ϑ through communications with farmers who choose behavior A. In the following session, we present a simple game model of two-farmer technology innovation adoption behavior (Figure 1).

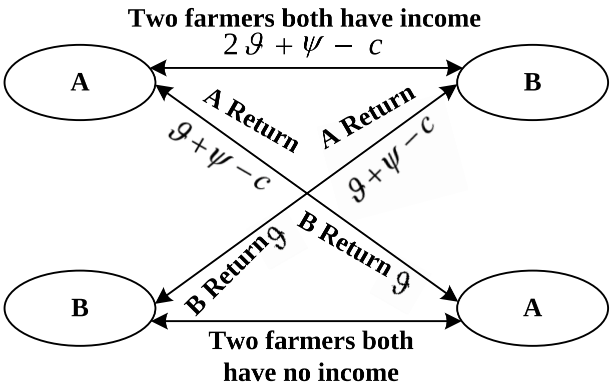

Figure 1. Two-Farmer Behavior Game Model

From Figure 1 we can get that, there are four scenarios for two-farmer communication process. When farmers A communicate with the same group people, they can get analytical earnings and double exchange earnings, but they have to pay analytical cost; when farmers A communicate with farmers B, farmers A can receive analytical earnings and exchange earnings with paying analytical expenditure, and farmers B can get exchange benefits; in the case of farmers B communicating with people in the same group, both of them have nothing to benefit.

Objective of farmers' adopting agricultural technology is to achieve higher expectation value. When they have confidence in the decision making, they choose behavior A; when they have less confidence, they go for behavior B. Assume the probability of all of the farmers choosing behavior B as p, choosing A as $1-p$,so the equation of expectation value when choosing A is shown below:

$$E_A = p(\vartheta + \psi - c) + (1-p)(2\vartheta + \psi - c)$$
$$= (1-p)\vartheta + \vartheta + \psi - c \quad (1)$$

The equation of expectation value when choosing behavior B:

$$E_B = p \times 0 + (1-p)\vartheta$$
$$= (1-p)\vartheta \quad (2)$$

Specific to each farmer, their self-decisions about choosing behavior A or B, can be transformed into the problem which comparing the expectation difference between behavior A and behavior B. We indicate the difference as ΔE , and equation of ΔE is :

$$\Delta E = E_A - E_B$$
$$= \vartheta + \psi - c \quad (3)$$

When $\Delta E < 0$, farmers normally would follow others' behavior to adopt innovation technology; when $\Delta E > 0$, farmers would adopt innovation technology by their own decision; when $\Delta E = 0$, farmers would adopt behavior A and B randomly.

Equation (3) shows that when analytical earnings ψ is bigger than analytical cost c , ΔE is greater than 0 permanently, and farmers will not follow others' behavior. Certainly, this would be an idealized situation. In practice, farmers would follow others' behavior with high possibility, which demonstrates analytical cost always higher than analytical earnings because of farmers suffering from their own limitation.

2.2 Spread Model of Multi-Farmers Technology Innovation Adoption

In Section 2.1, we penetrate into the mathematical basis of individual farmer' choice: self-decision or following others' behavior. In this section, based on Section 2.1, we derive game model of individual farmer into farmers' group spread model.

Assume group farmers who conducting innovation technology consist of N numbers of farmers, the probability q of intra-group of adopting others' behavior B is a variable varies with time t . As time t changes, q changes, group average expectation changes as well. See equation (4):

$$\overline{E} = (1-q)E_A + qE_B$$
$$= (1-q)(\vartheta + \psi - c) + (1-p)\vartheta \quad (4)$$

Hence, the dynamic changes of probability q of choosing to follow others' behavior B can be described by the following equation:

$$\frac{dq}{dt} = q(E_B - \overline{E})$$
$$= -q(1-q)(\vartheta + \psi - c) \quad (5)$$
$$= -q(1-q)\Delta E$$

In equation (5), its stability worthies to pay attention, which is the stabilized probability of group farmers choosing self-decision or following others' behavior in the process of innovation technology adoption, and this is the hinge measurement for herding effect on group farmers. The stabilized condition of variable q implies that q no longer changes, which indicates the condition of $\frac{dq}{dt} = 0$. According to equation (5), the dynamic changes of probability of group farmers adoption behavior is directly related to ΔE .

If ΔE = 0, equation of $\frac{dq}{dt} = 0$ establishes permanently, which means in the case of no difference between self-decision and following others' decision, any probability q of group farmers' behavior tends to be normal; If $\Delta E > 0$, $\frac{dq}{dt} \le 0$, only when $q = 0$ or $q = 1$,

$\frac{dq}{dt}=0$ can be established. However, based on the definition of ΔE, $\Delta E > 0$ indicates the anticipation earning of self-decision is greater, so $q=0$ makes $\frac{dq}{dt}=0$ established to be more consistent with practical situation, which means all of individual farmer adopts the strategy of self-decision. If $\Delta E < 0$, $\frac{dq}{dt} \geq 0$, only when $q=0$ 或 $q=1$, $\frac{dq}{dt}=0$ can be set up，but $\Delta E < 0$ shows the anticipation earnings of following others' decisions can be bigger，hence $q=1$ makes $\frac{dq}{dt}=0$ be more correspond to reality, which is the situation of all of the individual farmer following others' decisions, and this is also the deepest level of herding behavior.

Correspond to the previous assumption of farmers' random views $m \in [0,1]$, information exchange between two farmers is meaningful in the case of only opinions m and m' of two individual farmers have difference. But the difference between m and m' cannot be too significant, or it will weaken the possibility of reaching a consensus from two farmers.

Thus, we use distance range d to restrict this kind of difference. See equation (6):

$$\left|m-m'\right| < d \tag{6}$$

In fact, the difference between two farmers is more embodied in the differences in social status, knowledge level, financial ability and *etc.* So we can also call it as social distance. Farmers with smaller social distance can be easy to communicate and reach consensus.

Opinions variation of two individual farmers can be described by the following equation:

$$\begin{cases} m = m + \eta(m'-m) \\ m' = m' + \eta(m-m') \end{cases} \tag{7}$$

In this equation, η indicates the moderating effect factor to farmers generated from communication. When η =0, two farmers would retain their own opinions, which declares that communications have no moderating effect; when η =0.5, two farmers would reach a consensus, new opinions are the mean value of two old opinions; when η =1, two farmers would exchange their opinions, which rarely happens in reality.

Therefore, for different types of farmer group the values of η are different. For the stubborn farmer group, the value of η should be small; for the farmer groups which are easy to take others' advices, the value of η should be big.

3. Empirical Analysis of Multi-Farmers Innovation Technology Adoption

In the process of innovation technology adoption, farmers may be influenced by others to a large extent, and their decision would change owing to this influence, so that they tend to present upward convergence, which is called herding behavior. This paper constructs dynamic spread model on account of game theory, and based on this model, it will develop empirical analysis about multi-farmers innovation technology adoption. In the process of multi-farmers innovation technology adoption, the initial choice of each farmer can be measured by single-farmer decision model. After the formation of prime decision, each farmer would communicate with each other, the exchange earnings and exchange scope would contribute to significant effects on terminal decision consequence.

Exchange earnings indicate the earnings received from farmers' exchanging information; exchange scope is used to describe the ability of one farmer can communicate with others. The larger the scope is, the more numbers of one farmer communicate with others, and vice versa. In the following part, we will investigate the effects on multi-farmers innovation technology adoption from two different perspectives.

3.1 Effects of Exchange Earnings on Multi-Farmers' Innovation Technology Adoption

The game model of multi-farmers innovation technology adoption has been expounded in equation (1), equation (2) and equation (3); spread model can be interpreted in equation (4) and equation (7).

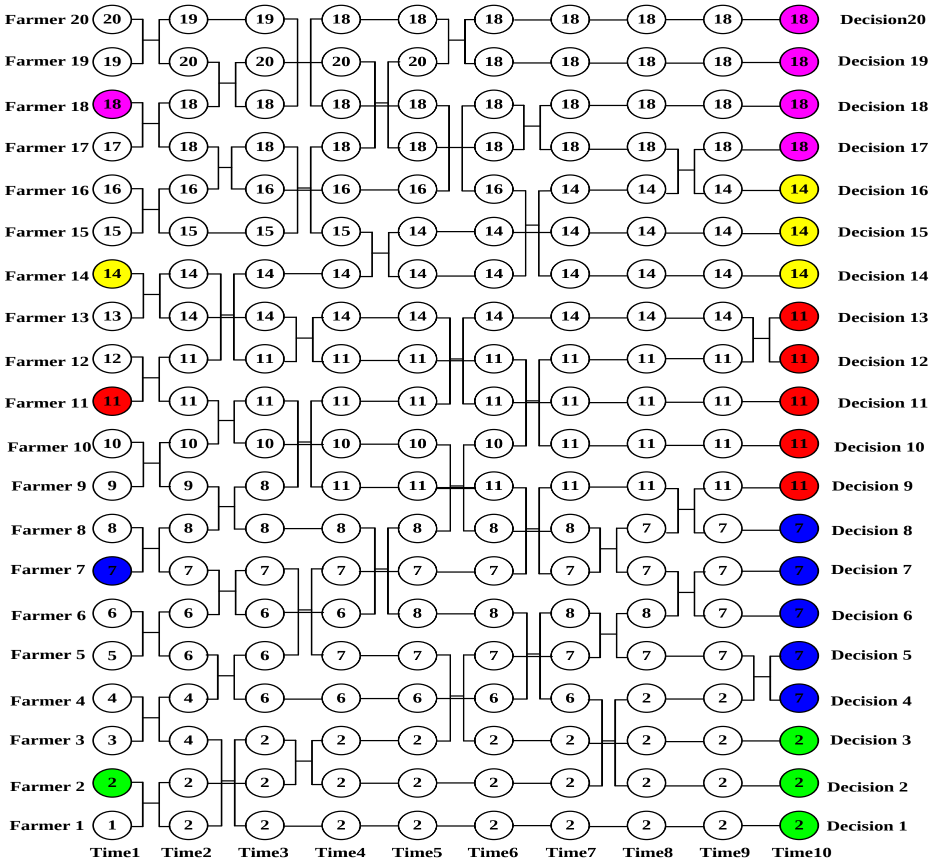

Figure 2. Exchange Earnings ϑ=2.0, Multi-Farmers' Technology Adoption Behavior

In an endeavor to develop the empirical analysis of game model and spread model, we firstly set up initial conditions of simulation process, assume the numbers of farmers Num=20, simulation time nodes t=10, exchange earnings ϑ=2.0, exchange cost $c=1.1$, regulatory factor of farmers 'communication η=0.5, the scope of farmers' communication scale = 4 (each farmer can exchange information with other four farmers frequently). Based on above conditions, relation curve between multi-farmers innovation technology adoption decisions and exchange earnings ϑ can be shown in Figure 2. In Figure 2, assuming 20 farmers have different initial innovation technology adoption and each farmer can only exchange information with upward two farmers and downward two farmers, which signifies farmers' communication scope four. Because of farmers 1 and farmers 20 located in the boundary location, so they can only communicate with two farmers next to them. In the meanwhile, assuming the initial communication condition of twenty farmers communicate with farmers next to them orderly, then communication appears to be randomly.

The ultimate decision results reveal that there are five consequences of farmers' adoption behavior: farmer 1, farmer2 and farmer 3 all adopt decision from farmer 2; farmer 4 – farmer 8 adopt decision from farmer 7; farmer 10 – farmer 13 adopt farmer 11's decision; farmer 14 – farmer 16 adopt decision from farmer 14; farmer 17- farmer 20 adopt farmer 18's decision. The results illustrate that in the case of exchange earnings ϑ=2.0, multi-farmers technology adoption behavior has exerted herding behavior, which means they do not tend to adopt the same technology, and generate the differentiation decision of adopting five different technical projects. Further investigate in the case of exchange earnings consistently reducing, the influences on multi-farmers' technology adoption behavior. (See Table 1)

Table 1. Exchange Earnings Change, Multi-Farmers' Technology Adoption Behavior

Num	t	ϑ	d	Scale	Decision No.	Convergence time
20	10	2.0	0.5	4	5	——
20	10	1.5	0.5	4	2	——
20	10	1.0	0.5	4	1	5
20	10	0.5	0.5	4	1	2

From the data and results of Table 1, we can see that the conditions set up for four simulation experiments, except exchange earnings ϑ changes; farmers numbers Num are all 20, simulation time nodes t are all 10, exchange regulatory factor η is 0.5, and farmers communication $Scale$ is 4. Farmers exchange earnings ϑ changes accordingly to four different scenarios: 2.0, 1.5, 1.0, 0.5, corresponding to four decision numbers: 5, 2, 1, 1, respectively.

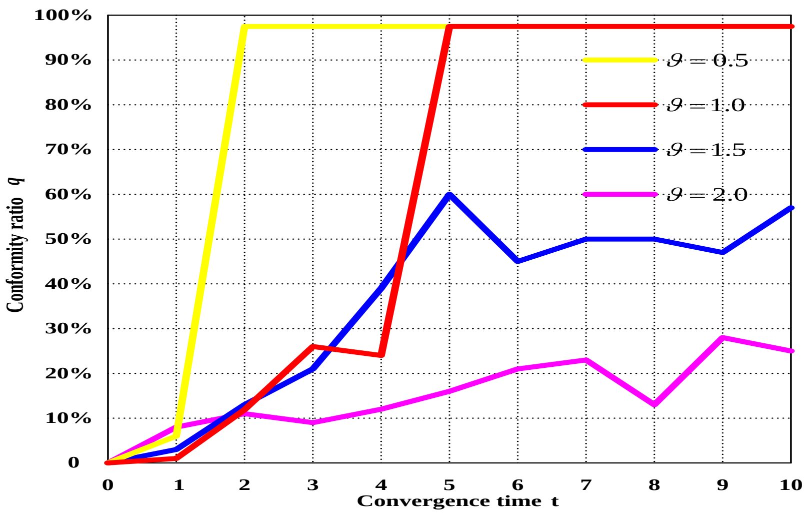

Figure 3. Convergence Time and Conformity Proportion

As a matter of fact, the visualized results of first group experiment indicates the circumstances of ϑ=2.0, and twenty farmers formalize five different adoption results, and no herding effects emerged. When ϑ=1.5, twenty farmers generate two different adoption, no herding effects as well. In the case of ϑ=1.0, twenty farmers tend to adopt the same type of technology, which exerts herding effects. When ϑ=0.5, twenty farmers adopt the same technology just similar last scenario, but the difference is, in this case, the convergence time is only two time nodes; twenty farmers' convergence behavior tend to be more rapidly. Compare above four different experiments' results, we can see that the lower of farmers' communication earnings, the herding effects of multi-farmers innovation technology adoption behavior tend to be more significant, speed of formation of convergence effects is faster.

In order to observe the results of herding effects intuitively, we draw a curve to show the convergence time and twenty farmers' conformity proportion from the four groups of experiments.（See Figure 3） From Figure 3 we can see that, the curves of exchange earnings $\vartheta = 0.5$ and $\vartheta = 1.0$ correspond to the conformity proportion are all nearly 100%, and convergence time correspond to 2 units of time and 5 units of time, which shows consistency with the herding effects of adoption from two experiments. Two curves of exchange earnings $\vartheta = 1.5$ and $\vartheta = 2.0$ correspond to conformity proportions are 57%and 25% respectively. Owing to the fact that herding effects have not happened, self-analysis and formation of adopting technology account for relatively large portion.

3.2 Effect from Exchange Scale on Multi-Farmers' Innovation Technology Adoption

Assume farmers quantity Num = 20, the simulation time nodes t =10, farmers communication regulatory factor η =0.5. In order to meet the decision-making behavior of the 20 farmers can generate herding effects, set the exchange earnings ϑ =1.0 to be fixed, exchange cost c from levels of 1 to 1.9 continuing to increase, then in the case of the scopes of communication are 4, 6, 8, respectively, the changes of time convergence nodes of multi-farmers' technology innovation adoption behavior as shown in Figure 4.

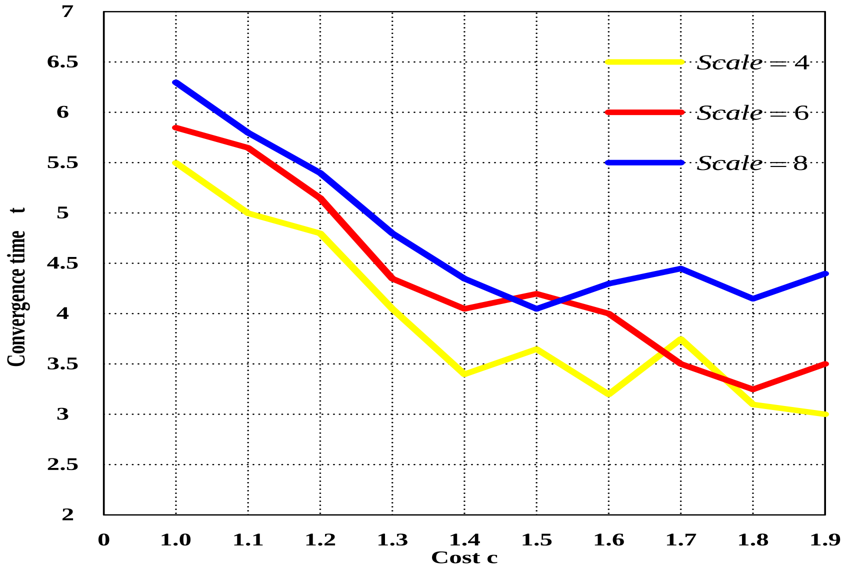

Figure 4. Changes of Exchange Scope and Exchange Cost Lead to Convergence Time Changes

In the Figure 4, see from the comprehensive performance of three curves, regardless of the farmers' communication range, with the increase of exchange cost, farmers' exchange earnings remain unchanged, and earnings obtained by the individual analysis will continuously decline, which leading to the possibility of prone to follow blindly gets even bigger, and the convergence speed of herding effects gets faster. We use the change curve of $Scale$ =4 as an example. When the communication cost c =1.1, time convergence nodes 5 and when the communication cost c =1.9, time convergence node is only 3.

The scope of communication also has great influence on multi-farmers technology adoption. Comparison between the three curves in the Figure, along with the continuous expansion of the scope of the exchange, the possibility of farmers tends to follow blindly decreases, and time convergence node of herding effect also increases. This shows that, with expand of communication range; farmers receive more knowledge from others. For the understanding of technology return, technology itself and risk situation appears to be more comprehensive; this would also increases knowledge and confidence of decision-making and thus gives up following others blindly.

4. Conclusion

In conclusion, we summary several theories about multi-farmers' innovation technology adoption:

1. Farmers regarded as limited rational individuals, in the decision-making processes related to technology adoption, can be influenced by other farmers. The impact extent can come to change the original decision, which means the herding effects can be greater than the impact of risk attitude, mental account, rate of return, return probability, loss aversion and other factors.

2. Exchange earning is an important determinant of whether farmers' decision behavior can trigger herding effects. When the exchange earnings are large enough, the farmers obtain enough knowledge and experience of the self-decision through the exchange benefits. Herding behavior is not happening due to following blindly; when the exchange earnings is very small (such as $\vartheta = 1.0$), herd behavior can be likely to occur, and along with the exchange profits decreases, formation speed of herd behavior gets more faster.

3. The communication scope and communication cost also have an effect on multi-farmers' adoption behavior. Exchange cost increases will lead to enhance the possibility of herding behavior and the speed of convergence. Expand the scope of communication can reduce the possibility of herding behavior and the speed of convergence.

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References

[1] T. J. Tarnoczi and F. Berkes, "Sources of information for farmers' adaptation practices in Canada Prairie agro-ecosystem", vol. 98, no. 1, **(2010)**, pp. 299-305.
[2] N. R. Kitchen, "Emerging technologies for real-time and integrated agriculture decisions", Computers and electronics in agriculture, vol. 61, no. 1, **(2008)**, pp. 1-3.
[3] X. Gine and D. Yang, "Insurance, credit, and technology adoption: field experimental evidence from Malawi", Journal of Development Economics, vol. 89, no. 1, **(2009)**, pp. 1-11.
[4] Z. Gan and S. H. P. Lau, "Demographic structure and overlapping generations: a simpler proof with more general conditions", Journal of Mathematical Economics, vol. 46, no. 3, **(2010)**, pp. 311-319.
[5] T. L. Friesz, "Foundations of the calculus of variations and optimal control", Dynamic Optimization and Differential Games, **(2010)**, pp. 79-146.
[6] N. Czernich, "Broadband infrastructure and economic growth", The Economic Journal, vol. 121, no. 552, **(2011)**, pp. 505-532.
[7] D. Comin and B. Hobija, "An exploration of technology diffusion", The American Economic Review, vol. 100, no. 5, **(2010)**, pp. 2031-2059.
[8] J. L. Burke, "Virtual determinacy in overlapping generations models", Econometrica, vol. 77, no. 1, **(2009)**, pp. 235-247.

