Modelling and simulating adoption behaviour of enterprise environmental innovation technology under niche strategy

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Abstract

Due to the complexity and diversity of human behavior, social system is unpredictable and difficult to be quantified. In this paper, we used computational experiment method to simulate the adoption behaviour of enterprise environmental innovation technology under different scenarios. The model was rebuilt referring to the abstraction of real world. It analyzed the relationship between internal dynamic mechanism and policy intervention during the emerging of stable innovation niche. The experimental results showed that policy intervention can influence the adoption of enterprise environmental innovation technology. Especially, through the combination of a set of policy, the advantages of environmental innovation niche can be fully employed in different market. By reducing the risks of adopting environment innovation technology, new product market can realize the phenomenon of "long tail". This would inspire more enterprises to adopt environmental innovation technologies.

Keywords: environmental innovation, niche, computational experiment, simulation

1 Introduction

To solve increasing environmental problems, it is important for enterprises to adopt new environmental technologies and carry out environmental innovation continually (Juan, 2011; Bergek and Berggren, 2014). Enterprises always adjust their strategy according to the demand of market. So the key of environmental innovation is that customers adopt environmental innovation product. However, enterprises must pay high premium expenditure for the new design of environmental innovation product, cleaner production, package for innovation product, distribution channel and advertising for innovation product, new public relation strategy, and so on (Joakm B and Marcus L, 2014). These would add the cost of product and lead to a certain degree of higher payment for consumers supporting the environmental innovation product (Gilli et al., 2013). Higher prices lead to obvious "attitude – behavior gap" among consumers (Cowe and William, 2000) when they make real purchase decision. Consumers seldom actually pay for environment innovation product although they said they would. This hinders the enthusiasm of enterprises to adopt environmental innovation technologies.

According to niche strategy (Schot et al., 1994), by the help of policy instruments, enterprises can increase their success probability when adopting environmental innovation technologies. Meanwhile, policy support can reduce the diffusion time for innovation technologies. Niche strategy has been used in many fields of sustainable development, such as wind energy (Kemp et al., 2001), renewable energy technology (Tsoutsosand and Stamboulis, 2005; Van der Laak et al., 2007; Caniels and Romijn, 2008; Lopolito et al., 2011; Lopolito et al., 2013), and so on. Scholars have explored the reasons for success or failure of innovation technology under specific conditions (Kevin et al.,2014). However, they seldom studied the relationship between internal dynamic mechanism and policy intervention, and didn't discuss the requirements for the emerging of stable innovation niche. In fact, new market of environmental product is influenced by many aspects, such as the product itself, related supporting imperfect, the mature degree of market mechanism, and so on. So policy supports are essential at the beginning of the new market. On the other hand, different combination of policy has its own mechanism and would have different effect on the market. Therefore, from the perspective of consumer psychology and behavior characteristics, we can observe consumers' reflect while they choose innovation products under different policy situation, and analyze the condition environmental innovation niche appears. This would have great significance to promote the market for environmental innovation products and inspire more enterprises to adopt environmental innovation technology.

In this paper, computational experiment method of social science (Xue 2013; Sheng and Jin, 2012; Jin and Sheng, 2012; Li et al, 2013) is employed to simulate the process of enterprises' adoption. We extracted the characteristics of a kind of commodity in real market, using multi-agent technology to construct a computational experimental model. The model referred to the real adoption process when enterprises facing environmental innovation technology. It simulated the forming procedure of niche

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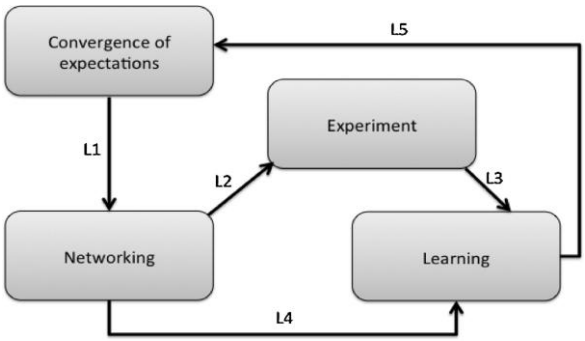
market of innovation product and the diffusion procedure of innovation technology. Then it analyzed the diffusion trajectory. By adjusting parameters, it also simulated the effect of different combination of policy on the emerging of niche market of environmental innovation products.

2 The computational model

Enterprises always decide to adopt a new technology according to their expectations for market prospect. However, the expectation value is not stable during the learning process. It changed with the understanding of the market and related policies and regulations. All of the enterprises participate in the innovation form a social network. By the interaction of each other, network members share factors conducive to technological innovation (such as reduce investment and cost by expanding the scale and mutual cooperation, etc.). At the beginning, because only a small number of enterprises participate in the innovation, there is lack of experience, customers' satisfaction is low. With the expansion of network, members can exchange technology experience and further improve market mechanism to continuously improve product quality, reduce costs, attract more consumers, and expand the size of market. Along with the more frequent information exchanges, more and more enterprises improve their expectations for innovation product, and eager to join the new product field. This would accelerate the diffusion of innovation technology and help to form niche market. The interaction mechanism within niche is shown in Figure 1.



Source: *Adapted from Raven (2005)*

FIGURE 1 Mechanisms interaction within the niche.

1) There are *n* heterogeneous traditional enterprises, corresponding to traditional enterprises produce a certain kind of production in real life. Enterprises have different additional earning expectations compared environmental innovation product with traditional product according to their own knowledge. Meanwhile, because of difference original production condition, the additional production cost of innovation product is different compared with traditional product. When one's additional earning expectation is greater than the additional production cost, the enterprise would adopt environmental innovation technology, and switch to an environmental innovation enterprise.
2) The maximum additional earning of environmental innovation product is *R*. However, due to the immature innovative technology, developing market and other reasons, the actual additional earning is uncertain while adopting innovative technology. So, the actual additional innovation earning rate of enterprise *i* on *t* time-step is $p_{i,t}(0 \le p_{i,t} \le 1)$ and the actual additional innovation earning of enterprise *i* on *t* time-step is $R \times p_{i,t} - C_{i,t}$.
3) When the actual earnings of environment innovation enterprises are larger than their expected earnings, other traditional enterprises will increase their expectations about future earnings using innovation technology, else, their expectations for innovation technology will decrease.
4) Along with the accumulation of experience and knowledge, enterprises adopted environmental innovation technology would lower their production costs and market risks, and their actual earnings will increase at the same time.
5) Enterprises are in a complex network environment of both competition and cooperation. Many environmental innovation enterprises randomly generate several small sub networks. Enterprises in the same sub network learn from each other, jointly develop market and share innovation knowledge. They reduce their production costs and market risks through the accumulation of knowledge. At the same time, environmental innovation enterprises compete on the new market, market risk is higher for enterprises whose production costs are higher than other enterprises, and their earnings always lower.

Based on above assumptions, we constructed the computational experimental model referring to real world. The model simulated the process of diffusion of environmental innovation technology under different scenarios. Scenario 1 represented a hypothesis without policy intervention, it simulated the diffusion process in different risks of market. In scenario 2, we randomly selected m enterprises to spread the knowledge of environmental innovation technology. By this way, to promote the selected enterprises to understand the environmental innovation technology, improve their expectations for innovation product. In scenario 3, we not only selected m enterprises to spread the knowledge about environmental innovation technology, but also implement subsidies for innovation enterprises to reduce their production cost while adopting environmental innovation technology.

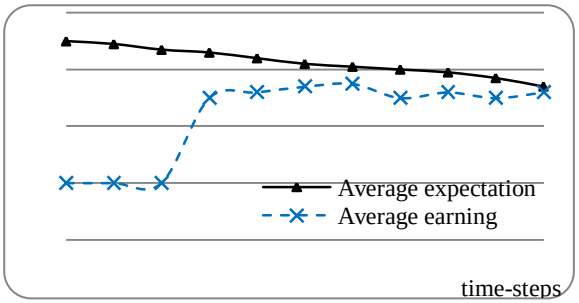
3 Experiments and results

Assume the number of enterprises n is 100, enterprises' additional earning expectations for environment innovation products follow the normal distribution (mean 0.5, variance 0.1), the additional costs of innovation enterprises than traditional ones follow the normal distribution (mean 1.5, variance 0.08), the initial knowledge of enterprises about environment innovative products is a random number of 0-1, the maximum additional earning R is 2, enterprises' average cost is 1.5, the actual average earning rate in high risk market is 40%, and it is 70% in low risk market, the initial average expectation of enterprises is 0.5,

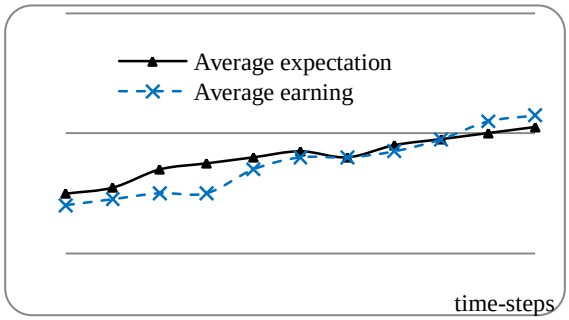
the simulation cycles are 100. Based on above assumption, we constructed enterprise agents, design their self learning logic and interaction logic, and built the computational experimental model. By changing parameters, simulate different combinations of policy, and explore the law of diffusion trajectory of environment innovation technology.

3.1 DIFFUSION TRAJECTORY WITHOUT POLICY INTERVENTION

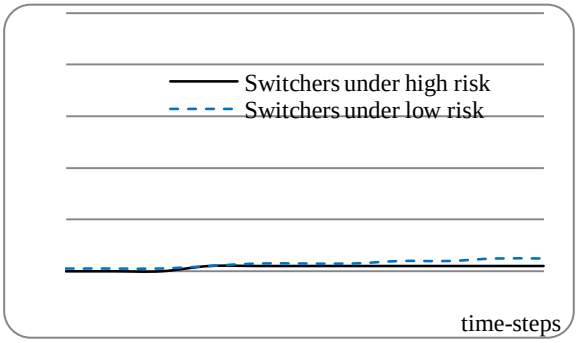
Based on above parameters, we simulated the diffusion process of environmental innovation technology in high risk market and low risk market. The result is shown in Figure 2.



a) Average expectation and earning under high risks



b) Average expectation and earning under low risks



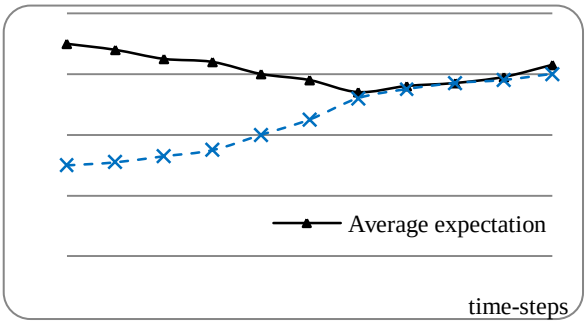
c) Switchers under different risk situations

FIGURE 2 Diffusion trajectory without policy intervention

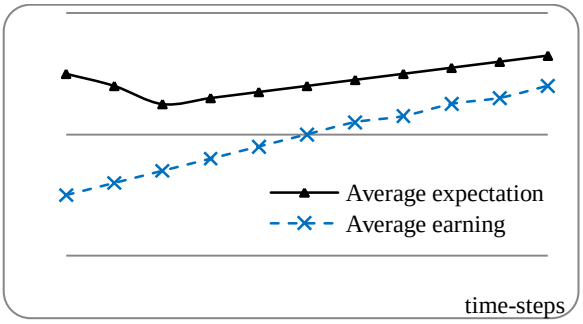
In high risk market, the actual incomes of environmental innovation enterprises are lower than their anticipate incomes. Therefore, enterprises adjust their expectations in the following cycles. This makes it more difficult for innovation technologies to diffuse. In low risk market, the expectations and the actual incomes are quite equal. However, because of the low actual incomes, the diffusion speed of environmental innovation technology is slow.

3.2 DIFFUSION TRAJECTORY WITH SPREADERS

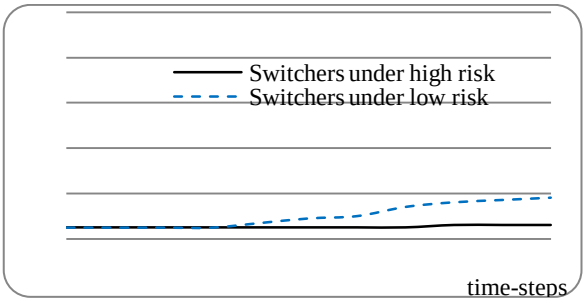
In this scenario, we select m ($m = 5$) enterprises as spreaders. We first spread environmental innovation technology knowledge to these enterprises to improve their expectations for the innovation product. Then they become pioneers and switch to innovation enterprises. The diffusion trajectory of environmental innovation technology under this scenario is shown in Figure 3.



a) Average expectation and earning under high risks



b) Average expectation and earning under low risks



c) Switchers under different risk situations

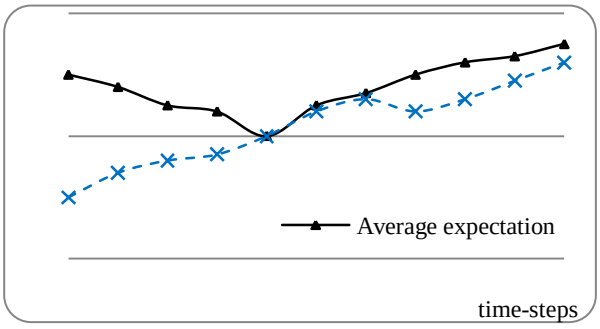
FIGURE 3 Diffusion trajectory with spreaders

In this scenario, enterprises' initial average expectation for innovation product is significantly improved compared with the former scenario. In high risk market, because of the lower actual incomes, enterprises' expectations decrease in the former 60 cycles. Then, with the accumulation of experiences and the maturity of market, average actual incomes increase, and lead to higher average expectations. In low risk market, the average actual incomes increase eventually, and the average expectations begin to increase

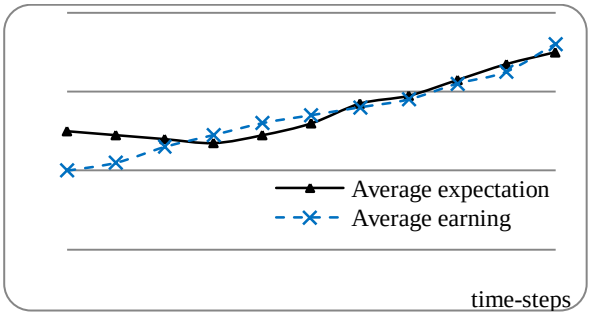
after cycle 20. The number of enterprises adopt environmental innovation technology is increased and the diffusion speed is quicker than scenario 1.

3.3 DIFFUSION TRAJECTORY WITH SPREADERS AND SUBSIDIES

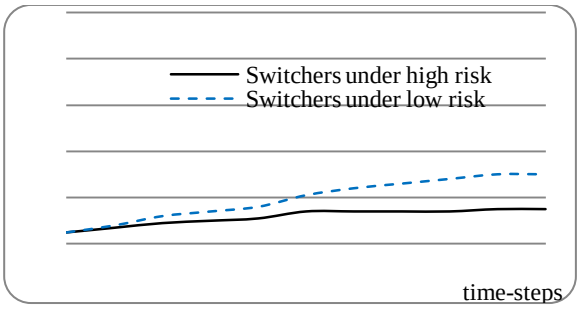
In this scenario, we not only select $m(m = 5)$ enterprises as spreaders, but also provide subsidies($f = 0.1$) to enterprises adopt environmental innovation technology. The diffusion trajectory of environmental innovation technology under this scenario is shown in Figure 4.



a)Average expectation and earning under high risks



b)Average expectation and earning under low risks



c)Switchers under different risk situations

FIGURE 4 Diffusion trajectory with spreaders and subsidies

In scenario 4, there are many enterprises adopt environmental innovation technology even in high risk market. In low risk market, the average expectation for innovation product is about equal to actual income. High expectations make more enterprises to join in innovation network, which accelerate the accumulation of experiences and knowledge. At the same time, high actual incomes increase the expectations of enterprises have not adopted the new technology, and lead them to join in the innovation network. Therefore, environmental innovation technology is diffused quickly. On the other hand, when the expectation value raised to a certain level can't be reached by actual income, enterprises would lower their expectations. So the expectation value has a limited value, and the market tends to be stable.

4 Conclusions

In this paper, we developed an agent-based model to simulate the diffusion trajectory of environmental innovation technology. In order to find out the mechanism of the rise of a stable innovation niche and the role of policy intervention, we assumed several scenarios corresponding to different combination of policy interventions. Generally speaking, we found that agent-based computational experiment is a useful analytical tool for mechanism research and long-term policy analysis, especially when the investigating system characterized by rather complex behaviours (e.g. heterogeneity, self-learning, adaptive behaviour).

The model developed in this study helped us to simulate the operation process of the strategy of niche management. As we discussed, there are four interrelated mechanisms affecting niche's development: convergence to high expectations, networking, learning, and experiment. These four are the basis for the success of innovation niche. Meanwhile, market and policy are external items influence enterprises' innovation adoption. We carried out repeated simulation experiments under different scenarios. In the absence of any policy intervention, even in low risk market, the diffusion speed of innovation technology is slow. Interestingly, each policy action modelled (i.e. subsidy or information spreading) showed its effect to the emergence of a stable innovation niche. However, in the case of merely information spreading scenario, we observed a drastic decrease of anticipate in the earliest stage in high risk market. Because of the low average actual income, more and more enterprises lower their exception, which delayed significantly the emergence of the innovation niche. Conversely, a policy action based on the combination of information spreading and subsidies succeeded in winning a high number of switchers and, in turn, facilitated the emergence of a dense network through which knowledge was effectively exchanged, resources were rapidly shared and, eventually, costs of production were reduced. As a consequence, environmental innovation technology was quickly spread.

The occurrence observed through this model showed the important role of policy interventions. Meanwhile, it indicated that government should employ different combination of policy interventions in terms of different market situation. In order to develop suitable policy, it is important for policy-makers to predict the effect of a certain policy action in advance. In this regard, agent-based computational experimental method can be employed as a useful tool.

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