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High Tech Innovation Diffusion and Intervention Based on Multi-agent Simulation

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Abstract: Based on the emergence of micro individual behavior at the macro level, this paper explains the formation of technological innovation diffusion wave from the interaction with the market and adopters. Theoretically, it changes the traditional assumption that the technological innovation diffusion wave is exogenous. In the framework of coordination and evolution, the diffusion wave of technological innovation is endogenously explained, on the one hand, enterprises can arrange and plan their own technological innovation behavior according to the diffusion wave of technological innovation; on the other hand, in the formation model of technological innovation diffusion wave in this paper, the fundamental reason for the formation of diffusion wave of technological innovation lies in the asynchrony between technological innovation and market, which further forms The diffusion of technological innovation is not synchronized with the market. If such asynchrony can be eliminated, the diffusion wave will be weakened or even disappeared. Therefore, technological innovation must be market-oriented. What enterprises need to do is to weaken the diffusion wave as much as possible, and adjust the innovation policy according to the formation of diffusion wave to promote the development of enterprises. In addition, innovation subsidies and tax incentives can significantly promote innovation diffusion.

Keywords: Innovation Diffusion, Intervention, Multi-agent Simulation.

1. Introduction

China's president Xi Jinping has clearly put forward that "implementing the strategy of innovation driven development determines the future and destiny of the nation". Schumpeter, the originator of technological innovation, divides technological progress and innovation process into three stages: invention, innovation and diffusion. Innovation diffusion theory is devoted to exploring how new ideas, new products and new methods can be spread in society (Rogers 1962). The term "diffusion" includes many concepts, including infection, imitation, social learning and organizational communication (strang and Soule, 1998).

2. Literature Review

Since the 1960s, the market tradition of diffusion research has become stronger and stronger. Early efforts to establish mathematical models of new product diffusion were rooted in infectious disease models, biological and ecological analogies. Four and woodlock (1960) developed a simple penetration model to predict the size of grocery store products. Mansfield (1961) developed a model to explore which factors determine the rapid diffusion of new technologies from one manufacturer to another. The most influential model is bass (1969), which defines the diffusion of innovation as an infectious process driven by external influences (advertising, mass media) and internal influences (oral transmission). More specifically, bass assumes that the possibility of an individual adopting a new product in time t depends on two aspects: the internal influence parameter q and the external influence parameter P. the internal influence parameter is related to the number of previous adopters, while the external influence parameter is not related to the number of previous adopters. On this basis, the condition for an individual not adopted in time t is defined by the model f (T) / (1-f (T)) = P + QF (T).

The comprehensive model based on macro level, such as bass, can only belong to the empirical generalization based on differential equation. Because there is no obvious consideration of the heterogeneity of consumers and the complex dynamics of social process, it is difficult to truly reproduce the innovation diffusion process in the real world.

Cellular automata (CA) is a kind of micro simulation model, which can simulate individual behavior and attributes at the micro level, and build the model from bottom to top.As the basic model of cellular automata simulation, there are obvious defects: (1) cellular state has only two states of adoption and non-adoption in the hypothesis of homogeneous individuals, and the lack of heterogeneous simulation is an important defect of this kind of model; (2) the embodiment of neighbors in rules and local rules are too simple, such as only calculating the number of adopters in neighbors, without considering the market Strategy. For these reasons, the basic cellular automata model of innovation diffusion can only get the time function of the number of adopters, which can be obtained in the basic mathematical model.

In order to overcome the limitations of cellular automata model and open up a new research channel, agent-based model and simulation have been widely used in diffusion research in recent years. This trend is consistent with the broader development of social sciences. One of the reasons why this method from detail to overall has been paid more attention in recent years is that the heterogeneity, social interaction and decision-making process of a single consumer are explicitly entered into the model to simulate the complex emergence phenomenon, which is often not achieved by the traditional model.

Heterogeneity is an important feature of agent-based innovation diffusion model. It is the simulation at the individual level that makes the agent-based innovation diffusion model better depict the real world, and has good interpretation and prediction ability. However, when explaining diffusion, they focus on market demand, that is, the adopters of diffusion, while ignoring the suppliers of diffusion. In fact, consumers' cognition and their willingness to pay will generate supply side competition. In turn, competition determines pricing and thus consumer adoption and perception. Supply and demand promote the diffusion of technological innovation in the process of co evolution.

Since the 1980s, cellular automata and agent-based simulation models have attracted more and more attention from scholars. Because agent-based simulation models can better reflect the heterogeneity of market entities and accommodate more market variables, the macro level diffusion characteristics emerge through multi-agent interaction and simulation at the micro level, which is the unique charm of agent-based simulation model, Considering the development trend of Social Science in recent years, agent-based simulation model will become the main research method of innovation diffusion theory.

3. Key Concepts and Basic Assumptions

3.1 Key Concepts

(1) Macro Innovation and Micro Innovation

For technological innovation, this model adopts the classification method of macro innovation and micro innovation. Mokyr (1990) called those major technological changes macro innovation. He thought that macro innovation was a fundamental new idea without precedent. For example, clocks, windmills and blast furnaces in the late Middle Ages in Europe created completely different new technologies. Mokyr believes that macro innovation is similar to the emergence of new species in biology. According to this analogy, macro innovation can be regarded as the emergence of a "new species of technology". Macro innovation is the core force behind long-term growth and structural change. It is accompanied by a series of micro innovations. These micro innovations do not change the core content of macro innovation, but only improve and improve on this basis, for example, it means higher quality and cost saving.

(2) Emergence

The study of global emergence is a "basic system problem" (Bertalanffy,1980). It refers to the phenomena, characteristics, attributes, behaviors, etc. that exist in the whole but do not exist in the decomposition (reduction) to the part, or the phenomena, characteristics, attributes, behaviors, etc. that do not exist when the whole is reduced to the low level (Miao Dongsheng,2008). The overall goal of this model is to generate a kind of innovation diffusion wave at macro level naturally in the simulation. This kind of macro level innovation diffusion wave emerges from the individual level behavior, that is, the overall adoption behavior at the macro level will show periodic fluctuations.

(3) Adoption threshold

"Threshold" was first proposed by Davies (1979): assuming that people take the relationship between "self-income" and "critical income" as the basis of their consumption decisions, they only buy when their income exceeds a certain threshold (i.e., critical income). In this model, each innovation has its own innovation value, but due to the heterogeneity of enterprises, it is impossible for enterprises to adopt any innovation without any difference. There are many factors that need to be considered when enterprises adopt an innovation, but the most important factor is whether the value of the innovation meets the minimum requirement of the enterprise, that is, the threshold value. In other words, innovation adopters do not adopt innovations whose innovation value is lower than the adoption threshold.

3.2 Basic Assumptions

(1) The behavior hypothesis of innovation adopters is: (1) according to the definition of adoption threshold, innovation adopters do not adopt those innovations whose innovation value is lower than the adoption threshold. The greater the innovation value of an innovation, the more likely the innovation adopters will adopt the innovation. (2) Innovation adopters tend to adopt innovations they are familiar with. (3) If the adopters adopt an innovation, their requirements for new innovation will be increased, and the adoption threshold will be increased. (4) The more micro innovations under a macro innovation adopted by innovation adopters, the greater the relevant macro value will increase under the effect of scale economy. In reality, the more enterprises adopt a certain innovation, the more likely the enterprises that have not adopted the innovation are to adopt the innovation (Abrahamson,1991; Abrahamson & Rosen kopf,1993) and vice versa.

(2) Attribute assumption of innovation adopters: this model adopts agent-based simulation analysis and netlogo 5.0 as analysis tool. Assuming that the number of potential innovation adopters is 100, they are randomly distributed in the torus world of netlogo, and move continuously in the simulation. The speed attribute defines the speed of innovation adoption by innovation adopters, which is expressed by the number of tiles moving in each time step. Each innovation adopter has an adoption

threshold for each micro innovation, which defines the minimum innovation value (INVA) requirement for each micro innovation to be adopted. The adoption threshold will be adjusted dynamically according to the parameters R + and R -, and these two parameters determine the speed of the adoption threshold. The parameter minimum adoption threshold defines the minimum of all adoption thresholds.

(3) The perception hypothesis of innovation adopters: this model assumes that the information is complete, or it can be considered that the cost of acquiring innovation by potential innovation adopters is negligible. Therefore, innovation adopters can perceive all macro innovation and micro innovation, as well as the innovation value of innovation in each time step.

(4) Classification hypothesis of innovation adopters: according to Rogers (2003) description of innovation adopters, the model divides innovation adopters into innovators, leaders and followers. These three types of innovators do not form a middle level collective in the model. They are scattered in the world of netlogo. For each type of adopters, their speed attributes, adoption thresholds, R + and R - are changing. Leaders are the reference type of innovation adopters and are given default values. Innovators move twice as fast as leaders, but their minimum adoption threshold is half that of leaders, and their adoption thresholds rise slowly, but fall faster. Followers move half as fast as leaders, but their adoption thresholds are twice as high as leaders, and their adoption thresholds rise rapidly and fall slowly.

(5) Randomness hypothesis: all procedures contain random factors: observers produce a random number of micro innovation and micro innovation value, the possibility of innovation adopters' adoption depends on innovation value, and their movement in space is also random. Since this model is an abstract ideational model without specific input data, the randomness of distribution can be used to simulate the variation of program running.

4. Model and Technology

4.1 Model introduction

In this model, the number of macro innovation is set as three categories. The three types of macro innovation are enough to simulate the whole macro evolution process and the competition process of macro innovation without making the model complicated. The three types of macro innovation are placed in the circular simulation world at equal distance, and the maximum distance between them is maintained. In this way, the agglomeration of macro innovation and the bias of simulation caused by synergy effect can be avoided. The attribute of each type of macro innovation is defined as macro innovation value, which is represented by MAVA. The value of each type of macro innovation reflects the social value of the macro innovation. In the initial stage, since it has not been applied to practice, it does not produce social value. Therefore, the macro innovation value in the initial stage is 0. In the whole simulation process, due to the adoption and test in the practice process, the macro innovation value of each type of macro innovation is 0 And development, the value will change dynamically and be between 0 and 1.

In each time step, the innovation value will be adjusted according to the number of innovation adopters. In the next time step, because the innovation adopters tend to adopt the innovation with high innovation value, the potential innovation adopters adjust their own behavior according to the situation of innovation adoption, that is, the innovation adopters move to the macro and micro innovation that has been adopted, and at the same time, the innovation adopters will adjust their behavior according to the situation of innovation adoption The adoption threshold of the adopted macro innovation will increase, while that of the non adopted macro innovation will decrease.

An overview of the events generated in the simulation of each time step is as follows:

Innovation generation: time is discrete, each time step represents a month, each time step will generate some micro innovation randomly under each macro innovation, and accompanied by a random micro innovation value, its value is between 0 and 1, indicating the practicability of a micro innovation, which is represented by Miva. The total innovation value of micro innovation (represented by invA) is expressed by the arithmetic mean of macro innovation value (MAVA) and micro innovation value (MIVA), which determines the diffusion ability of micro innovation.

Innovation adoption: each innovation adopter chooses and adopts an innovation, which needs to satisfy two conditions: (1) the innovation value of innovation is higher than the adoption threshold value of adopter; (2) the innovation value of innovation is higher than the random number between 0 and 1. In these innovations, leaders and followers choose the closest innovation to implement adoption behavior. If no valuable innovation is found, adopters will choose not to adopt it. The adopters will adjust the adoption threshold for all macro innovations. For the macro innovations that have been adopted, the threshold will rise with logistic curve, while for other macro innovations, the threshold will decline exponentially.

Upgrade procedure: with the successful adoption of innovation, the macro value of macro innovation MAVA will be constantly updated at each time step, that is, the more adopted, the higher the MAVA. At the same time, the adoption threshold and spatial position of innovation adopters will also be updated in the program simulation.

Innovation intervention: innovation intervention mainly includes innovation subsidy and tax preference, and mainly intervenes micro innovation. The impact of innovation intervention on innovation diffusion is mainly realized by reducing innovation cost.

In addition to the above three major events, the calculation and output of the results will be generated in each time step simulation, and the graphics will be drawn by netlogo. In the process of simulation, when all micro innovations are removed from the simulation world, the program ends. In the whole simulation, there is no interaction between agents.

This model is an abstract concept model, so it does not use the specific data of the actual technological innovation system, but assumes an abstract value, that is, the number of innovation adopters is set as 100. According to Rogers (2003), innovators accounted for 2.5%, early adopters accounted for 13.5%, early majority adopters accounted for 34%, late adopters accounted for 34%, and laggards accounted for 16%. By analogy, innovators and early adopters in Rogers (2003) are merged as the pioneer of this model, most early adopters in Rogers (2003) are equivalent to the leader of this model, and the combination of most late adopters and laggards in Rogers (2003) is equivalent to the follower of this model.

According to Rogers (2003), the process of innovation diffusion presents an "s" curve. At the beginning, the number of people is small, and the diffusion process is very slow. When the number of people increases to 10% - 20% of the number of residents, innovation suddenly accelerates, and the curve shows a rapid upward trend. Accordingly, the minimum adoption threshold for different types of adopters should be defined as follows: Leaders' adoption threshold is at the minimum value in this range, and they have a 10% probability of adoption, that is, 10% of potential adopters will adopt. The adoption threshold of followers is at the maximum of this range. For the sake of symmetry, innovators are set at half of the leader adoption threshold, or 5%.

The number of tiles that different adopters can move in each time step represents the speed attribute of different adopters, which represents the speed of adoption of an innovation by different adopters. Innovators move twice as many tiles per time step as leaders, while followers move only half as fast as leaders. Here, the initial value of leader's speed attribute is 2, correspondingly, the initial value of Innovator's speed attribute is 4, and the initial value of follower's speed attribute is 1.

4.2 The Simulation Process of Innovation Generating Event

In this model, according to self consistency and integrity, it can be divided into three events: innovation generation event, innovation adoption event, program upgrade event and innovation intervention event.

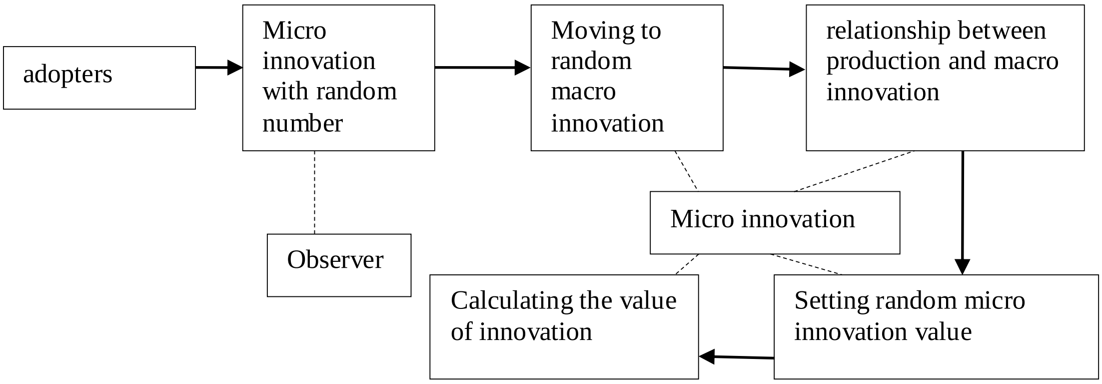


Figure1 the simulation process of innovation generating event

As shown in the figure, the innovation generation event is completed by the following four steps:

(1) Micro innovations that generate random numbers. The number of micro innovation follows Poisson distribution, and its mean and variance are 150. Poisson distribution is a discrete random distribution with only one parameter, which is the mean value and variance of Poisson distribution. Poisson distribution is usually used to simulate the occurrence of an event (law, 2006).

(2) Move to random macro innovation. Follow the average distribution.

(3) Set random micro innovation value. The mean value was 0.05. Exponential distribution is usually regarded as the approximation of power law. For a series of events, power law can better describe their scale or intensity. Therefore, random micro innovation value is also assumed to obey exponential distribution. Here, the reason why the average value is selected as 0.05 is that most of the innovation in reality is useless to the innovation adopters. The average is half of the leader's minimum threshold and a quarter of the follower's minimum threshold.

4.3 Innovation Adoption Events

As shown in the figure, the innovation adoption event is completed by the following three steps:

1. Judging whether it is a valuable innovation: the judgment principle is that the innovation value is greater than the adoption threshold and greater than random floating-point number 1. When an innovation adopter decides whether to adopt an innovation, it needs to consider two conditions: first, the innovation value of the innovation is higher than the adoption threshold value of the innovation adopter; second, the innovation value is greater than a random number between 0 and 1. The latter is to ensure that the whole process of innovation adoption is a random process, and the value of innovation is only an influence, not a decision on the adoption of innovation adopters.

2. Raise adoption thresholds for adopted innovations. The attention threshold of

innovation adopters increases according to logistic curve. Logistic curve is used to represent the growth process of constrained data, and its curve is S-shaped. Since the adoption of innovation by innovators is a strong restrictive resource, logistic curve is used to characterize the growth of adoption threshold of innovation adopters.

3.Reduce the attention threshold of unaccepted innovation. The reduction of adoption threshold follows the exponential equation, because if an innovation is abandoned or forgotten in the market competition, its value will rapidly decline.

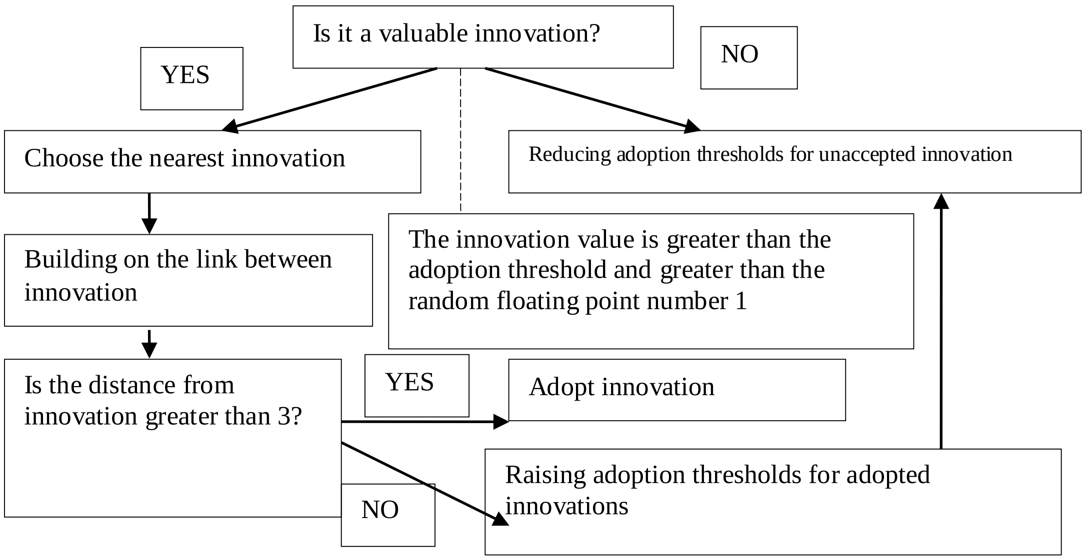


Figure 2 innovation adoption events

4.4 Upgrade Event

The upgrading process equation of macro value is set as the weighted average of the macro value of macro innovation and the average number of times each adopter adopts macro innovation and micro innovation subordinate to j in the current time step. Because the macro value of a macro innovation depends not only on the macro value of the macro innovation at the last moment, but also on the adoption of the macro innovation. The more adopted, the greater the macro value of macro innovation under the effect of scale economy and scope economy.

5. Simulation results and conclusions

According to the above simulation rules and model design, after 900 time steps, through the tracking and analysis of various indicators, we can clearly draw the following conclusions:

Conclusion 1: the macro innovation value shows cyclical fluctuations, but does not follow the strict cycle in the mathematical sense (as shown in Figure 3). The micro innovation value is evenly distributed without obvious periodic distribution (as shown in Fig. 4), but the innovation value of micro innovation shows obvious periodic fluctuation, but it also shows the characteristics of uniform distribution at the peak stage (as shown in Figure 5). It is obvious that the periodicity of innovation value of micro innovation originates from the cyclical change of macro innovation value.

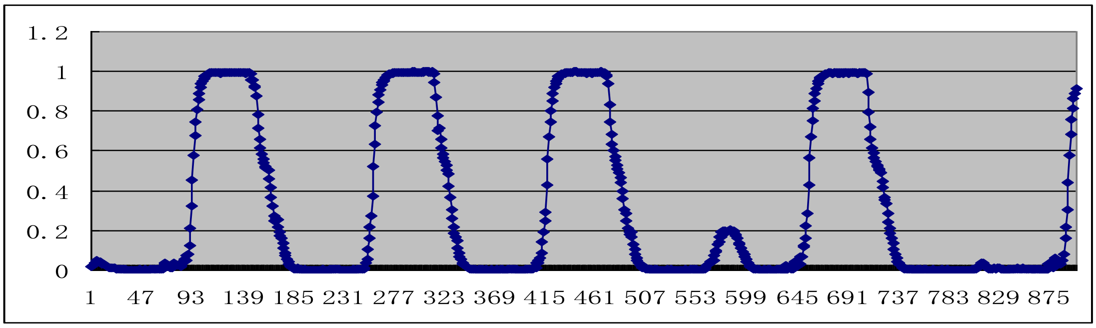


Figure 3 the change of macro value of a macro innovation

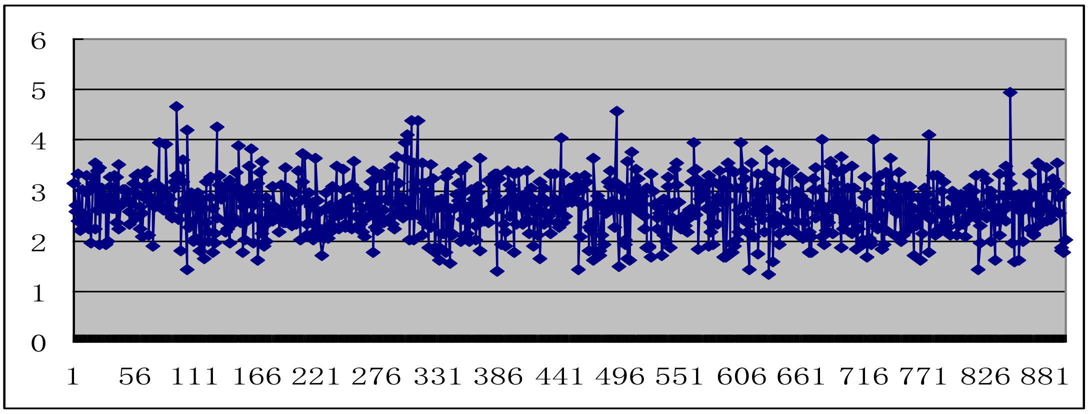


Fig. 4 micro value change table of micro invention under a macro invention

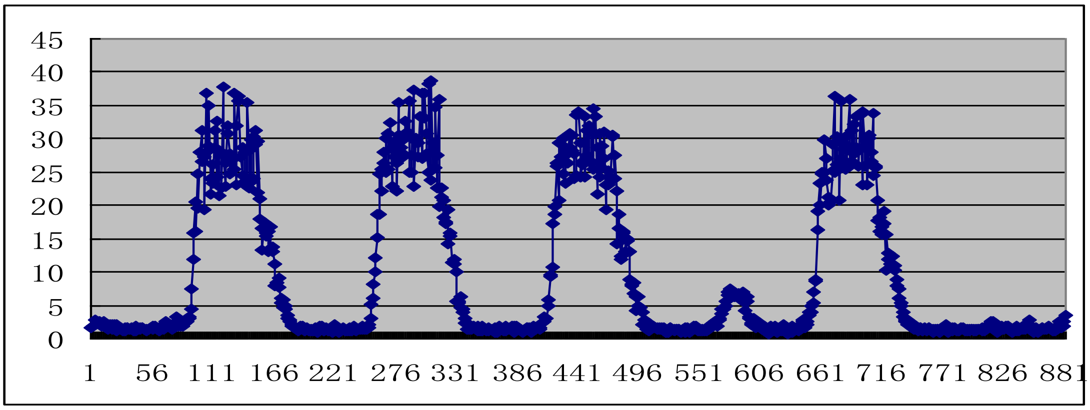
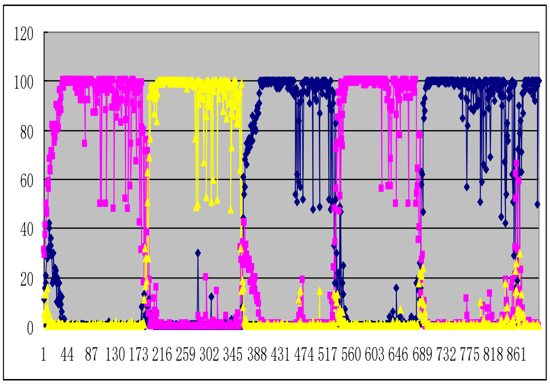
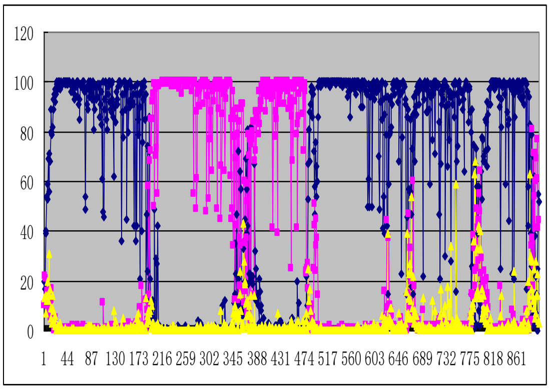


Figure 5 the innovation value change table of micro invention under a certain macro invention

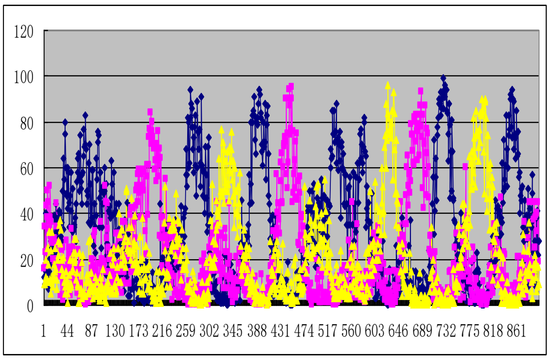
Conclusion 2: the number of innovation adopters fluctuates periodically, but it does not follow the strict mathematical cycle. The wavelength of all kinds of macro innovation is roughly the same, but the amplitude is different (as shown in Figure 6). This kind of periodic fluctuation can be called innovation diffusion wave. From its shape, it can be seen that there is a straight-line rise and a straight-line decline process in the adoption of a certain innovation, and there is always a peak and a trough. The peak may reach the maximum number of innovative adopters, and its bottom may be close to zero.

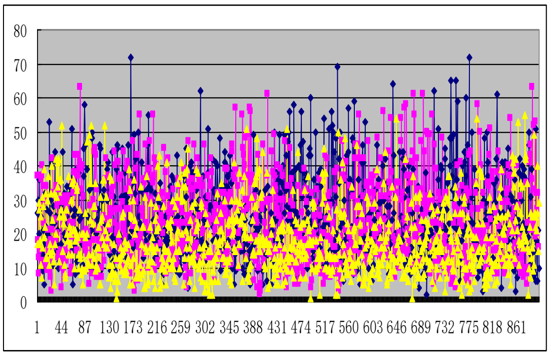
Conclusion 3: the innovation value of an innovation is the weighted average of the micro value of the innovation and the macro value associated with it. The weight determines the importance of the micro value of the innovation. For example, the greater the weight, the higher the quality and the more cost saving. In particular, if the weight is 1, the micro invention has formed a new "new species of technology", that is, it has evolved into a new macro invention. By changing the weight (as shown in Figure 6), it can be seen that the greater the weight, the less obvious the appearance of diffusion wave. In particular, when the weight exceeds 0.8, such as 0.9, the diffusion wave no longer exists. Therefore, it can be considered that one of the reasons for the formation of innovation diffusion wave is the existence of macro value related to an innovation.





a=0.6 a=0.7

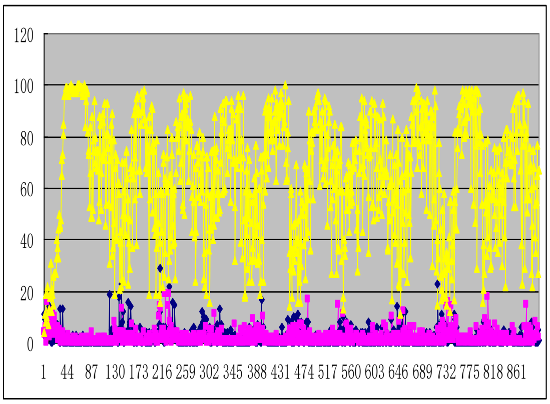




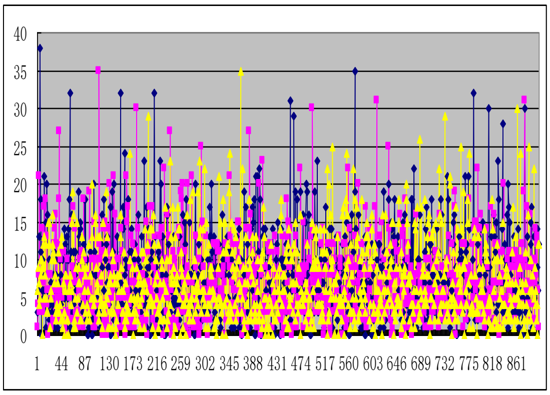
a=0.8 a=0.9

Figure 6 a shows the diffusion of innovation at 0.6, 0.7, 0.8 and 0.9, respectively

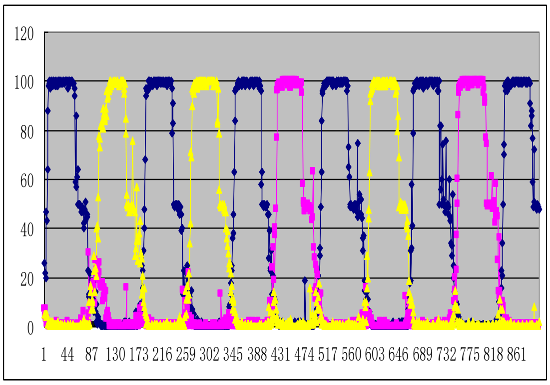
Conclusion 4: the upgrading process equation of macro value is set as the weighted average of macro value and the average number of adoption of macro innovation and micro innovation by each adopter in the current time step (the weight is b).



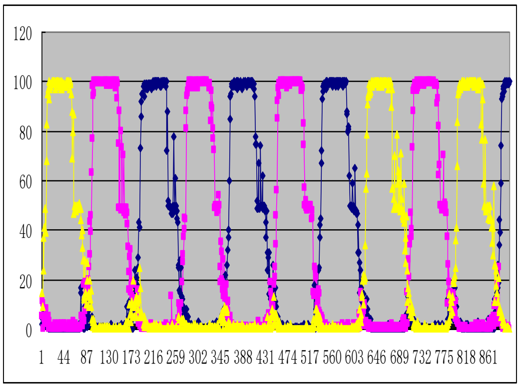
b=0.95



b=1



b=0.8



b=0.85

Figure 7 b shows the diffusion of innovation at 0.8, 0.85, 0.95 and 1, respectively Because the macro value of a macro innovation depends not only on the macro value of the macro innovation at the last moment, but also on the adoption of the macro innovation. As shown in Figure 8, by observing the weight change, when the weight exceeds 0.85, such as 0.95, the diffusion wave no longer exists. The greater the weight, the less important the micro value.

In conclusion 3 and conclusion 4, it can be concluded that the importance of micro value must be in a reasonable range in order to form the diffusion wave of innovation. Beyond this interval, the diffusion wave will no longer exist.

6. Conclusion

Based on the emergence of micro individual behavior at the macro level, this paper explains the formation of technological innovation diffusion wave from the interaction with the market and adopters. Theoretically, it changes the traditional assumption that the technological innovation diffusion wave is exogenous. In the framework of coordination and evolution, the diffusion wave of technological innovation is endogenously explained, and this diffusion wave will bring about production, on the one hand, enterprises can arrange and plan their own technological innovation behavior according to the diffusion wave of technological innovation. Because micro innovation has a clear purpose and can be predicted, it belongs to a Lamarckian evolution process from the perspective of evolution, so it can be done in different stages of technological innovation diffusion wave On the other hand, in the model of the formation of diffusion wave of technological innovation in this paper, the fundamental cause of the formation of diffusion wave lies in the asynchrony between technological innovation and market, which further forms the asynchrony between technological innovation diffusion and market. If such asynchrony can be eliminated, the diffusion wave will be weakened or even disappeared. Therefore, technological innovation must be market-oriented, and the government's promotion of technological innovation should also be shifted from the supply side to the demand side. However, the supply of technological innovation can not achieve the immediate change and diversion as the demand, so the diffusion wave can not be eliminated ultimately. What enterprises need to do is to weaken the diffusion wave as much as possible, and adjust the innovation policy according to the formation of diffusion wave to promote the development of enterprises.

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