Design and Analysis of Knowledge Transfer in the Process of University-Industry Collaborative Innovation Based on Social Network Theory

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Abstract

Any collaborative innovation activities can not be separated from the support of social networks. Many factors in the social network affect the knowledge transfer activities. Moreover, the effectiveness of knowledge transfer determines the performance of collaborative innovation. From the point of view of relevance between collaborative innovation behavior and social network, this paper analyzes the influence of some factors in social network on knowledge transfer of school enterprise synergy innovation. The purpose of this paper is to find out the laws of knowledge transfer in the process of University-Industry (U-I) collaborative innovation, and to verify the role of these laws through system dynamics simulation. Firstly, this paper summarizes the previous views on collaborative innovation and U-I knowledge transfer. Based on the analysis of literature, it puts forward the process model of knowledge transfer in U-I Collaborative Innovation and analyzes the factors that affect this process. Secondly, the paper uses a system dynamics method to analyze the causality of knowledge transfer in the process of U-I collaborative innovation, establishes the model of system flow diagrams, and uses Vensim PLE to test the validation and sensitivity of the model. Furthermore, the experimental results demonstrate that the model could fit well the actual knowledge transfer activities in the process of U-I collaborative innovation. And, the results show that some factors in social networks (trust, knowledge transfer capability, knowledge absorptive capacity, and contract mechanisms) affect U-I knowledge transfer in different degrees. Finally, some suggestions concerning the promotion of knowledge transfer are presented according to the simulation.

Keywords: Universities-industries, Collaborative innovation, Knowledge transfer, Social networks

1 Introduction

Since the 18th National Party Congress, China regards innovation drive and enhancing the ability of independent innovation as an important national development strategy. At the Academicians Conference in 2014, Xi Jinping emphasized that China must invest in collaborative innovation and form a powerful force to promote independent innovation. Collaborative innovation can bring vitality for enterprise, and as a new drive to promote economic growth. With the development of opening innovation, University-Industry collaborative innovation, as a new organization of innovative, came into being. It is an effective way to integrate innovative resources and improve the efficiency of innovation. University-Industry collaborative innovation (hereafter called U-I collaborative innovation) is actually a systematic project of cross border dynamic collaboration between universities, enterprises, governments and agencies. Since the "2011 Plan" has been proposed by the Ministry of Education, collaborative innovation has become a national innovation system strategy, with the collaborative innovation center as the carrier of implementation, to promote the deeper integration of universities and industry.

In recent years, there are many researches about collaborative innovation, which are mostly focus on the connotation, mode, motivation, operation mechanism of collaborative innovation from the macro perspective [1-3]. However, there are relatively few studies on knowledge activities in the process of collaborative innovation. The U-I collaborative innovation is a dynamic complex system with knowledge link [4]. The process of collaborative innovation is an interaction process between subjects, which essence is the knowledge flow and knowledge transfer between innovation subjects. Collaborative

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innovation is a series of innovation activities across the organization boundaries; knowledge transfer is an important part of collaborative innovation [5]. Knowledge among the U-I collaborative innovation is constantly increasing value in the flow, and the members of U-I collaborative innovation can achieve complementary resources and collaborative development through knowledge transfer. Meantime, the smooth flows of knowledge among the various members determine the collaborative innovation capability. Therefore, knowledge transfer is the essence of collaborative innovation activities, and it is a necessary process of collaborative innovation activities. The success of knowledge transfer effectively promotes the scientific research and personnel training level of universities and scientific research institutes and the innovation ability of enterprises, drives the rapid development of regional economy and the national economy, and it is the great significance for the formation and development of China's national innovation system.

However, knowledge transfer in the U-I collaborative innovation is a complicated and dynamic process. It is affected by many factors. So, it is not easy to fully grasp the the law of knowledge transfer and use these rules correctly in practice. Through literature research and field research, some difficulties and obstacles of the knowledge sharing and knowledge absorption has been found in the process of U-I collaborative innovation. All of these difficulties not only limit the effect of knowledge transfer, but also affect the level of U-I collaborative innovation. Therefore, it has important academic significance to study the knowledge transfer process in U-I collaborative innovation.

In this paper, the main work is as follows. The system dynamics method was used to analysis the causal relationship of knowledge transfer in the process of U-I collaborative innovation and to construct the system flow diagram model of knowledge transfer. Then the Vensim PLE platform was used to simulate and test the validation and sensitivity of the model. Finally, some strategy to promote knowledge transfer in the process of U-I collaborative innovation was proposed.

Based on the above research contents, the structure of this paper is as follows. The first part is introduction. It includes questions and main contents in this paper. The second part is relation work, summed up the predecessors' research results. The third part is the knowledge transfer process analysis based on the cooperative innovation between colleges. In the fourth part, this paper establishes the dynamic model of knowledge transfer in U-I collaborative innovation. The fifth part is the evaluation and analysis of the dynamics simulation results. Sixth part contains the conclusion of this paper and the significance, and the future work. The last part is acknowledgments and references.

2 Related Work

2.1 Research of Collaborative Innovation

Scholars studied the U-I cooperative innovation from many different perspectives. It includes the concept and connotation, mode, motivation and mechanism, collaborative innovation elements, performance, etc.

Ansoff first proposed the concept of collaborative. He pointed out that synergy depends on the symbiotic relationship between enterprises based on the resource sharing, and it exists in each department of the organization [6]. And he thinks that synergy is the source of company value increment, and is one of the four key elements of company strategy. Synergy is built on the basis of "cooperation", it will negotiate a lot of content, including the collaborative process and the distribution of the expected results, and will take care of each other [7]. Dahlander thinks that cooperative innovation is a concrete practice of open innovation mode, points out that cooperative innovation is actually an organization cooperation with other organizations (Suppliers, customers, competitors, universities, public research institutions, etc.) in order to develop new products, new technology [8]. These institutions agreed to share their information for complete the research task. To this point later also got the approbation of the open innovation proposes Chesbrough [9]. This paper summarizes their points of view and expresses the concept of collaborative innovation as: Collaborative innovation is a new organization model. In the model, Enterprise, government, knowledge production organization (university, research institute), agents and users, etc integrate resources in large span in order to achieve the great innovation of science and technology.

In the study of enterprise cooperative innovation motivation, Bao & Wang argued that the pursuit of cooperative surplus is the power of enterprise cooperative innovation [10]. Gallaud thought acquiring the knowledge of others especially tacit knowledge is the purpose of enterprise cooperative innovation motivation [11]. And Veugelers thought motive of "industry-university-institute" cooperation comes mainly from three aspects: the "heterogeneity" of knowledge and ability between companies and universities, save transaction cost, exclusive technology knowledge [12].

For the study of the collaborative innovation model, Gudergan and Devinney used the theory of transaction cost to analyze it, and pointed out that it has two modes: non-equity cooperation and equity cooperation [13]. Castro proposed a "strategic - knowledge - organization" triple interactive collaborative innovation mode, and he pointed out that the strategic synergy, knowledge coordination and organizational coordination are of the trinity, and the three are mutually conditional and promote each other, have the relationship of dialectical

unification [14]. In conclusion, some research involved in collaborative innovation model include: Strategic alliance, participate research plan by government funding, research under contract, informal cooperation, technology transfer/license, technical assistance, personnel training, knowledge transfer, exchange of researchers, etc.

There are many scholars research on the mechanism of synergy innovation. For example, one of the representative theory of cooperative innovation is three screw theory. It is intrinsically contains a relationship that the university, industry and government should be mutual coordinated between them, and need to improve the overall collaborative performance in national innovation system [15]. Yun and Won used multi-Agent method to study the dynamic mechanism model of the U-I collaborative innovation system, pointed out that the stability of industry-university-institute cooperative innovation is influenced in real life by the limited rationality and information block [16]. Joy divided the system power of production-study-research cooperative innovation into internal motivation and external motivation, and pointed out that the cooperative innovation ability is the internal motivation, policies and regulations is the external power [17]. Under the joint action of both, the system of industry-university-institute cooperative innovation would be develop from disorderly to orderly, and evolve into stable and sustained cooperation.

Cooke and Memedovic thought that regional innovation system is composed of five elements: area, innovation and network, the learning process and interaction [18]. And they pointed out the regional is regarded as legal administrative units what is characterized by cultural homogeneity; Network is of mutual benefit and reliable relationship based on trust, norms and contract; And the learning process is institutional.

Nieto and Santamara based on data from the Spanish manufacturing companies, pointed out that the synergistic degree of the collaboration network has a positive correlation with the enterprise innovation performance [19]. Gulbrandsen and Smeby believed that the cooperation of enterprise and university could produce a two-way flow of knowledge, promoted win-win situation [20]. Tsai pointed out it has the most significant effect that the collaborative innovation network about “enterprise to enterprise” to promote enterprise’s innovation performance [21].

Above all, the essence of U-I cooperative innovation process is the knowledge increment and re-creation. Therefore, in this process, enterprises need to work together with other institutions, constantly to exchange and share of knowledge as the main factors of innovation. These studies also show that the current social environment attach great importance to collaborative innovation, and enterprises need effective theory to explain and guide collaborative innovation activities.

2.2 Knowledge Transfer Research

The concept of knowledge transfer first put forward by Teece in 1977 [22]. He thought collaboration relationship between organizations could make knowledge and technology effective circulation and widely spread, and through the knowledge transfer could also effectively reducing the knowledge gap between regions. U-I knowledge transfer is a special kind of inter-organization knowledge transfer. Szulanski and Teece both to build the basic model of influence the knowledge transfer between organizations [23]. In Szulanski study, U-I knowledge transfer was divided into four stages: knowledge identification stage, transfer implementation stage, adjust stage, knowledge integration stage. By identifying and processing knowledge, it selected suitable for the recipient’s way to transfer knowledge. Finally, the receiver successfully digest and receives the knowledge, and turned it as their knowledge reserves. More research about knowledge transfer as described below.

Most scholars analyze the influence factors of knowledge transfer from the perspective of information network. It is mainly in four aspects: the nature of knowledge, knowledge receiver, knowledge transfer and knowledge transfer situation. Ekore made a review about the influence factors of knowledge transfer for collaborative innovation [24]. The main characteristics of knowledge, especially the implication, ambiguity, complexity, embedding, influence knowledge transfer effect [25]. Szulanski found that if the knowledge source lack of the power that the knowledge transfer would be eventually hindered [23]. Similarly, the absorptive capacity of knowledge receptors also plays an important role. Mukherji and Silberman argued that the knowledge absorptive capacity has a significant regulatory role, in which the upgrading of the small and medium-sized enterprises in metropolitan circle would be effected when they being collaborative innovation [26].

Some scholars pay attention to the media richness of knowledge transfer, and study the influence of different media on the knowledge transfer. Hasty et al. found that transfer channel has a decisive influence on knowledge loss [27]. In the process of knowledge transfer, media richness is more advantageous to reduce the fuzziness of knowledge. Low abundance of media is more advantageous to process simple information and standardized data. Blackman and Benson explored the mediating role of knowledge stickiness when knowledge transfer is influenced by knowledge transfer channel [28]. The results showed that the knowledge stickiness had complete intermediary role and the relationship between knowledge transfer channels and knowledge transfer was positively regulated by trading mechanism and relational mechanism.

And some scholars have studied the mechanism of

knowledge transfer. Wang explored an issue with reference to a product recall crisis of a motorcycle manufacturer using the method of system dynamics model [29]. His research findings illustrated the multiple knowledge transfer mechanisms had used and their influence on organizational performance during crises as a means of distributing critical knowledge and facilitating the development of collective understanding within organizations. Shu and Chen also analyzed the influencing factors of knowledge transfer in the process of cooperation, put forward that the cooperation and heterogeneity of knowledge transfer threshold sensitivity has a higher amount of transfer of knowledge [30]. And they also put forward to promote the establishment of the R&D alliance trust system and establish a good coordination mechanism of the R&D alliance and the establishment of effective incentive mechanism. Fritsch and Kauffeld-Monz analyzed information and knowledge transfer in a sample of 16 German regional innovation networks with almost 300 firms and research organizations involved [31]. Their results indicated that strong ties were more beneficial for the exchange of knowledge and information than weak ties.

2.3 Review of the Literature

The knowledge transfer between enterprises is an important way of collaborative innovation, which has been achieved in the research of enterprise knowledge transfer and collaborative innovation. But there are many places that need to be further studied. For example, our innovation activities mostly are through the ways of introduction, digestion and absorption. This needs to be combined with the specific situation in China. There is little study of the characteristics and mechanism of knowledge transfer in the U-I collaborative innovation in Chinese context. Besides, how do the factors that affect the U-I knowledge transfer in the innovation system of the enterprise play a role? In the long run, how will the synergy innovation behavior of enterprise knowledge transfer evolve? To pursue these evolutionary laws, a method of using system dynamics is needed. This is exactly the problem that this paper wants to discuss.

3 The Process Analysis of the Knowledge Transfer in U-I Collaborative Innovation

Knowledge transfer accompany with the process of collaborative innovation. In the process of cooperative innovation, knowledge transfer is not a simple linear process, but a complex dynamic process. In the process of knowledge transfer, the main subjects coordinate with each other in the constantly running, searching, filtering, acquisition, absorption, assimilation, appreciation, applications and other operations into knowledge in the organization, and circulate this series of operations. In the research of knowledge transfer process, the most representative theoretical models are: SECI model by Crossan [32], knowledge transfer four stage model by Szulanski [23], knowledge transfer five stage model by Gilbert and Cordey-Hayes [33].

Based on the previous research on knowledge transfer process, this paper divides the process of knowledge transfer into preparation stage, operation stage, knowledge integration and application stage, and information feedback stage. Among them, knowledge operation stage is the core part, it can be divided into initial stage, stable stage and mature stage. Therefore, this paper puts forward the following knowledge transfer theory model. Figure 1 shows the process model of collaborative innovation knowledge transfer between enterprises and enterprises.

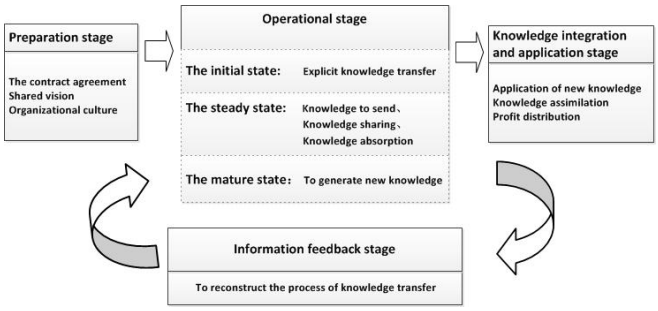

Figure 1. Knowledge transfer process model in U-I collaborative Innovation

3.1 Preparation Stage

At the beginning of the formation of the U-I cooperative innovation system, the main body of the collaborative innovation needs to examine the external national macroeconomic policies, so as to select and anticipate the cooperation projects. First of all, in the determination of good cooperation projects, they need to negotiate the project resources, personnel arrangements, the expected target, income distribution and other detailed regulations to form the contract. Secondly, they need to cultivate the organization atmosphere and cultural environment which is suitable for knowledge transfer, and to organize the staff to carry out the activities, and to establish a good team atmosphere.

In addition, the organizations within the alliance need to assess the level of knowledge of themselves. They also need to file the explicit knowledge about the project operation. And then, they need to organize their staff who participated in the project to communicate and summarize their knowledge. The purpose of this is to make the tacit knowledge explicit. A good knowledge base is an important prerequisite for knowledge transfer.

3.2 Operational Stage

Operation stage is the specific operation of knowledge transfer, and it is the key stage to produce

synergy advantages. In this stage, schools and enterprises interact in various forms according to the common innovation goal, which can be divided into initial stage, stable stage, mature stage.

In the initial stage, the emotional distance between the parties is long, and the technology paradigm of organizations are different, and the communication method between organizations is more rigid, and the knowledge transferred most is dominant knowledge, including technical documents, technical seminars etc..

When the operation enters the stable phase, the organization establishes the good trust relationship, and the work way unceasing fusion, forming the network inertia, making the invisible knowledge be more and more discovered and absorbed. Among them, each knowledge transfer between organizations can be divided into knowledge transmission, knowledge coordination, knowledge absorption.

In the mature stage, after a period of time in the collaborative innovation network which is stable, the stock of knowledge enterprise accumulated, the two sides constantly thinking collided, cooperation becomes cohesively, making both knowledge level and innovation ability reach a threshold value at a certain time. At that time, new knowledge will be produced, achieving the effect of knowledge transfer, which is called knowledge spillover.

3.3 Knowledge Integration and Application

Based on the realization of the common goal and the production of new knowledge, the main body of production and research collaboration may consider the termination of the operation stage, and enter the stage of knowledge integration and application. In order to get the knowledge of the recipient, knowledge receiver classified, digested and absorbed it, and applied it to the actual production, absorbing it a part of the self-knowledge system. At the same time, the both sides of cooperation deal with the value created by the collaboration to assess the value, to determine the ownership of intellectual property and to distribute the benefits.

3.4 Information Feedback

When new knowledge is used in R&D and production, knowledge transfer will get into the final stage of information feedback. Collaborative innovation is a long-term cooperative relationship. During the feedback stage, the arisen problems and improvement direction when new knowledge applied will be recorded to the knowledge provider, to ensure the long-term vitality. In addition, the feedback information contributes to the cooperative both sides to carry out further cooperation projects, making the collaborative innovation alliance stay stronger.

In the U-I collaborative innovation process, knowledge transfer is cyclical and constant. In this cycle, the efficiency of knowledge transfer is increasing. Knowledge transfer efficiency refers to the effect created by per unit of knowledge. Knowledge transfer efficiency is mainly reflected in the degree of knowledge utilization.

4 System Dynamic Model Construction of Knowledge Transfer in the Process of U-I Collaborative Innovation

The system dynamics method is a quantitative method used to study the complex system behavior based on the feedback control theory and the computer simulation technology. Knowledge system is an intelligent complex adaptive system. The knowledge transfer activity in the process of U-I collaborative innovation is the directional propagation process from universities to industries in a certain context. It is a process of mutual communication and narrowing the knowledge gap between organizations. In this process, the total amount of knowledge is constantly increasing. Therefore, the knowledge transfer system in the process of collaborative innovation is in line with the basic conditions of system dynamics modeling. Through the research, this paper designs the following system dynamics model of knowledge transfer in the process of U-I collaborative innovation.

4.1 Influencing Factors Analysis

At present, relevant research on influence factors of knowledge transfer mostly conduct from the view of network information, a large number of studies suggest that knowledge transfer influence factors are mainly come from four aspects: knowledge sender, knowledge receiver, characteristics of knowledge and the situation and channel of knowledge transfer [34]. With the development of social network theory, some scholars studied the influence factors of knowledge transfer base on social network theory [35]. Some others introduce an object-centered social network based on tagging practices across different sources [36]. It is more consistent to the diversification of the knowledge transfer subject in the process of U-I collaborative innovation.

Based on the comprehensive consideration of the research at home and abroad, the influence factors of knowledge transfer in the process of collaborative innovation are summed up, including the following categories:

(1) The endogenous factors of collaborative innovation network: the willingness of knowledge transfer, knowledge transfer ability, knowledge absorptive capacity, knowledge retention ability, knowledge complexity, knowledge gap.

(2) The situation factors of collaborative innovation network: trust, communication, contract mechanism, organizational distance, interact frequency.

(3) The external environmental factors of collaborative

innovation: Information level, intermediate support level, human resource input, socioeconomic environment and government support level.

In the process of collaborative innovation, as time passes, the amount of knowledge innovation, the quantity of knowledge transferred and the amount of knowledge elimination is increasing over time, thus the knowledge transfer system in the process of U-I collaborative innovation forms a dynamic and orderly system of dissipative structure.

4.2 Causality Analysis

In the process of collaborative innovation knowledge transfer, the knowledge of universities transfers to industries. The casual loop diagram is shown in Figure 2.

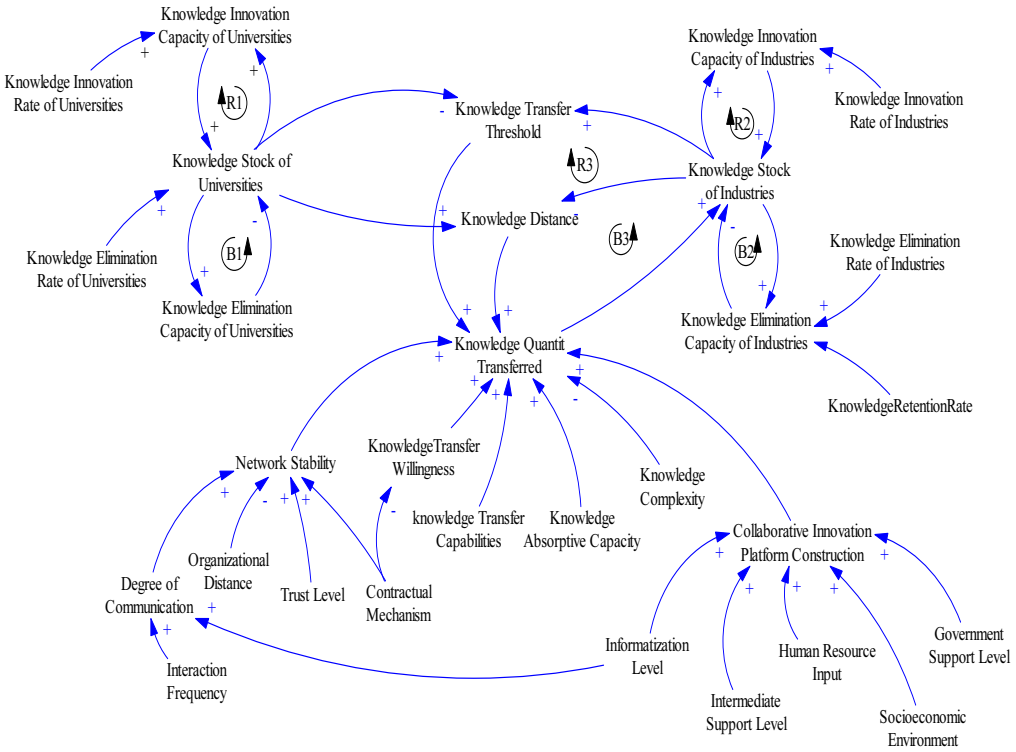

Figure 2. This shows the causality diagram of the knowledge transfer system in the process of U-I collaborative innovation

The feedback loop contained in the graph is as follows.

R1: Knowledge Stock of Universities→Knowledge Innovation Capacity of Universities→Knowledge Stock of Universities

R2: Knowledge Stock of Industries→Knowledge Innovation Capacity of Industries→Knowledge Stock of Industries

R3 Knowledge Stock of Industries→Knowledge Transfer Threshold→Knowledge Quantity Transferred Knowledge Stock of Industries

B1 Knowledge Stock of Universities→Knowledge Elimination Capacity of Universities→Knowledge Stock of Universities

B2 Knowledge Stock of Industries→Knowledge Elimination Capacity of Industries→Knowledge Stock of Industries

B3 Knowledge Stock of Industries→Knowledge Distance→Knowledge Quantity Transferred→ Knowledge Stock of Industries

4.3 System Flow Diagram

Basic assumptions of the model are as follows.

(1) Universities and industries are all knowledge production units, so their knowledge innovation rate is higher than the knowledge elimination rate;

(2) The direction of knowledge transfer is universities with high knowledge potential energy to the industries with low knowledge potential energy;

(3) The initial knowledge stock of universities is larger than that of industries and the knowledge innovation rate of universities is higher than that of industries. Industries are more close to the market, the knowledge update rate is faster, and the knowledge elimination rate is higher than that of the University;

(4) The government policy is favorable for collaborative innovation.

The system flow diagram (Figure 3) is transformed from the causality diagram, which reflects the knowledge transfer process of U-I collaborative innovation. The system structure constructed includes 2 state variables, 5 rate variables, 15 auxiliary variables and 8 constants, as shown in Table 1.

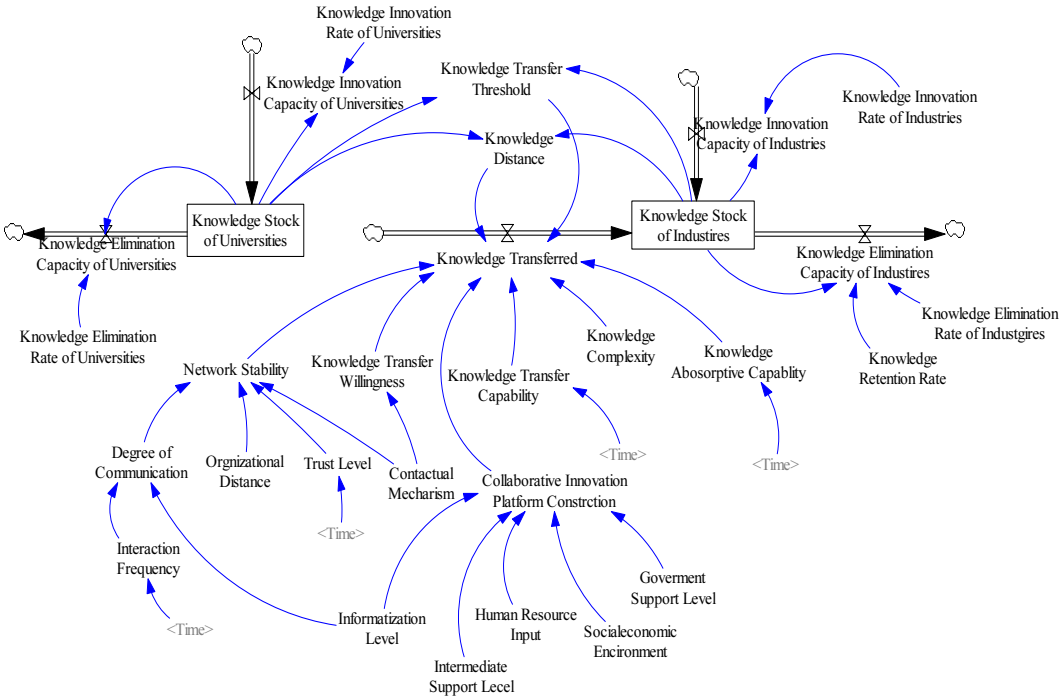

Figure 3. This shows the system flow diagram of the knowledge transfer system in the process of U-I collaborative innovation

Table 1. Related variables in system flow diagram

Variables Type	Variables
state variable	Knowledge Stock of Universities, Knowledge Stock of Industries
rate variable	Knowledge Innovation Capacity of Universities, Knowledge Elimination Capacity of Universities, Knowledge Innovation Capacity of Industries, Knowledge Transferred, Knowledge Elimination Capacity of Industries
Auxiliary variable	Knowledge Distance, Knowledge Transfer Threshold, Knowledge Transfer Willingness, Knowledge Transfer Capability, Knowledge Absorptive Capability, Network Stability, Collaborative Innovation Platform Construction, Degree of Communication, Trust Level, Interaction Frequency, Intermediate Support Level, Human Resource Input, Information Level, socioeconomic Environment, Government Support Level
constants	Knowledge Innovation Rate of Universities, Knowledge Elimination Rate of Universities, Knowledge Innovation Rate of Industries, Knowledge Retention Rate, Knowledge Elimination Rate of Industries, Knowledge Complexity, Contractual Mechanism, Organizational Distance

4.4 Design and Description of the Main Equation

The design and description of the main equations in the system are as follows:

- Knowledge Stock of Universities= INTEG (Knowledge Innovation Capacity of Universities-Knowledge Elimination Capacity of Universities, 100)
- Knowledge Stock of Industries= INTEG (Knowledge Innovation Capacity of Industries + Knowledge Transferred - Knowledge Elimination Capacity of Industries, 50)
- Knowledge Innovation Capacity of Universities = Knowledge Stock of Universities * Knowledge Innovation Rate of Universities
- Knowledge Elimination Capacity of Universities = Knowledge Elimination Rate of Universities * Knowledge Stock of Universities
- Knowledge Innovation Capacity of Industries = Knowledge Innovation Rate of Industries * Knowledge Stock of Industries
- Knowledge Elimination Capacity of Industries = (Knowledge Stock of Industries * (1-Knowledge Retention Rate)) * Knowledge Elimination Rate of Industries
- The knowledge stock of industries comes partly from knowledge transferred. Therefore, the knowledge loss of the enterprise is not only related to the knowledge elimination rate, but also related to the knowledge retention rate.
- Knowledge Distance = Knowledge Stock of Universities- Knowledge Stock of Industries.
- Knowledge Transfer Threshold = IF THEN ELSE

(Knowledge Stock of Industries / Knowledge Stock of Universities < 0.9, Knowledge Stock of Industries / Knowledge Stock of Universities, 0.9)

- Knowledge transfer threshold is the ratio of the universities knowledge stock and the industries knowledge stock, which reflects the degree of protection on knowledge of universities. When the knowledge transfer threshold reaches 0.9, universities will no longer transfer knowledge to the industries.
- Knowledge Transferred = DELAY1I (IF THEN ELSE (Knowledge Transfer Threshold<0.9, Knowledge Distance * Knowledge Transfer Willingness * Knowledge Transfer Capability * Knowledge Absorptive Capability * Network Stability * Collaborative Innovation Platform Construction * (1-Knowledge Complexity), 0), 2, 0)
- Knowledge transfer occurs when the threshold of knowledge transfer is less than 0.9. Knowledge transfer is a very complex process, it takes a long time to prepare, send, receive, and understand knowledge. So the first order delay function is used to reflect the process, the knowledge transfer delay is two months, and the initial knowledge of the transferred knowledge is 0.
- Network Stability = Degree of Communication* Trust Level * Contractual Mechanism * (1-Orgnizational Distance)
- Knowledge Transfer Willingness=IF THEN ELSE ((1-Contactual Mechanism)> 0.7, 0.7, (1-Contactual Mechanism))
- Knowledge Transfer Capability = WITH LOOKUP (Time, ([(0, 0) - (36, 1)], (0, 0.5), (36, 0.9)))
- Using the table function simulates the knowledge transfer capability of universities, as the knowledge transfer capability continuous improvement with the time in the process of knowledge transfer. The knowledge transfer capacity is set as the linear function with the initial value 0.5 and the final value 0.9. The function settings of knowledge absorptive capacity, the level of trust and interactive frequency are similar.
- Knowledge Absorptive Capability = WITH LOOKUP (Time, ([(0, 0)-(40, 1)], (0, 0.3), (36, 0.9)))
- Degree of Communication = 0.8*Interaction Frequency +0.2*Information Level
- Interaction Frequency = WITH LOOKUP (Time, ([(0, 0)-(40, 1)], (0, 0.3), (36, 0.9)))
- Collaborative Innovation Platform Construction = Intermediate Support Level * Human Resource Input * Information Level * Social economic Environment * Government Support Level
- The value of intermediate support level, human resource input, information level, Socioeconomic environment and government support level is Random variables of [0.5, 1].

5 Performance Analysis of Knowledge Transfer in the Process of U-I Collaborative Innovation

5.1 Initial Value Selection and Parameter Setting

This paper use Vensim PLE to simulate the system dynamics model of knowledge transfer in the process of U-I collaborative innovation. Combined with the previous research results and the characteristics of the simulation subjects, we set the simulation time is 24 months, the simulation step is 1 month. The initial value setting of the remaining variables is shown in the Table 2.

Table 2. The initial value setting

Variables	value	Variables	value
Knowledge stock of universities	50	Knowledge stock of industries	100
Knowledge innovation rate of universities	0.1	Knowledge innovation rate of industries	0.15
Knowledge elimination rate of universities	0.02	Knowledge elimination rate of industries	0.04
Knowledge retention rate	0.8	Contractual mechanism	0.4
Organization distance	0.2	Knowledge complexity	0.6

5.2 Model Validity Test

The Figure 4 to Figure 6 show the changing trend over time of knowledge stock of universities, knowledge stock of industries, knowledge transferred respectively.

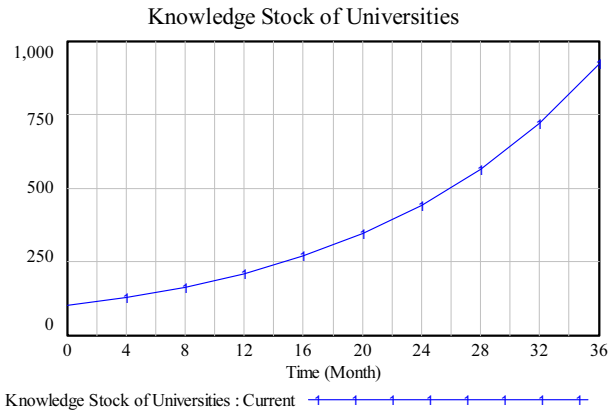

Figure 4. This shows the simulation result of knowledge stock of universities

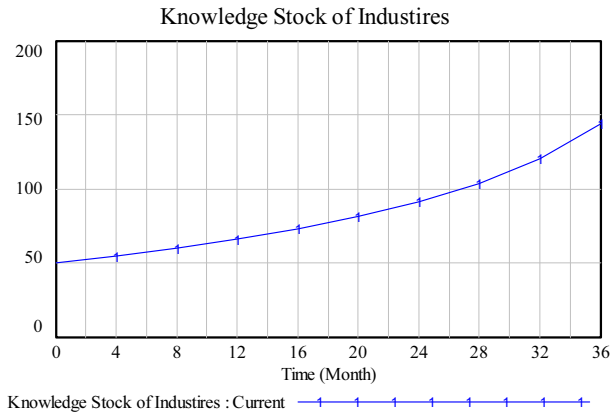

Figure 5. This shows the simulation result of knowledge stock of industries

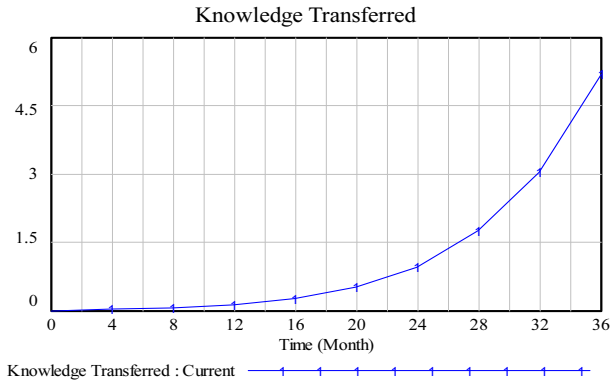

Figure 6. This shows the simulation result of knowledge transferred respectively

(1) From the first two figures, during the simulation, the knowledge stock of universities and enterprises are growing, and the growth rate of knowledge is increasing. This was caused by the reason that the knowledge innovation rate of universities and industries were higher than the knowledge elimination rate of them. Then, the increase of amount of knowledge innovation is far greater than the lost knowledge with the increase in the knowledge stock, further lead to constantly increase in knowledge stock of universities and industries.

(2) From the last figure, the curve of knowledge transferred showed that the amount of knowledge transferred increase slowly in the early period. While it shows exponential growth in the late period. In the initial simulation stage, various external conditions are not mature enough, such as low level of trust, lower knowledge transfer capacity and absorptive capacity, so the amount of knowledge transferred is relatively less. Later, the quantity of knowledge transferred shows steady growth trend due to the dual role of the good U-I collaborative innovation conditions and incremental knowledge distance.

(3) During the simulation, the amount of knowledge innovation in universities is higher than the amount of enterprise knowledge innovation, thus Knowledge distance between universities and industries is increasing, although the knowledge loss of universities is higher than that of industries; because the gap is increasing, the transfer threshold is not reached, knowledge transfer is in progress.

The simulation results are consistent with the reality, which shows that the model is effective and can reflect the evolution of the knowledge transfer in the process of collaborative innovation to a large extent.

5.3 Sensitivity Analysis

Sensitivity analysis is to study the influence of the model by changing the parameters of the model and the structure of the model, to provide decision-making instructions for the research work. In this paper, the sensitivity analysis is carried out from the following four aspects.

Knowledge transfer threshold. In order to reflect the impact of knowledge transfer to enterprises, Current1 set the value of knowledge transfer threshold to 1, thus, the quantity of transferred knowledge is 0, the enterprise will entirely carry on independent knowledge innovation. The simulation result is shown in the Figure 7.

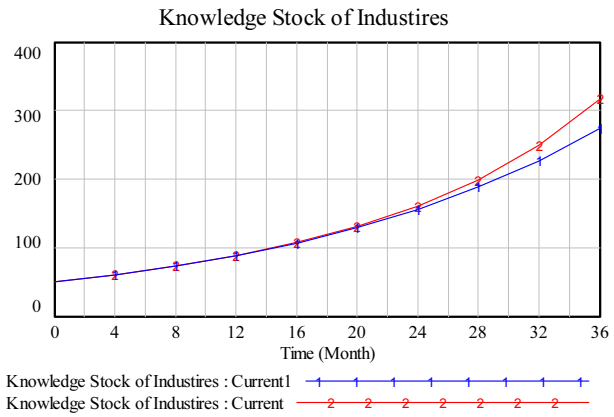

Figure 7. This shows the sensitivity analysis of knowledge transfer threshold

Compared current and current1, we can find knowledge stock of industries shows significant growth trend through knowledge transfer in the process of U-I collaborative innovation, which proves collaborative innovation can truly bring knowledge benefits for the enterprise. In addition, at the beginning of the simulation, the two curves approximate coincidence, while they show significant difference in the later period of simulation. It indicates that it takes some time to deliver results of knowledge transfer.

Knowledge retention rate. In the initial model, knowledge retention rate of industries is 0.8; in the Current1, knowledge retention rate is set to 0.4 on the basis of other conditions remain unchanged. The simulation result is shown in the Figure 8.

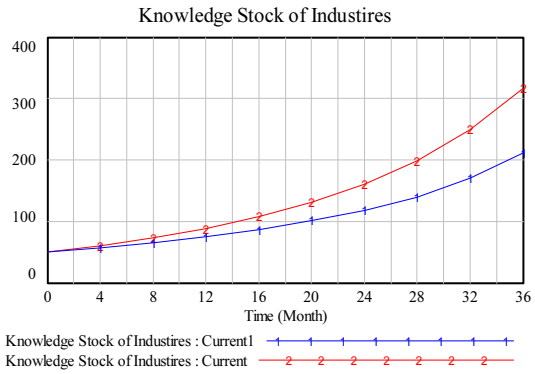

Figure 8. This shows the sensitivity analysis of knowledge retention rate

With reference to Figure 8, This system shows high sensitivity for the variable of knowledge retention rate. When knowledge retention rate of industries decrease, the quantity of industries' knowledge elimination will significantly increase, thus, the stock of knowledge enterprises will significantly reduce.

Trust, knowledge transfer and absorptive capacity. In the simulation, there are some variables, whose value increased linearly over time, such as trust level, knowledge absorptive capacity, knowledge transfer capacity. They have a positive effect directly or indirectly on the variable of knowledge transferred. In Current1, the slope of the three variables increases to 1.5 times than them in Current. The simulation result is shown in Figure 9 and Figure 10.

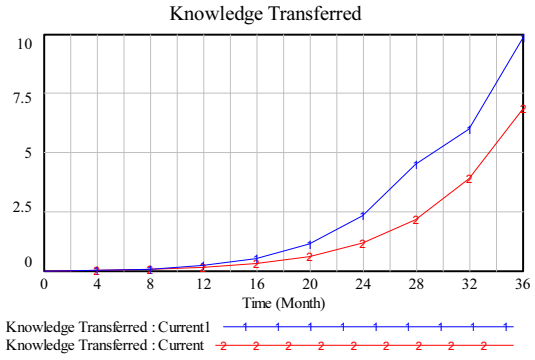

Figure 9. This shows the sensitivity analysis of Trust, knowledge transfer and absorptive capacity

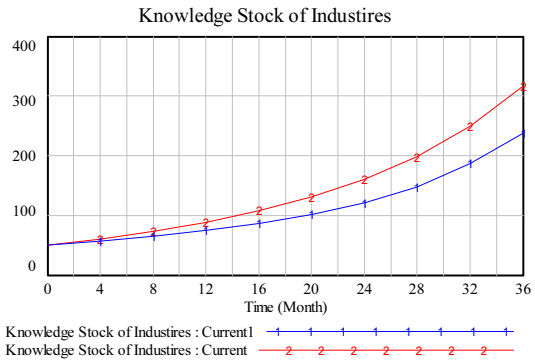

Figure 10. This shows the sensitivity analysis of trust, knowledge transfer and absorptive capacity by knowledge stock of industries

As seen in the first figure, in Current1, knowledge transferred shows dramatic growth compared to Current, which lead to knowledge stock of industries showed steady growth compared with Current in the next figure.

It follows that it is efficient for knowledge transfer success to establish trust rapidly and form high knowledge transfer capacity and absorptive capacity In the process of U-I collaborative innovation.

Contract mechanism. In the simulation, contract mechanism has a two-way role to knowledge transfer. On the one hand, it can strengthen the network stability to promote knowledge transfer. On the other hand, over strict contractual mechanism will make negative influence to knowledge transfer willingness of universities, thus to hinder knowledge transfer. In the initial model, the strength of the contract mechanism is 0.4, which has no effect on the knowledge transfer willingness. In Current1, the strength of the contract mechanism is 0.8, thereby knowledge transfer willingness is 0.2 calculated by the formula. The simulation result is shown in Figure 11 and Figure 12.

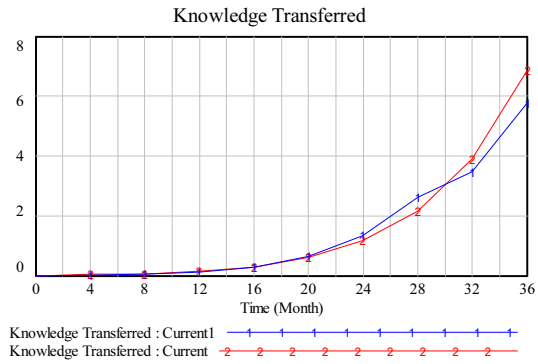

Figure 11. This shows the sensitivity analysis of contract mechanism by knowledge transferred

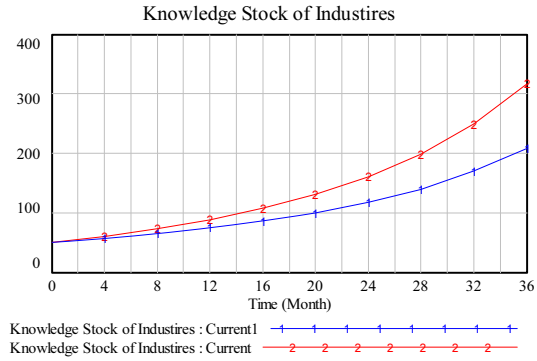

Figure 12. This shows the sensitivity analysis of contract mechanism by knowledge stock of industries

From the two curves of the first graph, it can be found that the influence of the contract mechanism on network stability is greater than that of knowledge transfer willingness. At the initial stage of simulation, the curve Current1 is above the curve Current. However, it was the inverse case at the late stage of

simulation, the amount of knowledge transferred becomes less under the over strict contractual mechanism. Thus the knowledge stock of industries in Current1 is relatively less than Current in the second figure.

To conclude, the contract mechanism in the process of U-I collaborative innovation should be moderate. Highly strict contract mechanism is often counterproductive.

6 Conclusion

In the U-I collaborative innovation process, the foundation is that the U-I have a common vision of innovation. They rely on the sharing of complementary resources to achieve progress, then to achieve the purpose of innovation. The knowledge transfer plays the main role in the process. It shows that U-I collaborative innovation and U-I knowledge transfer complement each other. The close degree of collaborative innovation is advantageous to the knowledge transfer, and the results of knowledge transfer turn back to promote their collaborative relationship deeply, so as to realize the technological innovation.

This paper describes the knowledge transfer process in U-I collaborative innovation based on system dynamics. Its main work has the following several aspects. The first is introduces the related work of collaborative innovation. The second is to construct the evolution process model of knowledge transfer in the process of U-I collaborative innovation and to analyze the simulation results about the model. The results show that the model can well simulate the actual process of knowledge transfer. The third, the article makes sensitivity analysis for the model, and analyzes the influence of different factors on knowledge transfer results. Finally, the paper puts forward the following strategies according to the results of the simulation which could promote knowledge transfer in the process of U-I collaborative innovation.

The first suggestion is to strengthen the willingness and ability of knowledge transfer of the members. Collaborative Innovation Members should formulate internal incentives that are conducive to knowledge transfer. The second is to enhance the ability to absorb knowledge. Organizations within the collaborative innovation union should focus on strengthening publicity and education to raise the staff aware on the importance of knowledge absorption. The third proposal is that collaborative innovation members must improve knowledge holding capacity. In the U-I collaborative innovation process, knowledge gained should be use in-depth to improve the effectiveness of knowledge. The improvement of knowledge holding capacity could perpetuate the knowledge transfer results. The next suggestion is that establish stable collaborative innovation network. In the operation stage of collaborative innovation network, it is important to ensure the stability of the network, stable partnership is conducive to knowledge transfer. In addition, Information degree of the collaborative innovation network to bring more convenient to knowledge interaction. Finally a proposal is to establish a good trust relationship between members, and design the contract matching with it. In the collaborative innovation alliance with low trust, companies can develop complex, detailed procedures and improve collaboration contract coordination mechanism to gradually increase trust among members, while the partner with high trust could continue to improve coordination function of contract and jointly promote knowledge transfer of the alliance. In addition, enterprises should pay attention to choose the right level of control contract.

The future work, on the one hand is to further validate this paper views through specific case studies and empirical research. These studies include looking for other aspects of the influence factors, such as channel factors, etc. It will make the influence factors which is proposed in this paper more comprehensive. On the other hand, it will further study the performance evaluation of knowledge transfer in U-I collaborative innovation, which could be enrich the research system.

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