Forming mechanisms and structures of a knowledge transfer network: theoretical and simulation research

Xiaoguang Wang

Xiaoguang Wang is based in the School of Information Management, Wuhan University, Wuhan, People's Republic of China.

This research has been made possible through financial support by the National Natural Science Foundation of China under grant numbers 71003078 and 71173249.

Received 29 June 2012
Revised 29 December 2012
1 January 2013
Accepted 2 January 2013

Abstract

Purpose – *This paper aims to analyze the exchange and reciprocal mechanism behind individual knowledge transfer activities as well as their impact on the individual knowledge transfer networks.*

Design/methodology/approach – *The author conducted theoretical and simulation research. Agent-based technology is employed to construct an agent dynamics agent-based model that simulates and explains how an individual initiates the evolution of a knowledge network through knowledge transfer activities.*

Findings – *The results demonstrate that the two mechanisms can improve the knowledge levels of the network members; the exchange mechanism is more efficient as it can improve the values of both sides. Individual knowledge transfer networks evolve from random networks to small-world networks.*

Research limitations/implications – *The research model must include more variables. Computer simulation research will be cross-confirmed by other research methods in future studies.*

Practical implications – *Individual knowledge transfer networks form and subsequently evolve as a result of social interaction. The research findings will contribute to the policy making for knowledge management in organizations.*

Originality/value – *Little has been published about the dynamics of individual knowledge transfer networks. The author believes that the paper is the first to analyze the internal mechanisms behind individual knowledge transfer activities and test them with agent-based technologies.*

Keywords *Knowledge transfer, Economic exchange theory, Social exchange theory, Reciprocal theory, Computer simulation, Agent-based technology, Information networks, Modelling*

Paper type *Research paper*

1. Introduction

Knowledge is a valuable resource that is essential to an organization's ability to innovate and compete. With the development of the information economy, knowledge has become a strategic asset of organizations (Bollinger and Smith, 2001). Recent years have seen increasing research on intra-organizational and inter-organizational knowledge transfer. This literature has focused on various factors influencing knowledge transfer, including personal willingness, absorption capacity, physical distance, cultural differentiation, etc. Alongside the emergence of the social network research paradigm, a related idea has emerged that social networks are not only a vehicle for knowledge flow, but also provide the situational element for tacit knowledge flows. The relational network of actors, as a whole, prompted by knowledge transfer and sharing reveals the process and path of knowledge diffusion.

Many researchers in sociology have emphasized the information flow through social networks and across weak ties (Milgram, 1967; Granovetter, 1973; Burt, 1992; Rogers, 1995). Recently, literature from social physics (Watts, 1998; Watts, 2004; Barabási and Réka, 1999, Barabási, 2003; Christakis and Fowler, 2009) has demonstrated that a variety of social networks, such as online social networks, e-mail networks, worldwide web and sex networks exhibit small-world and scale-free characteristics. Information and knowledge, as a kind of

social resource, spread quickly in such kinds of social networks. From the perspective of the formation of social networks, an individual knowledge transfer network is a result of social interaction. Apparently, individual psychological motivation and the mechanism of social interaction are, respectively, the internal basis and external condition of knowledge transfer networks. To date, only a few articles have combined the emergent network perspective and traditional institutionalism to explain the formation and evolution of individual knowledge transfer networks. How the evolution happens and what the resulting network will evolve into are still in need of further study.

This paper conducts a theoretical and simulation analysis of the social exchange mechanism and reciprocal altruism mechanism based on agent-based technologies. It is an exploratory study of the influence of social interaction mechanisms on the formation and structural evolution of individual knowledge transfer networks. A network structure impacts its functions compactly. A small-world network is a good channel for the flow of information and knowledge (Watts and Strogatz, 1998). However, it is necessary to study the impact of individual behavioral motives on the formation of network structures. These findings will benefit the design of knowledge management strategies in organizations to promote the evolution of dynamic networks and therefore the formation of network structures that are suited to knowledge transfer.

In the following, a review of knowledge transfer research, social exchange theory and reciprocal altruism theory, and their impact on the individual knowledge transfer process, is first carried out. Next, the research methods are detailed, followed by simulation analysis and conclusions.

2. Literature review

The study of knowledge transfer originated from the discussion on technology transfer. Teece (1977) initially conducted research on the phenomenon of technology transfer, exploring it from two aspects:

1. transfer cost; and
2. understanding the decisive factors for transfer.

This research indicated that enterprises could accumulate a large amount of transnational applied knowledge through international technology transfers. Thereafter, with the large-scale rise of multinational enterprises, research on knowledge transfer has gradually moved away from a technology focus and instead has been focusing more on the internal mechanisms for knowledge transfer.

Kogut and Zander (1992) believe that knowledge transfer and flow in enterprises at the international level is the source and foundation for their competitive advantages. Knowledge diffuses more easily within a firm than between firms. Therefore, if knowledge transfer processes are codified and made teachable, enterprises cannot obtain the corresponding profits from the transfer. Subsequently, multinational enterprises will not transfer the knowledge. Improving the performance of the enterprise is the driving force for internal knowledge transfer within multinational enterprises (Prahalad and Hamel, 1990; Grant, 1996; Dinur and Inkpen, 1996). Through internal knowledge transfer processes, multinational enterprises can not only achieve knowledge re-utilization and maximum profits (Bartlett and Ghoshal, 1989), but can also ensure that each business unit has the same competitive advantage as the best business unit in the enterprise (Kogut and Zander, 1992).

In order to accelerate the speed of knowledge transfer and expand the its scope of its diffusion, technicians place their hopes on knowledge management systems (KMSs). A KMS is a computer-mediated knowledge communication system constructed under the guidance of information-processing theory and organization collaboration ideology. The insufficiency and inefficiency of KMSs have been demonstrated in many cases studies. The primary reason for this insufficiency is the intangibility of human-computer interaction, which decreases the trust humans place in computer-mediated knowledge exchanges. The second reason is that critical context information bound to knowledge is filtered out by

electronic text, thus decontextualzing knowledge. Therefore this knowledge cannot be accurately absorbed by the seeker and receiver.

Social networks and social capital must be considered in the study of knowledge transfer processes. From real-world observations, directed communication between individuals is the most common knowledge flow form. The interaction between the knowledge sender and the receiver usually occurs in social networks. What the receiver gets is dependent on his own social capital. Knowledge acquisition is a direct benefit of social capital (Adler and Kwon, 2002).

The social relationships between the knowledge transfer participants, the structure, and the extent of those social connections have an impact on knowledge transfer performance. Face-to-face interaction shaped through social relationships provides linkages, which are the framework within which individuals can create, retain, and transfer knowledge, especially tacit knowledge (Nonaka and Takeuchi, 1995). Social network analysis (SNA) facilitates the study of the frameworks. Hansen (1999) first initiated research on knowledge sharing and knowledge transfer from the perspective of SNA and social relationships, and discussed the function of weak ties on knowledge sharing in organizational subunits. Tsai (2001) analyzed the effects of network position and absorptive capacity on business unit innovation and performance. Reagans and McEvily (2003) researched the impact of network cohesion and its range on knowledge transfer. Levin and Cross (2004) demonstrated the impaction of strong and weak ties on tacit and explicit knowledge transfer mediated by competence- and benevolence-based trust. Senthil and Margaret (2005) also conducted research on the function of social relationships on the processing of knowledge transfer within multinational groups from the perspective of knowledge-based theory and social network theory. While regarding the impact of the structure of a relationship network on the system performance, Inkpen and Tsang (2005) revealed the impact of social capital that is embedded in different network structures when processing knowledge transfers. Jackson and Dutta (2001), Bala and Goyal (2000), Singh (2005), Michael and Martina (2008), Zhou *et al.* (2010) also conducted research on this topic from different perspectives.

Cowan and Jonard (2004) first analyzed the relationship of network structures and different forms of knowledge transfer based on agent technology and found that knowledge transfer networks meet small-world network criteria and further, that the knowledge transfer network with such structural features has the highest average knowledge level.

Three conclusions can be drawn from research literature. First, most of this research is based on neoclassical economics paradigms. The pursuit of exchange efficiency is the fundamental reason to achieve knowledge transfer, while the exploration of knowledge transfer based on exchange mechanisms is a deeper subject. Second, the methodology of social networks has facilitated the subject relationship analysis, an effective measure to explore knowledge transfer under different exchange mechanisms. Third, a simulation analysis of an exchange process based on multi-agent technology has paved a new way for the further research of knowledge transfer and sharing.

3. The social mechanism of knowledge transfer

3.1 Exchange mechanism

According to the hypothesis of the rational person from the view of economic exchange theory, a rational person will not transfer knowledge unless the resulting returns exceed the costs. In a specific social network, knowledge transfer is typically beneficial to the recipient but can be costly to the source, considering that a rational knowledge owner will evaluate the costs, returns and results of knowledge transfer before he or she shares knowledge. Knowledge senders face a variety of risks in knowledge transfer. These risks include the potential threat to his or her position as a professional, which could consequently undermine his or her bargaining position with prospective employers. The time and energy consumed in the process of knowledge transfer and negative effects on his or her reputation as a result of transferring inappropriate knowledge are also risks incurred. For these reasons, a system is

required that motivates knowledge owners to share knowledge, maintain a balance between losses and gains, therefore raising their willingness to cooperate in a transfer.

For an individual, the most common motivation includes promotion, verbal recognition and awards. However, knowledge transfer effects cannot be effectively measured objectively by a third party outside the transfer due to the tacit features of knowledge. When an organization sets up a reward system encouraging individual knowledge transfers, employees are inclined to protect their exclusive possession of high value knowledge and are more likely to transfer knowledge of a lower value and cost. This has proved to be an ineffective motivational system with a diluted, inefficient effect. Bock *et al.* (2005) have shown that in the rational behavior model, anticipated extrinsic rewards fail to alter the employee's attitude to knowledge sharing. It can be deduced, therefore, that awards cannot explain the underlying motivation of knowledge transfer, and are not the dominant factor contributing to knowledge transfer instances. Thus, this frequently used knowledge management strategy cannot give rise to the expected results. There is, however, a more reasonable mechanism and practical path – i.e. social exchange.

Social exchange theory is a social psychological approach to the study of human interactions. Homans (1958) introduced economic concepts to this discipline theorizing that interpersonal interaction is a process where participants and their partners engage in activities and exchange valuable resources. People will not interact with each other unless they find the exchange beneficial. In various situations; those who interact must be willing to provide resources which meet one another's needs. In terms of organizational intelligence, knowledge transferred among employees constitutes organizational knowledge, and the activities of knowledge transfer form a knowledge trading market (Davenport and Prusak, 1998). In contrast with the social market, the intra-organizational knowledge market is built on mutual trust where the object of the knowledge transfer is not money but social capital (Homans, 1958), such as reputation and trust (Blau, 1964). The knowledge owner earns reputation and trust by transferring knowledge and as a result, he increases his social capital, bargaining chip and psychological advantage in future exchanges.

According to economic exchange theory, the other side of the exchange is not other actors, but the entire market. This point is significant when differentiating between economic exchange theory and social exchange theory. Social exchange mechanisms use the social capital to compensate for the opportunity cost of knowledge senders, offsetting the negative affects of extrinsic rewards. For example, Employee A passes on his/her experience to B or Division C for free so as to gain prestige and reputation; Employee D often learns skills from B so as to gain his/her trust and favorable opinion. Free social exchange meets an individual's specific needs and can initiate the self-organization of various social resources. Among the members of an organization, social exchange can increase the frequency of interaction, relational intensity, mutual trust and cognitive consistency, thereby raising the social capital of the organization as a whole and further lowering extrinsic resistance which hinders knowledge flow and the circulation of other social resources.

3.2 Reciprocity mechanism

Economics stems from the classic hypothesis of the rational person. A rational person is egoistically motivated and seeks to maximize his/her interests. A pure self-interest model is, however, incapable of accounting for some behaviors of a rational person where economic interests are at stake (Roberto and Colin, 2003). There are occasions where the behavior of a rational person is inconsistent with the basic principle where individuals seek to maximize their interests, these are the occasions where the behavior is driven by altruism. Coleman (1988) argues that altruism and reciprocity, as common social phenomena, are one of the leading principles in social existence. Individuals in a social network, particularly those in an organization with a specific target must learn from other members of the same organization in order to fulfill certain tasks, despite whether the relation is strong or weak. Consequently, altruism in tandem with direct assistance actively aids the fulfillment of the individual's tasks, both are gratuitous actions. Different from social exchange, altruism is common between

strangers, even though their information is asymmetric, gratuitous help is also given with no thought of reward.

Wilson categorized altruism into conditional altruism (reciprocal) and unconditional altruism (pure). In 1976, Becker, an economist, innovatively introduced this categorization into economics, this led to further and more in-depth analysis of motivations underlying reciprocity being conducted in the economic research field, contending that the aim of benefactor's altruism is to gain more payoffs in the long run by temporarily reducing his adaptability. Altruistic people speculate with a view to an increase of return on investment. More specifically, there is still an expected return on altruism, but a time gap between a act of altruism and return is often more significant. A benefactor will not necessarily anticipate direct return from the beneficiary; as a result this option-like investment has uncertainty, it can only exist in a relatively long-term repeated game. It demands a certain identification mechanism in a bid to decrease moral risks and individual opportunism.

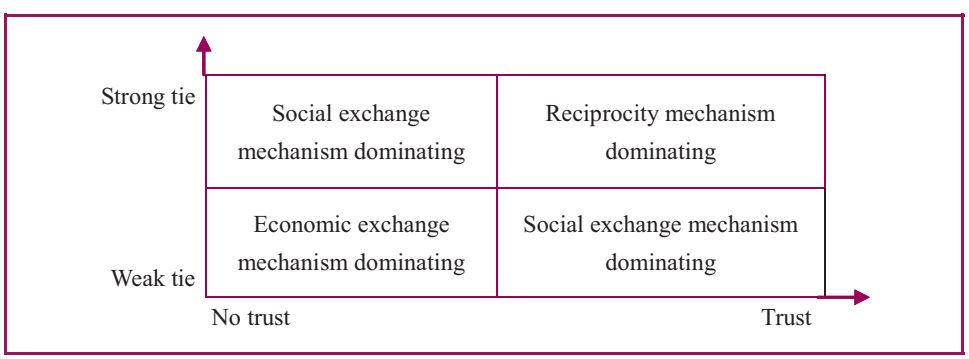
Pure altruism can be explained by group selectionism. According to group selectionism, natural selection is occurs at the level of biological population. When an individual's altruism benefits the population, the altruism trait will be preserved along with an increased benefit in the interests of the population as a whole. In the event of a potential existential crisis, a biological population with altruistic traits is more adaptable than one without such a spirit of sacrifice as altruism (Ye, 2005). From the economic perspective, when an individual is incorporated into a population as a result of blood relation, geographic location, or employment, the accompanying social interaction produces in him/her another logical rationality demanding communal life and recognition, and the maximization of interests. The element of satisfaction for the demand is also regarded as an improvement of personal utility; one contributing factor is ''credentials'' granted by the group, or social capital.

Whatever the type of altruism, reciprocity is the key to information transfer (Carol, 2006) and information is in the process of knowledge transfer (Wilson, 2002), so it is can be deduced that, the reciprocity mechanism is also at the core of knowledge transfer. An exchange mechanism is based on egoism, while reciprocity mechanism is based on altruism.

Within an organization with strong ties, the frequent and long-term interaction among its members of staff forms a repeated game. If the game produces high-level social capital for the organization, the facilitated reciprocal mechanism will take effect. In this situation, staff will seek to maximize individual and organizational interests by spontaneously establishing a community where knowledge practice and resource sharing is common place, even in the absence of a reward system in the organization. If mutual trust between the staff is low, they, as rational actors anticipating payoffs, will still transfer knowledge (see Figure 1).

Within an organization with weak ties, rational actors of different units will provide each other with goodwill trust based on shared organizational targets and reciprocal promises. In this situation, the social exchange mechanism becomes the dominant factor in enabling knowledge transfer. However, if a relationship between units falls short of trust, an economic

Figure 1 The relationship between tie, trust and knowledge transfer mechanism



exchange mechanism becomes the dominant mechanism and high exchange cost is unavoidable.

4. Research design

In previous sections the dynamic mechanism of knowledge transfer has been analyzed, consisting of an exchange mechanism and a reciprocity mechanism. The mechanism will vary for actors according to their interaction partners. For example, A is a senior financial professional, B is A's colleague in the same division, while C belongs to another division. Knowledge transfer from A to B is a result of a reciprocal mechanism, while that from A to C is a result of exchange mechanism. Despite the context in which one of the two mechanisms takes effect, according to the hypothesis of the rational person, an individual will either strengthen or weaken his ties with others in order to maximize their own individual interests. This individual pursuit will lead to the evolution of a network structure. The result is that the member with high-level knowledge is more popular. In addition, it becomes easier for members with similar knowledge or a common ground of knowledge to establish a practice community.

In the following, agent-based technology will be employed to construct a dynamic model to simulate and explain how an individual initiates the evolution of a knowledge transfer and sharing network through knowledge transfer and exchange.

This agent-based model is a ''top down'' model. It presents the basic behavior of heterogeneous and self-adaptive agents in a simple algorithm to allow analysis, and models the global pattern of agents' interaction. A system of this type is not readily accounted for in transition modeling. Agent-based models provide theoretical leverage where the global patterns present more than just aggregation of individual attributes. However, global patterns cannot be explored without modeling the dynamic micro-relations.

Suppose that every actor in a social network is an agent, and the social network in its initial stage is a random network (N, p) consisting of N agents. The probability of connection between any two agents is p. When $p = 0$, all agents are isolated – that is, there is no connection between any the agents; when $p = 1$, all agents are connected and the network is globally coupled. The average degree of this random network is $\langle k \rangle = p(N-1) \approx pN$; at the moment t, the degree of agent i is $k_i(t)$, $0 \leq k_i(t) \leq N-1$, and the knowledge of agent I at the moment i is $r_i(t)$, which is a random value ranging from 0 to 1. For the convenience of computation, the individual knowledge level is a unidimensional vector. The network regards agents with a high knowledge level as the most professional. The value of agent i, $V_i(t)$, is dependent on its degree at the moment, knowledge level and values of its neighbor nodes. The function is as follows:

$$\begin{cases} V_i(t) = \sum V_j(t-1)/k_i(t) + r_i(t) \\ V_i(0) = r_i(0) \end{cases}$$

$V_i(t) = \sum_{j \in U(i)} V_j(t-1)/k_i(t) + r_i(t)$Based on the hypothesis of the rational man, any agent tends to maximize his/her values (see Table I). It will choose either to add or cancel links in accordance with the direction of value change. Given that either the link addition or cancellation involves two agents, the interaction involved is a game. Suppose that two

Table I Agent's game strategies and its choice in adding and canceling links

		Rule	*Result*	*Description*
A^+	I	$\max_{a \in A^+} \{v_i^a(t+1) - v_i(t)\}$	a^*	Bilateral decision
	J	If $\{v_j^{a^*}(t+1) - v_j(t)\} > 0$	a^* accepted	
A^-	I	$\max_{b \in A^-} \{v_i^b(t+1) - v_i(t)\}$	b^*	Unilateral decision
	J		b^* accepted	

agents in a game have perfect information – the game can then be described as a perfect information game and the strategy is as follows: if the establishment of a link would increase the value of agent i, $V_i(t+1) > V_i(t)$, agent i will add links. In A^+, a collection of agents with whom agent i could add links, agent i will choose to add links with those who will bring him the most value. However, the success of adding links is dependent on whether the link enables V_i to improve its value or not. If yes, V_i will accept the addition of links, and so the addition of links is realized, a^* represents a strategy for adding links. If canceling a link could increase its value, agent i will cancel links. In this case, it is i's unilateral decision to choose from A^-, a collection of agents with whom agent i could cancel links. An agent with whom the cancellation of links will cause i the least value loss, irrespective of the latter's decision, b^* represents a strategy for canceling links. The foregoing game process and agent's choice of strategy form the algorithm base of simulating network evolution.

The result of link addition and/or cancellation is a change in the degree, knowledge level and value of agent and the whole network structure will change. There are two types of change concerning knowledge level. The first is cost-bearing knowledge transfer, a result of exchange relationship, and the second is cost-free knowledge transfer, a result of reciprocal relationship. The change of agent's knowledge level in the two relationships are different, as shown in Table II. In Table II, α represents absorptive capacity (range [0, 1]), c represents the cost coefficient in the relationship of exchange, which is assumed as a complete transfer with payments – that is, payment transfer on the part of one side equals to the payoff increase on the part of the other side.

As a result of adding or canceling links through which an agent aims to maximize its own value, the network structure changes. There are numerous references for measuring the evolution of network, including entropy change in the network nodes, the change in the network clustering coefficient, node degree, and the average shortest distance metrics commonly deployed when analyzing social networks and thus employed here.

5. Results

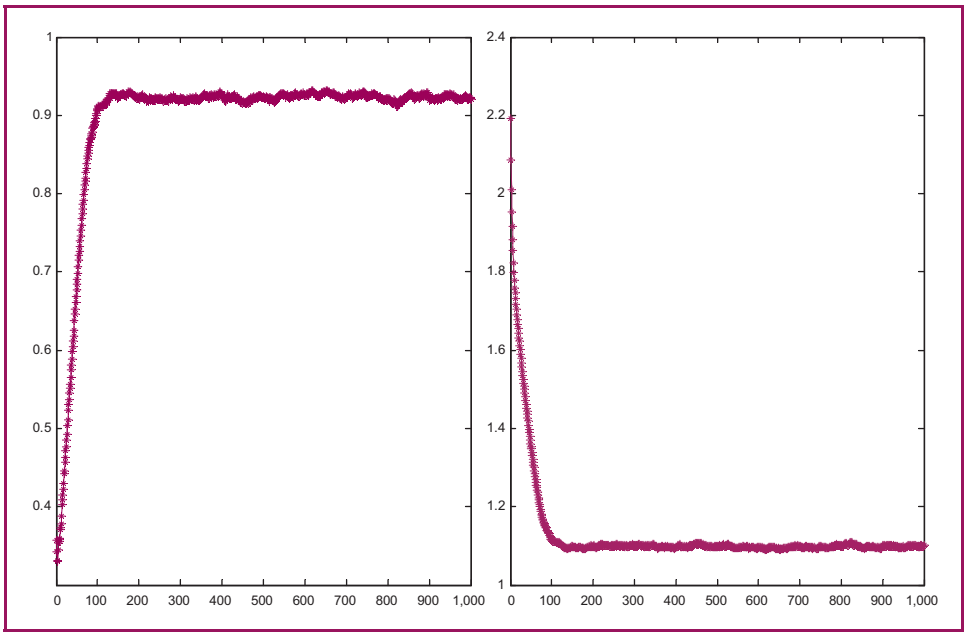
Matlab6.0 is employed to simulate the evolution of network and it is assumed that $n = 100$, $p = 0.1$, $\alpha = 0.4$ and c is a random value within the range [0, 1]. The clustering coefficient C and average shortest distance L of the network evolutes with time, and Figure 2 shows the results.

Figure 2 shows that after a period of evolution, the structural characteristics of a random network change markedly. The average shortest distance L gradually decreases, while the clustering coefficient C increases significantly and rapidly reaches a stable position. This indicates that agents gradually cluster over time and stop after reaching a particular level. These connections are maintained, which results in a continuing decrease of the average shortest distance. The computation of the agent's node degree shows that the initial average node degree is 100; when it reaches 200, the average node degree increases to 125, while the average node degree of those agents with a lower initial knowledge level is 110. This result indicates that at the initial stage where agents bear no noticeable difference in social capital, it is easier for an agent with high-level knowledge to gain social capital, and therefore to obtain more competitiveness and potential to grow into a leader.

Table II The change of agent's knowledge level

	Type	*Description*	Δr_i	Δr_j
$r_i < r_j$	Exchange	Irrespective of transfer costs	$(r_j - r_i) \cdot \alpha \cdot (1 - c)$	$(r_j - r_i) \cdot \alpha \cdot c$
$r_i > r_j$	Reciprocity	Respective of transfer costs	0	$(r_i - r_j) \cdot \alpha$

Figure 2 The characteristics of simulated network evolution: based on an individual dynamic mechanism



6. Discussion

6.1 From random network to small-world network

Traditional research on networks has focused on the constraint of network position on actors and presupposed that network structures are fixed. Therefore the creation and evolution of networks were generally ignored. Since Brass and Burkhardt (1992), the research in this area has shifted its focus towards the exploration of how a network is constructed. In this perspective, managers exert their influence on the network, which makes possible the active management of the relation structure among the staff by the managers. At the same time, the relation structure also is of significance when monitoring and managing the communication structure, arranging the organizational communication structure in accordance with the tasks (Ahuja and Carley, 1999). The managers' influence along with the micro-interaction among actors pushes forward the formation and evolution of a network. The findings in this section indicate that in knowledge transfer and exchange, members of the network seek initial and further connections under the principle of profit maximization. As a result, members with high-value are popular targets for connection. By connecting with high-value members, common members with equal status will also connect with each other and therefore form more and more triads. The phenomenon of network gathering emerges while simultaneously the average shortest distance decreases. In view of the network as a whole, a network will evolve from initial randomness to a small world at the end. Although the evolution occurs as self-organization without managerial intervention, a manager's manipulation will have the potential to accelerate the process.

6.2 More knowledge, more social capital and more links

A social network not only influences and constrains in non-trivial ways the behavior of individuals but also contributes to aspects generically referred to as social capital, favoring the emergence of coordinated actions or collaboration (Astaa *et al.*, 2012). Through the change of individual knowledge level and social capital, it is easier for network members with high initial knowledge level to gain relations and exchange knowledge because they are more attractive to other members and boosts their acquisition of social capital. Lee *et al.* (2011) has investigated the emergent hierarchical structures in multi-adaptive games of a social system. They found a similar phenomenon that an individual has adaptability and

prefers to contact with participants who can bring more benefits when he or she chooses new interactive members. In gaining external links, the speed of growth of the high-level network members' knowledge and social capital also accelerates and is higher than that of the average network members. This leads to the ''knowledge gap'' phenomenon, which refers to the fact that the knowledge level of some organizations, groups, areas and nations is much higher than that of others. This causes further differentiation between economic development and sustainability, threatening social stability and hindering development. It is therefore necessary for network managers to take administrative or economic measures to distribute its professionals evenly so as to improve the average knowledge level of every group, narrowing or filling the ''knowledge gap''.

6.3 Value of exchange and reciprocal mechanism

Under the impact of reciprocal and exchange mechanisms, the link addition between any two nodes will bring about the growth of knowledge and value of either one or both sides. However, due to the difference of absorptive capacity and type of mechanism in effect, there exists a discrepancy between the two sides of knowledge growth, varying with absorptive capacity and transfer costs. The parameter will not change the direction of network evolution. By comparing the reciprocal mechanism and exchange mechanism, although both mechanisms can improve the knowledge of its network members, the exchange mechanism is more efficient as it can improve the values of both sides of the transaction. Therefore, it is necessary for administrators to construct or improve the knowledge exchange market within the organization to reach the free flow of knowledge (Davenport and Prusak, 1998).

6.4 Implications for practitioners and researchers

Overall, the impact of individual behavior dynamics on the formation and evolution of social networks is significant. Although the reciprocal mechanism and exchange mechanism result in different modes of actions, subjects, and situations, they both can potentially lead to the small-world phenomenon, which refers to the situation where actors with low knowledge level will gather around those with high knowledge level through gradual knowledge transfers.

The findings of this study accord with real-world observations. In scientific research, for example, researchers usually build social relationships and transfer knowledge on the basis of exchange and reciprocity. Researchers with similar interests interact with one another more frequently, as the result of which the small-world structure gradually takes shape in the scientific collaboration network. If a cluster in the collaboration network contains one or more high-level actors, the average performance of the cluster will be higher than other ones. Hence research universities, in the hope of improving their academic status, always compete for outstanding researchers and attract talents with substantial benefits. In multinational corporations, the entire marketing employee network is a small-world network. The marketing departments in different regions are connected by weak ties while they each constitute a closely collaborating group. If a group has one or more competent salesmen, the average sales performance will be higher than other regions. So it is common that salesmen in leading regions are appointed managers of poorly performing departments in order to increase their average performance level.

According to the theories of complex networks, the evolution of a network is not only influenced by individual motivations, but also individual self-organization. In the absence of external rules, activities driven by the principle of personal value maximization can give birth to optimal network structures. Unconscious autonomy replaces business management strategies to some extent and complements the plan, coordination, and control in the organization's hierarchy. But the process will be affected by formal rules undoubtedly. So to accelerate the increase of average knowledge level and organizational competitiveness, the administration should make policies that encourage exchanging and reciprocal activities as well as the formation of knowledge trading markets in organizations.

7. Conclusions

With the knowledge-based theory spreading, more and more researchers and practitioners have realized that knowledge management abilities are the basic components of organizational competitiveness. Increasing the average knowledge level of organizations with the individual knowledge transfer network may be propitious to innovation and competition.

In this research, the author studied the impacts of exchange mechanism and reciprocal mechanism on individual knowledge transfer with the agent-based technology and complex network simulation methods. The result has proved that exchange mechanism and reciprocal mechanism can result in the emergence of small-world features separately or synergistically. The result is consistent with Watts's (2004) findings, so small-world network is suitable for knowledge and information diffusion.

There are still some limitations in this research. Firstly, the author limited the quantities of variables, interactive rules and agents in the simulation modeling, so the model is incomplete and the results should be confirmed with other research methods in the future. Secondly, some kind of human activities, such as non-cooperative games and punishments, were not considered in this paper. Anyway, the author believes that it is unavoidable to analyze the internal mechanisms behind individual knowledge transfer activities to improve the knowledge management efficiency in organizations.

The computer simulation is a new research method in the field of knowledge management though it is quite popular and has a history use in management science. In the future, the author will focus research on the impacts of the position of an actor in the social network on its activities and performance through traditional questionnaire survey methods in conjunction with social network analysis tools.

References

Adler, P.S. and Kwon, S. (2002), ''Social capital: prospects for a new concepts'', *Academy of Management Review*, Vol. 27 No. 6, pp. 17-40.

Ahuja, M.K. and Carley, K.M. (1999), ''Network structure in virtual organizations'', *Organization Science*, Vol. 10 No. 6, pp. 741-7.

Astaa, L.D., Marsilib, M. and Pind, P. (2012), ''Collaboration in social networks'', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 109 No. 12, pp. 4395-400.

Bala, V. and Goyal, S. (2000), ''A non-cooperative model of network formation'', *Econometrica*, Vol. 68, pp. 1181-229.

Barabási, A.-L. (2003), *Linked: How Everything Is Connected to Everything Else and What it Means for Business, Science and Everyday Life*, Penguin, New York, NY.

Barabási, A.-L. and Réka, A. (1999), ''Emergence of scaling in random networks'', *Science*, Vol. 286 No. 5439, pp. 509-12.

Bartlett, C.A. and Ghoshal, S. (1989), *Managing across Borders: the Transnational Solution*, Harvard Business School Press, Cambridge, MA.

Blau, P. (1964), *Exchange and Power in Social Life*, Wiley, New York, NY.

Bock, G.-W., Zmud, R.W., Kim, Y.-G. and Lee, J.-N. (2005), ''Behavioral intention formation in knowledge sharing: examining the roles of extrinsic motivators, social-psychological forces, and organizational climate'', *MIS Quarterly*, Vol. 29 No. 1, pp. 87-111.

Bollinger, A.S. and Smith, R.D. (2001), ''Managing organizational knowledge as a strategic asset'', *Journal of Knowledge Management*, Vol. 5 No. 1, pp. 8-18.

Brass, D.J. and Burckhardt, M.E. (1992) in Nohria, N. and Eccles, R.G. (Eds), *Centrality and Power in Organizations, Networks and Organizations: Structure, Form and Action*, Harvard Business School Press, Boston, MA.

Burt, R.S. (1992), *Structural Holes: The Social Structure of Competition*, Harvard University Press, Cambridge, MA.

Carol, D. (2006), ''Recipients: the key to information transfer'', *Knowledge Management Research & Practice*, Vol. 4 No. 1, pp. 17-25.

Christakis, N.A. and Fowler, J.H. (2009), *Connected: The Surprising Power of Our Social Networks and How They Shape Our Lives*, Little Brown, New York, NY.

Coleman, J. (1988), ''Social capital in the creation of human capital'', *American Journal of Sociology*, Vol. 94 No. 5, pp. 95-120.

Cowan, R. and Jonard, N. (2004), ''Network structure and the diffusion of knowledge'', *Journal of Economic Dynamics & Control*, Vol. 28 No. 8, pp. 1557-75.

Davenport, T.H. and Prusak, L. (1998), *Working Knowledge: How Organizations Manage what They Know*, Harvard Business School Press, Boston, MA.

Dinur, A. and Inkpen, A.C. (1996), *Transfer of Knowledge in the Multinational Corporation*, *Proceedings of the Academy of Management Annual Meeting*, *Cincinnati, OH*.

Granovetter, M.S. (1973), ''The strength of weak ties'', *American Journal of Sociology*, Vol. 78 No. 6, pp. 1360-80.

Grant, R.M. (1996), ''Prospering in dynamically-competitive environments: organizational capability as knowledge integration'', *Organization Science*, Vol. 7 No. 4, pp. 375-87.

Hansen, M.T. (1999), ''The search-transfer problem: the role of weak ties in sharing knowledge across organization subunits'', *Administrative Science Quarterly*, Vol. 44, pp. 82-111.

Homans, G.C. (1958), ''Social behavior as exchange'', *American Journal of Sociology*, Vol. 63 No. 6, pp. 597-606.

Inkpen, A.C. and Tsang, E.W.K. (2005), ''Social capital, networks, and knowledge transfer'', *The Academy of Management Review*, Vol. 30 No. 1, pp. 146-65.

Jackson, M. and Dutta, B. (2001), ''On the formation of networks and groups'', in Jackson, M. and Dutta, B. (Eds), *Models of the Strategic Formation of Networks and Groups*, Springer, Berlin.

Kogut, B. and Zander, U. (1992), ''Knowledge of the firm, combinative capabilities, and the replication of technology'', *Organization Science*, Vol. 3 No. 3, pp. 383-97.

Lee, S., Holme, P. and Wu, Z.-X. (2011), ''Emergent hierarchical structures in multiadaptive games'', *Physical Review Letters*, Vol. 106, p. 028702.

Levin, D.Z. and Cross, R. (2004), ''The strength of weak ties you can trust: the mediating role of trust in effective knowledge transfer'', *Management Science*, Vol. 50 No. 11, pp. 1477-91.

Michael, F. and Martina, K.M. (2008), ''The impact of network structure on knowledge transfer: an application of social network analysis in the context of regional innovation networks'', *The Annals of Regional Science*, Vol. 44 No. 1, pp. 21-38.

Milgram, S. (1967), ''The small world problem'', *Psychology Today*, Vol. 1 No. 1, pp. 61-7.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York, NY.

Prahalad, C.K. and Hamel, G. (1990), ''The core competence of the corporation'', *Harvard Business Review*, Vol. 68 No. 3, pp. 79-91.

Reagans, R. and McEvily, B. (2003), ''Network structure and knowledge transfer: the effects of cohesion and range'', *Administrative Science Quarterly*, Vol. 48 No. 2, pp. 240-67.

Roberto, A.W. and Colin, F.C. (2003), ''Cultural conflict and merger failure: an experimental approach'', *Management Science*, Vol. 49 No. 4, pp. 400-15.

Rogers, E.M. (1995), *Diffusion of Innovations*, The Free Press, New York, NY.

Senthil, K.M. and Margaret, A.W. (2005), ''Learning and knowledge transfer in strategic alliances: a social exchange view'', *Organization Studies*, Vol. 26 No. 3, pp. 415-41.

Singh, J. (2005), ''Collaborative networks as determinants of knowledge diffusion patterns'', *Management Science*, Vol. 51 No. 5, pp. 756-70.

Teece, D. (1977), ''Technology transfer by multinational firms: the resource cost of transferring technological know-how'', *The Economic Journal*, Vol. 87 No. 346, pp. 242-61.

Tsai, W. (2001), ''Knowledge transfer in intraorganizational networks: effects of network position and absorptive capacity on business unit innovation and performance'', *Academy of Management Journal*, Vol. 44 No. 5, pp. 996-1004.

Watts, D.J. and Strogatz, S. (1998), ''Collective dynamics of small world networks'', *Nature*, Vol. 393, pp. 440-2.

Watts, D.J. (2004), *Six Degrees: The Science of a Connected Age*, W.W. Norton & Co., New York, NY.

Wilson, T.D. (2002), ''The nonsense of 'knowledge management''', *Information Research*, Vol. 8 No. 1.

Ye, H. (2005), ''On the economic explanation of altruistic behavior'', *Economist*, Vol. 3, pp. 22-9.

Zhou, S.H., Siu, F. and Wang, M.H. (2010), ''Effects of social tie content on knowledge transfer'', *Journal of Knowledge Management*, Vol. 14 No. 3, pp. 449-63.

Further reading

Fowler, J.H. and Christakis, N.A. (2010), ''Cooperative behavior cascades in human social networks'', *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 107 No. 12, pp. 5334-8.

Zander, U. and Kogut, B. (1995), ''Knowledge and the speed of the transfer and imitation of organizational capabilities: an empirical test'', *Organization Science*, Vol. 6 No. 1, pp. 76-91.

About the author

Xiaoguang Wang is an Associate Professor of the School of Information Management, Wuhan University, China. He worked as postdoctoral fellow at the Digital Humanities Center, Ritsumeikan University, Japan, from April 2008 to March 2009. His research interests are in the areas of knowledge network analysis, digital assets management and semantic publishing. He won 2012 First Batch of Top-notch Young Scholar, awarded by the Central Government of China. He also won the 2011 Luojia Excellent Young Scholar, awarded by Wuhan University. He has published in, or has papers forthcoming in, *Journal of Information Science*, *Chinese Journal of Library and Information Science*, *Proceedings of the International Conference on Information Systems*, and *Journal of Informetrics*. He currently serves as an anonymous reviewer for *Journal of Computer-mediated Communication*. Xiaoguang Wang can be contacted at: wxguang@whu.edu.cn

This article has been cited by:

1. Natalie Solveig Mikhaylov. Development of Personal Learning and Social Networks: Strategies for Knowledge Creation and Sharing in Online Learning Environments 127-139. [Crossref]
2. ChengShih Yu (Cheryl), Shih Yu (Cheryl) Cheng. 2017. Leader-member exchange and the transfer of knowledge from Taiwanese managers to their Chinese subordinates. *Leadership & Organization Development Journal* **38**:6, 868-882. [Abstract] [Full Text] [PDF]
3. Mario Oscar Steffen, M?rian Oliveira, Andrea R Balle. 2017. Knowledge sharing among companies in a science and technology park. *Business Information Review* **34**:2, 101-108. [Crossref]
4. Nuha Zamzami, Andrea Schiffauerova. 2017. The impact of individual collaborative activities on knowledge creation and transmission. *Scientometrics* **111**:3, 1385-1413. [Crossref]
5. Adriana Valencia Valencia, María del Carmen Trejo Cázares. 2016. Academic and research networks management: challenges for higher education institutions in Mexico. *International Journal of Educational Technology in Higher Education* **13**:1. . [Crossref]
6. VătămănescuElena-Mădălina, Elena-Mădălina Vătămănescu, AndreiAndreia Gabriela, Andreia Gabriela Andrei, DumitriuDiana-Luiza, Diana-Luiza Dumitriu, LeovaridisCristina, Cristina Leovaridis. 2016. Harnessing network-based intellectual capital in online academic networks. From the organizational policies and practices towards competitiveness. *Journal of Knowledge Management* **20**:3, 594-619. [Abstract] [Full Text] [PDF]
7. Natalie S. Mikhaylov, Isidro Fierro. 2015. Social capital and global mindset. *Journal of International Education in Business* **8**:1, 59-75. [Abstract] [Full Text] [PDF]
8. Xiaoguang Wang, Qikai Cheng, Wei Lu. 2014. Analyzing evolution of research topics with NEViewer: a new method based on dynamic co-word networks. *Scientometrics* **101**:2, 1253-1271. [Crossref]
9. Si-hua Chen, Wei He. 2014. Study on Knowledge Propagation in Complex Networks Based on Preferences, Taking Wechat as Example. *Abstract and Applied Analysis* **2014**, 1-11. [Crossref]
10. James M. Bloodgood, Michael A. Chilton, Thomas C. Bloodgood. The Effect of Knowledge Transfer Motivation, Receiver Capability, and Motivation on Organizational Performance 232-242. [Crossref]