

The Performance of Knowledge Collaboration in Virtual Teams: An Empirical Study

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Abstract

Knowledge collaboration is an effective management method to promote the appreciations of intellectual capital and social capital. In a virtual team, team atmosphere, team network and the individual attributes, etc. shall affect the performance of knowledge collaboration (KC) in different degrees. The paper will build the theoretical framework that affects the performance of virtual team's knowledge collaboration, and use the Bootstrap-based structural equation model to perform empirical study on the theoretical framework. Empirical results show that network characteristics of virtual team, team attributes, individual attributes and collaborative efficiency all have significant impact on the performance of KC. Empirical conclusions will provide a theoretical basis and practical reference for promoting the performance of knowledge collaboration.

Keywords: *Virtual Teams; Knowledge Collaboration; Performance*

1. Introduction

With the rapid development and extensive application of information and communication technology, the virtual team collaborated across time, space and organizational boundary has become an important organizational structure for enterprises to cope with the increasingly accelerated market change. The virtual team, with advantages such as including diverse staff, broad organizational boundaries, flexible organizational structure and innovation resources allocation, *etc.*, has been widely adopted in many fields including service outsourcing, IT and innovation research and development, *etc.* The previous research has shown that a virtual team is an effective model to settle the complex task on wide-scope and cross-disciplinary knowledge demand within the organization [1]. Therefore, how to effectively improve the performance of virtual team has been a focused issue in the business and the academic circles.

From the perspective of knowledge management, the virtual team is essentially the use of "Heterogeneous" subjects for collaborative knowledge innovation. In addition to compensate for the knowledge gaps to effectively solve the problem of knowledge scenario embedding and path dependence, the knowledge collaboration model also can obtain collaborative effects of multi-subject, multi-target and multi-tasks. However, because of staff diversity, and the use of electronic information technology as the primary means of communication, lacking of face to face communication, the knowledge collaboration and performance of a team is facing many problems. Therefore, in terms of the characteristics of virtual teams, it is necessary to study how to further enhance the collaborative efficiency of the virtual team and improve the performance of knowledge collaboration by integrating the collaborative innovation resources. On the basis of defining the performance of knowledge collaboration and collaborative efficiency, and taking Chinese service outsourcing enterprises team as research objects, this paper performs empirical analysis on the critical factors influencing the performance of the virtual team's

knowledge collaboration, and proposes corresponding suggestions on this research basis.

2. Research Summary

2.1. Virtual Teams and Knowledge Collaboration

(1) Virtual teams

Currently, there is no an agreed definition of virtual team. Lipnack and Stamps (1997) considered a virtual team as a group of people, inter-space, inter-time and inter-organizational boundaries, who work independently from each other for a common target relying on the technology [2]. Kirkman *et al.*, (2002) insisted that virtual teams were composed of employees with unique skills, located at a distance from each other, who must collaborate to accomplish important organizational tasks , and put forward five challenges to virtual team success [3]. Zigrus (2003) summarized the concept of virtual team in the current research field preferably, he thought that virtual team is a collection of individuals, and those individuals have the dispersion characteristics in different dimensions; the dispersion dimension mainly includes: regional dimension, organizational dimension, time dimension and culture dimension; the individual works collaboratively via information and communication technologies, so as to achieve a certain goal [4]. Chen Yali (2009) holds that, in terms of the establishment of a virtual team, the team member mainly consists of scientific and technical personnel based on knowledge, skills and capabilities, and pays more attention to individual capabilities, cooperative capability, and the matching degree of adaptation, *etc.*, [5]. Li Yanyong (2013) thought that the fields adopting virtual team as the organizational form are mainly concentrated in the innovative field, involving in fields such as high and new technology, design and research and development, software development, scientific research and consultation, *etc.*, and its knowledge or product is the main output [6]. Therefore, for the virtual team, from the perspective of either the team's formation of target and output of purpose, or the team's own characteristics, the knowledge innovation is the soul of its existence.

(2) Knowledge collaboration

Karlenzig (2002) first put forward the concept of “Knowledge Collaboration”, he thought that it is an organizational strategy, which could dynamically assemble the internal and external systems, business process, technology and relation (community, customer, partner and the supplier), to maximize the business performance[7]. After this, many scholars proposed different definitions from different perspectives and levels. From the enterprise perspective, Mckelvey *et al.*, (2003) thought that knowledge collaboration is a kind of “Activity”, such as, collaborative development and collaborative authoring, *etc.*; the members participated in the activity strive to create personal knowledge and form a valuable result eventually [8]. Tong Zehua (2012) comprehensively thought knowledge collaboration is a kind of effective collaborative status in time and space achieved by the subject, object and environment, *etc.* in the knowledge management, and achieves at the right time and space, and it is multidimensional dynamic process that transferring appropriate information and knowledge to appropriate target or object to achieve knowledge innovation. Knowledge collaboration is the advanced stage of knowledge management, and its ultimate target is to achieve knowledge innovation, which is the target of virtual teams [9]. In addition, at the micro level, Leijen and Baets (2003) pointed out that knowledge collaboration refers to a knowledge requester realized that himself/herself does not have the capacity to solve a problem, while another knowledge provider just having the capacity in this aspect, if both parties could reach a consensus,

they can integrate their knowledge to make for the knowledge demand of the knowledge requester, so as to solve the problem [10]. At the macro level, Chen Kunyu and Chen Kunqiong (2002) thought that via integrating the internal and external knowledge resources of the organization, the enterprise could make the overall efficiency of organizational learning and knowledge utilization and creation greater than the sum of each independent component, and its purpose is to obtain the knowledge collaborative effect of “1+1>2” [11]. Since the micro individual can solve problems through knowledge collaboration, and the macro-organizations can create benefits through knowledge collaboration as well, it is a necessary action to research the performance of knowledge collaboration.

2.2. Knowledge Collaboration Performance Model

The so-called "Performance" refers to the final results showing the overall operational activities of the organization, meanwhile, it is a factor to measure the degree of successful achievement of the organization's tasks or targets [12]. In performance of knowledge collaboration, the current researches are mainly focused on the effect of or the relation between the knowledge management, knowledge sharing, knowledge transfer and knowledge collaboration, etc. on organizational performance, enterprise performance, team performance, management performance and innovative performance, etc. For example, Wan Youqing and Deng Mingran (2007) analyzed the collaborative innovation performance of industry cluster based on the angle of knowledge view, and constructed the collaborative innovation performance model of industry cluster from the aspects of enterprise knowledge's base stock, enterprise innovation power, innovation capacity and the collaboration between enterprises, etc., [13]. Du Baocang and Li Chaoming (2009) built a relevant indicator system for the collaborative work performance of the inter-organizational knowledge workers, and carried out an application example using the multi-level extension evaluation method [14]. Xu Qiang and Jian Zhaoquan *et al.*, (2010) constructed the model on the mutual relation between network relation, trust, knowledge sharing and the technology innovation performance, through empirical research, they believed that: the degree of trust, network relation and knowledge sharing between enterprises have positive influence on the enterprise's technology innovation performance [15]. Zheng Xiaodan (2010) started with the organizational collaboration of parent-subsidiary Corporation, taking knowledge collaboration as intermediary variable, analyzed the relation among the organizational collaboration, knowledge collaboration and innovation performance of the parent-subsidiary corporation, and constructed corresponding conceptual model [16]. Zhou Fang and Guo Yan (2012) built a theoretical model of tripartite relation of supply chain social capital, knowledge sharing and innovation performance, and holds that, through empirical research: There is a positive relation between social capital and supply chain enterprise innovation performance, knowledge sharing between supply chain enterprises plays an important intermediary role in social capital and supply chain enterprise innovation performance [17]. By taking knowledge integration as intermediary variables, Shi Liping *et al.*, (2013) studied the mechanism of interaction memory systems and knowledge team performance. In this literature, they constructed interaction memory system, the theoretical framework of the relation between knowledge integration and performance of knowledge group, but the measurement of performance of knowledge group did not be subdivided. Nevertheless, this literature proves that knowledge integration between internal and external knowledge has a positive impact on performance of knowledge group; this conclusion explains the necessity and feasibility of the performance of knowledge collaboration in virtual teams' research from a side [18].

From the existing literature, empirical research on the measurement and influencing factors of performance of knowledge collaboration is insufficient. For existing literatures

discussing the performance issues of knowledge from the knowledge itself, it only stay in discussing the performance of knowledge sharing and effect of knowledge transfer and did not mention the performance, result or efficiency measurement of knowledge collaboration. In fact, knowledge collaboration is a complex process including knowledge sharing, knowledge transfer and knowledge creation [19].

2.3. Knowledge Management based on Social Network

Research on knowledge management and knowledge transfer based on social network perspective is not a new topic. As early as 1999, Seufert considered knowledge network is a kind of social network among knowledge participants to achieve value creation through knowledge creation and transfer in levels such as individuals, groups, organizations and interior, *etc.*, [20]. Hansen (1999) presented an opinion that weak ties is more conducive to knowledge transfer, opening a prologue of researching on knowledge sharing and knowledge transfer from the perspective of social networks and social relation[21]. Singh (2005) researched the knowledge collaboration network, and provided a knowledge network collaborative model. Currently a lot of research literatures adopt empirical research forms to argue in different levels, which aim at different social networking characteristic' influence relation to knowledge management, knowledge sharing or knowledge transfer [22]. For example, Inkpen *et al.*, (2005) used the social network method to construct the theoretical framework of knowledge transfer among virtual teams, to research how to organize the organizational knowledge of virtual team and the incentive problem of how to solve the problem of task knowledge, they found that social relations including trust, and emotional joint, *etc.* make knowledge transfer easier [23]. Stephen and Irene (2008) researched how to apply social network-based system to support interactive collaboration in knowledge sharing over peer-to-peer networks [24]. Zhu (2009) demonstrated the influence of the network characteristics (associative strength, network density, network scope and network centrality) of knowledge resource enterprise and knowledge receiving enterprise on the knowledge transfer effect among enterprises, by taking the knowledge transfer effect as research object, and taking the individual attributes of knowledge resource enterprise and knowledge receiving enterprise as intermediary variable [25]. Yanli (2010) took a particular virtual team as example, used social network method to analyze the knowledge sharing mechanism within the virtual team; the research found that the emotional joint among the team members is beneficial to knowledge sharing, and the network accessibility and the number of small group will influence the efficiency of knowledge sharing within the team [26]. Shen Huimin (2013) researched the impact of social network characteristic on community knowledge creation. She considered that community network characteristics (network density and connection strength) have important influence on community knowledge creation. Good community networks are conducive to the formation of effective collaboration atmosphere; and high connection strength among community members is conducive to increase collaborative work opportunities to improve the performance of social knowledge creation [27].

The above existing research shows that the function that social networking characteristics on knowledge management have been demonstrated, the existence of influence relation is positive. The difference is that under different research objects and different research situation, the play mechanism may be different; and knowledge collaboration is a dynamic process, and its play mechanism will be different as well. Therefore, in the study of performance of knowledge collaboration in virtual teams, social networking characteristic will be an indispensable key factor.

2.4. Critical Review

If we take the virtual team as a system, we could decide, no matter from the input (the composition of the team and resource access) or from the output (form of output: new

products and new knowledge), that the virtual team is existed for the purpose of knowledge innovation. And effective knowledge collaboration mechanism is a good way for knowledge creation and knowledge innovation. Although there are many literatures discussing the problems related to knowledge management of virtual teams, but currently research on performance of knowledge collaboration in virtual teams is insufficient. Knowledge collaboration is a dynamic process, throughout the process of knowledge transfer, knowledge sharing, and knowledge innovation. Although it may contain links or stages such as knowledge sharing, knowledge transfer, knowledge learning and knowledge creation, etc., the performance of any single link is unable to represent the overall performance of knowledge collaboration. In consequence, this research will focus on the measurement of the performance of virtual team's knowledge collaboration, and analyze the principal factors influencing the performance of the virtual team's knowledge collaboration from the social network perspective, the attribute of virtual team, the individual attributes and the efficiency of knowledge collaboration, *etc.*

3. Theoretical Models and Assumptions

3.1. Performance of Knowledge Collaboration (KC) and its Measurement

Knowledge collaboration(KC) is the process of interpersonal knowledge interaction; knowledge subjects integrate their own knowledge with that gained from others to form new knowledge. Due to the intangibility, sharing competency and non-depreciation of knowledge capital, in the effectiveness of KC, except for the final intellectual products (taking products or service as carrier) delivering to the customer, the intellectual achievements contained in the intellectual products also become the appreciation part of enterprise's knowledge capital, which are reflected as the capability improvement of individual and the team, the accumulation of experience and the improvement of process, and also reflected as the increase of explicit knowledge (the increase of experience summary, process documentation and knowledge base, *etc.*). In addition, knowledge collaboration is the process in which individual knowledge demanders look for knowledge providers and exchange their knowledge. In this process, the connection among subjects of knowledge tend to be more and firmer; the trust, reciprocity and mutual respect approval among subjects tend to be enhanced; their languages, stands and viewpoints tend to be unanimous. These increments formed the increase in social capital amount. Therefore, performance of knowledge collaboration can be measured from appreciation of two aspects including the knowledge capital and social capital.

(1) Measurement of knowledge capital

Knowledge capital includes all the assets created by intellectual activities including knowledge acquisition, innovation and establishment of value chain, *etc.* Knowledge collaboration is the process of knowledge creation, in the process, the capabilities of knowledge worker are promoted, the knowledge gets renewals and extensions and the organization environment and business process get improved, all these belong to the category of knowledge capital (Chen, 2014)[28]. Therefore, the results of knowledge collaboration will lead to the increase of knowledge capital; in other words, the appreciation of knowledge capital can be used to measure the effectiveness of knowledge collaboration.

(2) Measurement of knowledge capital

From the perspective of epistemology, knowledge creation has three modes, namely, cognitivists, autopoietics and connectionists; it is obvious that connectionists is consistent with the knowledge creation of knowledge collaboration, which could be explained as that the intellectual individual triggers the connection between each other in solving the

collaborative problem, and the new connection results in new knowledge. The connectionists introduced the concept of social capital to knowledge collaboration, considering that social capital is the interest, value, or assets, etc. generated by social connections and social interactions. In the analysis of knowledge creation, numerous researchers take social capital as one of the major researching elements (Nahapiet & Ghoshal, 1998) [29].

The purpose of knowledge collaboration is knowledge creation. The knowledge creation of virtual teams is the process of constantly acquiring social capital through social network. The social capital of virtual team has a positive role in promoting knowledge innovation, which is advantageous to the knowledge collaboration; knowledge collaboration means that the reinforcement of the connection in knowledge network and the increase of new connection, promoting the appreciation of social capital (Chen, 2014) [28]. Therefore, good knowledge collaboration will lead to the increase of social capital; in other words, the appreciation of social capital can be used to measure the effectiveness of knowledge collaboration.

3.2. Social Network Characteristics and Performance of KC

(1) Network density

Network density is the structural index of social network, which refers to the ratio of numbers of actual presence connections and possible connections in the network (Wang, 2009)[30]. It describes the close degree between network nodes. The higher density network is, the more closely node links. When the network density approaches to the value of 1, there are strong direct links between one and each other node, which means every node is in the “eye sight” of any other node. McFadyen (2004) believes that the node relations in the network structure are conducive to form the strong trust mechanism, which has the positive function to form this trust mechanism for knowledge innovation and cooperation relations [31].

In virtual teams, each node is an independent knowledge carrier, among these individuals there is a network structure of knowledge circulation established in a flexible manner across time and space. In the network virtual team, the higher the network density is, the closer the relation among knowledge carriers are, and the more internal knowledge sharing nodes are, and the better the effect of knowledge collaboration is (Wang, 2009)[30]. Network density has important influence on the transfer effect of individual knowledge (Fritsch *et al.*, 2010) [32]. The higher the network density is, the closer the relationship between individuals of virtual team is, and the more easy to form the trusted channel of knowledge transferring, and also more helps to improving performance of KC. Therefore, we put forward the following hypothesis:

H1a: Network density has positive influence on performance of KC; the higher the network density is, the higher performance of KC is.

(2) Network centrality

“Centrality” is the basic concept of distinguishing network status in social network analysis, which is used to measure which level the individual or organization is positioned in social networks. “Point of potential” and “degree centrality” is the two kinds of index. The former is used to describe the overall centrality of network graph, and the latter is used to describe the centrality of any single point in a network. This paper will use the “Point of potential” to describe network centrality.

According to social network theory, “Point centrality” is measured by the number of points in the network which directly connect to it. If an individual point is directly connected to many other points, then it means the point has high degree “Point

centrality". In the structure of a network, a node, which is directly connected to other nodes, is the central position of network structure, and has great power of resource acquisition.

Social network provides effective knowledge circulation and collaborative innovation platform for knowledge collaboration. The key node in the central position of a network plays an important role in the network structure collaboration and knowledge sharing. Chen Lu *et al.*, (2009) stated that individual relation network variable such as network structure (centrality) and the diversity of knowledge has positive influence on the virtual team's performance [33]. Reinholt *et al.*, (2011) noted that network centrality would foster network positions that provide access to nonredundant knowledge [34]. According to social network theory, if the individual has higher degree of centrality in the network, then he or she has more contact with other individuals, and there is more channel for him or her to exchange knowledge with other individuals, and therefor promote the knowledge collaboration. Thus, in virtual teams of social networks, the higher degree individual centrality are, the higher performance of KC is. Therefore, we put forward the following hypothesis:

H1b: Network centrality has positive influence on performance of KC, the higher degree of network centrality is, the higher performance of KC is.

(3) Connection strength

The network density and centrality is the structure dimension index of social network, while the connection strength is relational dimension index. The relationship is a beneficial supplement to the dimensions of the structures (Yao & Ming, 2008) [35]. There are many researches about the influence of the connection strength on knowledge sharing and knowledge transferring. The study shows the connection strength plays a very important role in the process of knowledge transferring among the groups (Hansen, 1999; Reagans & McEvily, 2003; Uzzi & Laneaster, 2003; Zhaoguo, *et al.*, 2011) [21,36-38]. The shorter and the more number the individuals connected, the more knowledge acquisition node in the team, the shorter the project completion time is. In the same meaning, the higher connecting strength is, the higher the accuracy and timeliness of knowledge collaboration is. Therefore, we put forward the following hypothesis:

H1c: Connection strength has positive influence on performance of KC.

In summary, we can assume that:

H1: The characteristics of social network and the performance of KC is positive correlation. To strengthen the social network construction is conducive to enhancing the performance of KC.

3.3. Individual Attributes and Performance of KC

(1) Collaborative intention

Knowledge collaboration is usually used for completing a knowledge-intensive task, therefore, the team members should have strong collaborative intention, and operate various forms of knowledge capital in the collaborative process, and complement knowledge to each other, which is the important characteristic of knowledge collaboration, and it also the basis to perform collaboration among the knowledge subjects, especially that knowledge is implicit, which is required the team members having strong collaborative intention. Jente (2008) investigated 499 respondents and found that individual attitudes had significantly impact on organizational knowledge sharing[39]. In the research of this paper, collaborative intention refers to the subjective desire of whether the team members and to what extent are willing to share their own knowledge to other members, and are willing to accept the knowledge of other members, which is a two-way process. Knowledge collaboration not only can contribute to the

transformation and upgrading of individual knowledge, but also can support team members to achieve their own work targets. In the team collaboration, the team member often comes from different professional fields and plays different roles, only on the premise that the employees approve the concept of knowledge collaboration, can they make a positive contribution of their own knowledge and constantly absorb knowledge to achieve knowledge innovation. Therefore, the individual collaborative intention will exert great influence on the energy and time, *etc.*, devoted into the knowledge sharing, knowledge transfer, organizational learning and knowledge creation by the team members, so as to influence the performance of knowledge collaboration correspondingly. Therefore, the following assumption is put forward:

H2a: Individual collaborative intention has positive influence on the promotion of performance of KC.

(2) Collaborative capacity

In addition to the collaborative intention, another important factor affecting the employees' knowledge collaboration behaviors is employees' individual collaborative capacity. The individual collaborative capacity includes not only the capability to assess the own needs of the individual accurately, and more importantly it includes the capacity of whether the individual could clearly express to other members their own knowledge and the capability to absorb knowledge. These collaborative capabilities of the team member may partly be the result of their own talents, but mostly they are affected by postnatal environment, such as organizational training, *etc.* When team members have good collaborative capacities, the transformed quantity, quality, speed and effectiveness of the knowledge will be greatly improved, and the promotion of performance of knowledge collaboration will be more remarkable. Therefore, the following assumption is put forward:

H2b: Individual collaborative capacities have positive influence on the promotion of performance of KC.

In summary, we can assume that:

H2: Individual attributes and performance of KC are positive correlation and strong intention of individual collaboration and collaborative capacity will facilitate improvement of performance of KC.

3.4. Team attributes and performance of KC

(1) Collaborative atmosphere

Sveiby and Simons (2002) conducted in-depth research on the collaborative atmosphere in their paper, they thought that collaborative atmosphere refers to the value, belief and imagine, *etc.* influencing knowledge sharing and the knowledge creation behavior and intentions, and they conducted measurement from four aspects of employee attitude, work group support, direct manager and the organizational culture [40]. In the knowledge collaborative process, the knowledge innovation is accelerated to be achieved through vast collaborative effect by team members with different knowledge background, and the collaboration among members is nothing else than the formative effect of collaborative atmosphere. In good collaborative atmosphere with information sharing, mutual respect and mutual trust, team members with different perspectives and ways of thinking are more willing to share own talent and experience inside the and among organizations. Communication and cooperation among members will facilitate the search, transfer and creation of knowledge and increase intellectual capital, social capital, ultimately improving the performance of KC. Therefore, the following assumption is put forward:

H3a: Collaborative atmosphere and performance of KC are positive correlation and good collaborative atmosphere will facilitate improvement of performance of KC.

(2) Collaborative culture

Collaborative culture refers to the beliefs, value system and behavioral norms formed in the organizational learning process of the team and obtained the mutual recognition from the team members, which is mainly reflected in aspects including cohesion, core concept and team spirit, etc. Collaborative culture is a kind of intangible assets, it is difficult to describe and imitate its value, and it is formed through constantly breaking-in and accumulation in the long-term practice process of the team members, which has binding effect on the behavior and consciousness of the team members. Under the common value theory and core concept, the members will enjoy freedom, independence and being respected at work, and will form a strong sense of belonging to the team; the members will devote themselves to the team work with the co-sensed "Team Spirit" comprehensively, to create amazing achievement. Previous researches, such as López et al (2004) and Li, *et al.*, (2009), found that collaborative culture has a significant positive correlation to organizational performance and knowledge sharing through empirical research [41-42]. We believe that relaxed and harmonious, co-learning and inter-motivated collaborative culture will help the team members to exchange knowledge and share resources and produce new ideas and thoughts, and then promoting the performance of KC. Therefore, the following assumption is put forward:

H3b: Collaborative culture and performance of KC are positive correlation and good collaborative culture will facilitate improvement of performance of KC.

(3) Motivator

Motivation is a process that can stimulate people's behavioral motive to generate a specific behavior. In the team collaboration process, motivation measures is an effective mean of team management, which could not only promote the knowledge capability of the organization and the members, but can empower the organization and the member with sustainable power and core competition advantages. In the knowledge collaboration process, need to build scientific and effective motivation mechanism based on individual level and team level to improve the performance of knowledge collaboration. By giving the affirmation of both spiritual and material to the contribution of the team members promptly, and obtaining abundant financial support in the work activities, could not only provide opportunity for the members to express and develop themselves, but could attract and encourage exchanging, sharing, integrating and creating knowledge to each other, to realize knowledge innovation finally. Therefore, the following assumption is put forward:

H3c: Motivator and performance of KC are positive correlation and good motivation system will facilitate improvement of performance of KC.

In summary, we can assume that:

H3: Team attributes and performance of KC are positive correlation, and good collaborative atmosphere, cultural and effective motivator, *etc.*, will facilitate improvement of performance of KC.

Based on the above analysis, the theoretical model of this paper is shown in Figure 1:

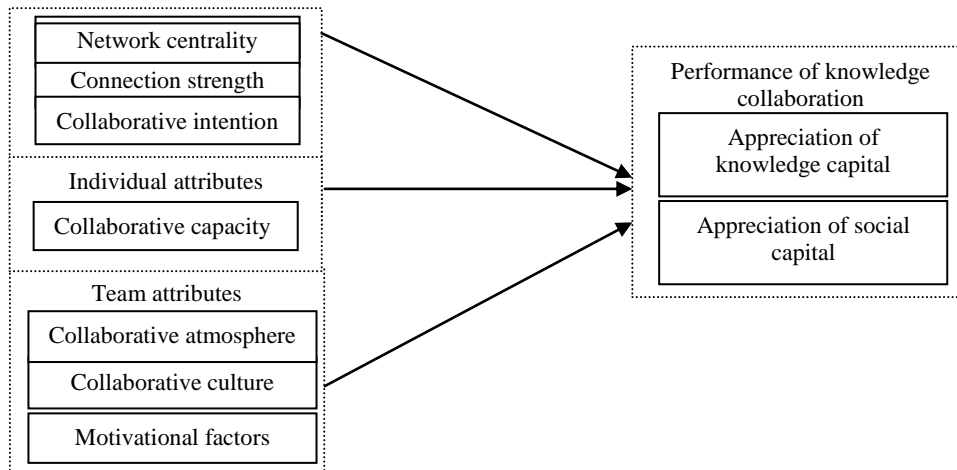


Figure 1. Theoretical Model

4. Research Design

4.1. The Scale and Questionnaire

This paper uses structural questionnaire to gather data, and the measurement index in the paper mainly uses the existing research scale at domestic and overseas, and combines with the knowledge collaboration characteristics of Chinese service outsourcing enterprises to improve the observational variables, to further adjust and amend the questionnaire items via interviews and pre-examination, and the final questionnaire includes 35 items. Among which, there are respectively three items for network density and network centrality; there are 5 items for network connection strength; there are respectively 5 items for team collaboration atmosphere and collaboration culture; there are 4 items for motivator; there are respectively 5 items for the two dimensions of performance of KC, namely the appreciation of knowledge capital and social capital. Scoring formula of questionnaire adopts Likert scale with 5 points, in which "1" representing strong disagreement and "5" representing strong agreement. Measurement dimension and summary of index of each variable are shown in Table 1.

Table 1. Variables Measuring Dimensions

Variables	Measuring dimension	Meaning of index	References of measuring items
Network Characteristics	Network density	Connected number and tightness between nodes	Luo, 2009[43]; Zhu, 2009[44]
	Network centrality	Amount of direct contact between other nodes and the some node in the consulting network; understanding the level and consulting intention	
	Connection strength	Recognizing duration, interact frequency , intimate topics and intimate action	Granovetter,1973[45]; Masden& Campbell,1984[46]
Individual Attributes	Collaborative intention	Initiative and enthusiasm	Zhu, 2009[44];
	Collaborative capacity	Usage of tools and hold of collaboration processes, etc.	Zhui, 2009[44]

	Collaborative atmosphere	Trust and sharing	Zhu, 2009[44]
Team Attributes	Collaborative culture	Understanding, identity and consistency	Xie, 2010[47]
	Motivator	Salaries, emotion and investment	
	Appreciation of knowledge capital	Enhancement of social interaction: the enhancement of connection strength, increase of new connection; enhancement of trust: trust, reciprocity, recognition and attribution; enhancement of shared cognition: common language, target and opinion.	Liu, 2013[48]
Performance of KC	Appreciation of social capital	Appreciation of explicit knowledge: increment of patent / technology/ flow and module / knowledge / case base, etc.; appreciation of implicit knowledge capital: increase of individual experience and technique, improvement of team ability, enhancement of organizational culture and conventions.	(Nonaka,1994)[49]

4.2. Sample

This research takes the service outsourcing enterprise team as the research subject, entrusts the third party research company to carry out a questionnaire inquiry for two months from October to December, 2013. There are 266 copies of questionnaires being recovered, of which 235 copies are valid, with the effective recovery rate of 88.3%. In this survey, the project teams from Beijing Baidu Network Technology Co., Ltd., Beijing Topsec Software Co., Ltd., Glodon Software Company Limited, Beijing Tongfang Dingxin Information Technology Co., Ltd. and Dongfang Futong (Beijing) Software Co., Ltd., etc., a total of 27 enterprises received the survey. These teams are the virtual teams in the Research and Development and innovation field, and the positions of the respondents in the team include Research and Development Manager, Project Manager, Senior Consultant, Engineering and developer, etc.; they have better familiarity and sensitivity on the items involved in the questionnaire, regardless of their work experience, expertise or qualifications, and the respondents have higher pertinence.

5. Data Analysis and Hypothesis Test

5.1. Reliability and validity test

Reliability of variables or factors is tested with Cronbach's α coefficient in this research, and its results are shown in Table 2. Cronbach's α value of variables or factors are more than 0.7, indicating that the scales used in this research have a good reliability. In terms of validity, this research has a good content validity to a certain extent since the questionnaire used in this research draws on the existing literature scales, and has been

consulted, pre-tested and modified by experts and business people. To further examine the structure validity of scales used, the specific items are inspected by confirmatory factor analysis (CFA) in this paper, and its results are shown in Table 2. KMO values of network characteristics, individual attributes, team attributes and performance of KC are more than the minimum level of 0.5, which are significant. Factor loading of each item is more than 0.5, indicating that factors have a stronger explanatory power to the corresponding latent variables; therefore the questionnaire has good structure validity.

Table 2. Validity and Reliability

Variable	Dimensions and Items		Factor Loading	KMO	Cronbach's α
Network characteristics	Network density	wlmd_1~wlmd3	0.565~0.683	0.739	0.815
	Network centrality	wlzxd_1~wlzxd_3	0.610~0.739		
	Connection strength	ljqd_1~ljqd_5	0.591~0.778		
Individual attributes	Collaborative intention	gtyy_1~ gtyy4	0.642~0.765	0.768	0.802
	Collaborative capacity	gtnl_1~ gtnl_4	0.678~0.814		
Team attributes	Collaborative atmosphere	tdfw_1~tdfw_5	0.558~0.805	0.838	0.841
	Collaborative culture	tdwh_1~tdwh_5	0.612~0.713		
	Motivator	tdjl_1~tdjl_4	0.763~0.825		
Performance of KC	Appreciation of knowledge capital	zszb_1~zszb_5	0.671~0.828	0.865	0.859
	Appreciation of social capital	shzb_1~shzb_5	0.648~0.812		

5.2. The impact of network characteristics, individual attributes and team attributes on performance of KC

Let network density, network centrality and connection strength as the independent variables, performance of knowledge collaboration as the dependent variable. Then we can use SPSS19.0 software to do regression analysis. Similarly, regression analysis is performed through letting Individual collaborative intention, individual collaborative capacity as the independent variables, performance of KC as the dependent variable. We can also proceed regression analysis with collaborative atmosphere, collaborative culture, motivator and performance of KC. The results are shown in Table 3.

Table 3. The Impact of Network Characteristics, Individual Attributes and Team Attributes on Performance of KC

Hypothesis	Assuming path	Standardized regression coefficients results	Test
		(significance level)	
H1a	Network density→Performance of KC	0.105**	Support
H1b	Network centrality→Performance of KC	0.152***	Support
H1c	Connection strength→Performance of KC	0.197***	Support
H2a	Collaborative intention→Performance of KC	0.307***	Support

H2b	Collaborative capacity→Performance of KC	0.209***	Support
H3a	Collaborative atmosphere→Performance of KC	0.235***	Support
H3b	Collaborative culture→Performance of KC	0.348***	Support
H3c	Motivator→Performance of KC	0.186**	Support

Note. * *p _ .05, ** *p _ .01.

By analyzing data, we found that network density, network centrality, the connection strength have positive influence on performance of KC. It means that the performance of KC will be better when network density, network centrality and connection strength are rising. In addition, the collaborative willingness and ability of individuals affect positively on the performance of KC. Similarly, collaborative atmosphere, collaborative culture and motivator have positive influence on the performance of KC. So, the assumptions of H1a, H1b, H1c, H2a, H2b, H3a, H3b, H3c are supported.

5.3. Structural Equation Analysis

We will using AMOS19.0 structural equation modeling(SEM) software to study the mechanism between variables. The path diagram is shown in Figure 2.

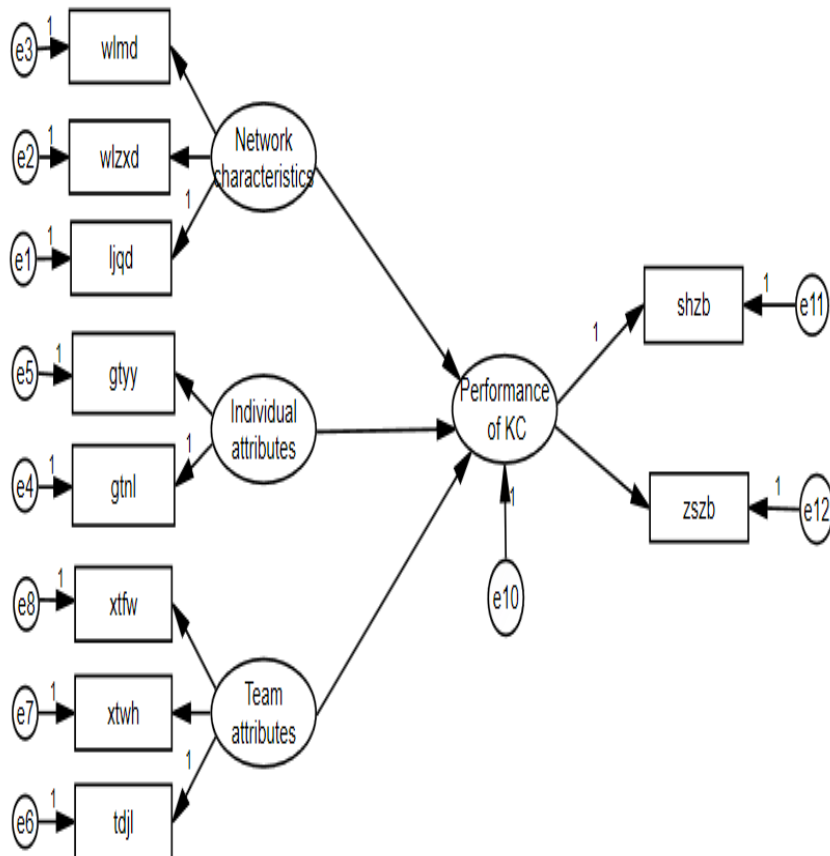


Figure 2. Path Diagram

Since SEM using the maximum likelihood method, this method requires that the data should be compliance with the assumption of multivariate normality, otherwise chi-square

estimates will swell and the model fit will become deterioration. Therefore the data should be tested firstly whether the data meet the assumption of multivariate normality. The results are shown in Table 4.

Table 4. Joint Normal Distribution Test Results

Index	Kurtosis	Critical value
Multivariate	37.972	18.839

Hau Kit-tai, *etc.*, (2004) pointed out that when data's absolute value of kurtosis is less than 10, or critical value is less than 5, it indicates that data follow the normal distribution[50]. Table 4 shows that mmultivariate kurtosis is equal to 37.972 and critical value is 18.839. Both values exceed the threshold value. Therefore it can be considered that the data does not meet the assumption of multivariate normality.

Since the data is non-normal distribution, we use the Bootstrap method to do path path analysis and verify impact mechanism among network characteristics, individual attributes, team attributes and the performance of KC. In the AMOS structural equation model, we set the 2000 Bootstrap samples in Bollen-Stine Bootstrap operation and achieved the convergence in 19 iterations. The results show that the model has a good fit in 1837 Bootstrap samples, and the poor fit in 163 Bootstrap samples. The significant probability of Bollen-Stine Bootstrap is 0.082. Thus, although the data does not meet the assumption of joint normal distribution, but t the fitness of the model is acceptable.

The results of path analysis show that absolute fit index χ^2/df is equal to 3.27, more than 3, GFI is 0.877, less than 0.9, RMSEA is 0.082, more than 0.08; relative fit index NNFI is 0.903, IFI is 0.832, CFI is 0.902, these index do not all meet the above 0.9 requirements. Overall, the data failed to better fit the research model and the original model should be modified. We can use the modified index (MI) provided by AMOS19.0 to adjust the theoretical models. By adding the error covariance in "wlmd ~ wlzxd", "gtln ~ gtyy", "xtfw ~ xtwh", we can get the following results (see Table 5).

Table 5. Revised Model Fitting Index

Fit Index	χ^2/df	GFI	RMSEA	RMR	IFI	NNFI	CFI
Value	2.574	0.927	0.058	0.070	0.959	0.981	0.957

The modified fitting indexes are improved obviously and reached the standard. Test results show that the structural model's goodness of fit that based on Bootstrap is acceptable, and the model can better fit the data. Therefore, we will test the research hypothesis proposed in this paper according to the path coefficient. The results are given in Table 6.

Table 6. Path Assumptions and Hypothesis Testing

Hypothesis	Path hypothesis	Path coefficient	p-value
H1	Network characteristics→Performance of KC	0.22	0.053
H2	Individual attributes→Performance of KC	0.47	0.000
H3	Team attributes→Performance of KC	0.55	0.000

Note. Path coefficients are standardized coefficients.

When the significance level of the path coefficients is less than 0.05, the hypothesis is true. When the significance level of path coefficient is less than 0.1, it means that significance is weakly and hypothesis is partially supported. From the result we can see, path coefficient of network characteristics impact on performance of KC is 0.216 and its

significance level is close to 0.05, so the hypothesis 1 was established. Individual attributes has a significant positive effect on performance of KC ($P < 0.001$), hypothesis 2 is supported. Similarly, team attributes also has a significant positive impact on performance of KC, hypothesis 3 was established.

6. Research Conclusions and Implications

6.1. Research Conclusions

At present, the virtual team is an important organizational form of knowledge creation in many fields, especially in IT service outsourcing industry. Creating virtual team, giving full play to the collective intelligence of their knowledge-based employees to create more new knowledge, new technologies and new products via creating efficient mechanism of collaborative working, is the target of many innovative enterprises. Structural characteristics of network are further verified in this paper through theoretical analysis and empirical research (network density and network centrality), and lifting the role of relation characteristics of network (connection strength) on efficiency of knowledge collaboration is also verified in this paper. The network density, network centrality and connection strength all have important effect on improving performance of KC in virtual teams. And individual collaborative attention and capacity all have positive influence on performance of KC. It also found the influence relation of the attribute of the virtual team on performance of KC, and verified the beneficial action of the team's collaborative atmosphere, collaborative culture and motivator on improving performance of KC.

6.2. Practical Implications

Empirical conclusions will provide a theoretical basis and practical reference for promoting the performance of knowledge collaboration. Based on the research, this paper propose some advice to a virtual team.

(1) Setting up knowledge collaboration work platform to provide team members with a good cooperative environment.

The enterprise should construct technology platform for collaborative work, provide their employees with internal unified platform for knowledge sharing and communication, business collaboration and collaborative operation, to reduce communication costs and to promote the smoothness of the knowledge circulation channels; and the enterprise should create collaborative knowledge base, on the one hand, to improve the efficiency of the team's knowledge sharing, and on the other hand, to provide sources and reserves of knowledge for the team's knowledge update and creation.

(2) Strengthening social network and provide convenient approach for social capital accessing.

Whether there are the structural characteristics of network density and network centrality, or the relation characteristic of connection strength, they all reflect that the closeness of the connection between the internal and external individuals of the team, playing a very important role in the effectiveness and efficiency of knowledge collaboration. Moreover, the appreciation of social capital is inseparable from breadth and depth of social network. Therefore, the strengthening of construction and maintenance of social network is an important mean to improve performance of KC, appreciation of social capital and accumulation of knowledge capital. Especially for virtual teams without time-space limit, with fuzzy boundaries and flexible structure, effective and self-organized social network is a magic weapon to avoid drawbacks due to its flexibility.

(3) Creating a good collaborative culture and atmosphere.

Virtual teams are strong support and organizational guarantee to carry out collaborative innovation. In virtual teams, it seems to be particularly important to establish confidence mechanism among team members due to characteristic including looseness, etc. of organization structure. Only if there is a good mutual trust relation among team members, the seamless joint of knowledge sharing can be completed, and the channel of knowledge flow can be smooth. Therefore, the construction of collaborative culture should be strengthened in virtual teams, and humanistic environment with mutual trust, being happy to share and convenient communication among team members is created from value orientation. Meanwhile, the team organizer should consciously encourage and promote the knowledge collaborative behavior within the team, and form the "Sharing among People", mutual understanding, mutual recognition and collaborative atmosphere which could main consistency on the tasks and targets gradually.

(4) Formulating constitutions and standardized system, adopting flexible motivation measures to stimulate team collaboration

Virtual team is the organizational carrier of knowledge creation, in order to achieve knowledge creation, it needs smooth knowledge sharing and effective knowledge transfer in the first place, and all these need the subjective initiative of the relevant knowledge nodes within the virtual team and the efficient connection among them to achieve the knowledge transfer, digest, absorption and utilization effectively. Therefore, the organizer of the virtual team should adopt targeted and flexible motivation measures directing at the personality of different members, formulate constitutions and standardize system to motivate the knowledge sharing intentions of the subject of knowledge creation and to improve its efficiency of knowledge collaboration; and give positive motivations to the activity and behavior helping to promote the efficiency and performance of knowledge collaboration, so as to form the healthy motivation and feedback mechanism, to improve the efficiency of virtual team's knowledge collaboration and to promote the creation and application of new knowledge ultimately.

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