

Factors affecting the performance of knowledge collaboration in virtual team based on capital appreciation

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Abstract Knowledge collaboration (KC) is an important strategy measure to improve knowledge management, focusing on not only efficiency of knowledge cooperation, but also adding value of intellectual capital and social capital. In virtual teams, many factors, such as team's network characteristics, collaborative culture, and individual collaborative intention, affect the performance of KC. By discussing the nature of KC, this paper presents that the performance of can be measured from two aspects: effectiveness of collaboration and efficiency of cooperation. Among them, effectiveness of collaboration is measured through value added and efficiency of cooperation is measured through accuracy and timeliness. Then the paper discusses the factors affecting the performance of KC from network characteristics, individual attributes and team attributes. The results show that network characteristics, individual attributes and team attributes in virtual team have significant impacts on the performance of KC.

Keywords Virtual team · Knowledge collaboration · Intellectual capital · Social capital

1 Introduction

With the rapid development of information technology, virtual team has become an important part in enterprises' operations to respond to the quick changes in the marketplace. It breaks the barriers of communication in time and space, and makes long distance, rapid communication available. As a task-oriented alliance, a virtual team can handle the complex task on wide-scope and cross-disciplinary knowledge demand, being widely adopted in many fields including service outsourcing, IT and innovation research, etc. It is very important to collect, share, transfer and use knowledge within virtual team members of IT outsourcing. But there are two tremendous difficulties to bask effective knowledge work, known as customer knowledge dependence and tacit knowledge transfer. As different firms, outsourcing client and its supplier have different recognition, asymmetric information, variable and opportunism partnership [45], which usually block knowledge transfer from client to supplier. Even in supplier firms, their team members may be physical distributed, or belong to different units, or have less understanding of tacit knowledge [7, 46], usually blocking knowledge transfer between them. In many firms, it is difficult to find out who knows who, and who knows what. Employees should spend many times on re-researching topics or making decisions that do not reflect the company's best thinking.

Knowledge transfer is a field of knowledge management (KM), transferring knowledge from one set of individuals to another. Transferring knowledge across global boundaries has become an important factor for organizations to success. Most research blames the failure on transferring knowledge as the main cause for poor project management, together with lack of executive sponsorship. Very little

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knowledge transfer and sharing between project teams play a key role in allowing these failures to occur. Since knowledge transfer is usually one of the first task of transitioning to an outsourced model, it is sometimes overlooked or under-planned, resulting in a shaky start to the outsourcing relationship.

Knowledge Collaboration (KC) is not just as about knowledge transfer or sharing. In the literature, knowledge is an understanding of information about a subject which has been obtained by experience or study, and which is either in a person's mind or possessed by people generally. Knowledge Collaboration is a collaboration activity between two or more people to create and build the knowledge through a structured platform in order to achieve objectives. KC has been one of the new developing research fields [35] in KM. To understand KC well, we can focus on the effectiveness and preciseness of knowledge transferring in details [11], as well as on the '1 + 1 > 2' synergy of knowledge cooperation and value added of intellectual capital in a whole [6]. Knowledge collaboration takes innovative thinking for IT outsourcing companies to improve their performance of KM. Base on KC thinking, IT service vendor can put the add-value evaluation of intellectual capital into an important position to guide the rapid accumulation of business knowledge, so that the problem of customer knowledge dependence could be partly solved and the vertical industry advantage can be accumulated gradually. They can also take the add-value evaluation of social capital in the same way to enhance knowledge transferring/cooperating among employees, customers, team members, so that the dilemma of tacit knowledge transferring should be partly improved and trusts between employee and customers can be built up.

However, because of staff diversity and the limitation of using electronic information technologies as the primary means of communication, it is difficult to communicate face to face in a virtual team. In many firms, KC is facing many new problems and challenges. Among them, how to improve the performance of KC in virtual team has become a focused issue. This study focuses on the factors affecting the performance of KC. Based on the discussion of performance index of KC, we construct a relationship model and undertake a survey from the IT outsourcing industry. In this paper, main factors that affect the performance of KC have been revealed by conducting a factor analysis. We put forward some practical implications and suggestions. The study not only enriches the theory system of KC, but also provides a practical reference for the knowledge management of IT service outsourcing virtual team.

2 Literature review

2.1 Virtual teams and KC

2.1.1 Virtual teams

There's no unified definition of "virtual team" so far. Lipnack and Jeffrey [20] considered that virtual team was a group of inter-timed, inter-spaced people, who work independently for a common target and rely on the technology. Kirkman et al. [17] thought that virtual team was composed of separately located employees with unique skills, who work together to accomplish organizational goals. Ziggers [50] mentioned that virtual team was a collection of individuals who have the dispersion characteristics in different dimensions, and they work collaboratively via information and communication technologies to achieve a goal. Li and Zhu [19] thought that virtual team mainly concentrates on the innovative field, and the main production is knowledge. Therefore, for the virtual team, knowledge innovation is the soul of its existence, either for the team's formation of target and output purpose, or the team's own characteristics.

2.1.2 Knowledge collaboration

Karlenzig [15] firstly launched the concept of "Knowledge Collaboration". He thought that it was an organizational strategy, which could dynamically assemble many kinds of knowledge resources to maximize the business performance. Since then, many scholars proposed different definitions. Chen and Chen [6] thought that via integrating the internal and external knowledge resources of the organization, the enterprise could obtain the knowledge collaborative effect of "1 + 1 > 2". Mckelvey et al. [26] considered that KC was a kind of "activity"; the members who participate in the activity strive to create personal knowledge and get a valuable result eventually. Tong [35] presented that KC was a kind of multidimensional dynamic process that promotes appropriate information and knowledge to achieve knowledge innovation. Knowledge collaboration is different from knowledge sharing, knowledge transfer, and knowledge management. Therefore, it is necessary to conduct in-depth research on KC.

2.2 Measures of KC effect and performance

Knowledge synergy is the additional value that is generated by combining two or more information or knowledge objects and creating new knowledge. But how can we measure this additional value? Many studies have worked on it.

2.2.1 Measures of KC effect

Shi [32] analyzed the connotation of KC and pointed out that the KC effect is the sum of expectation goals and its additional value, which reflects the aggregation of marginal change in KC activities through the time. Then the effect of KC can be measured as:

$$E = f(k_1, k_2, \dots, k_n) + \varphi(r_1, r_2, \dots, r_m) \quad (1-1)$$

In which E means the total effect of KC, $f(k_1, k_2, \dots, k_n)$ as the expectation goal effective function, and $k_i (i = 1, 2, \dots, n)$ as the knowledge unit attached to behavioral agent. The function $\varphi(r_1, r_2, \dots, r_m)$ is add-value of expectation goal function, which means the synergy of KC, and $r_i (i = 1, 2, \dots, m)$ denotes activities in the collaboration process.

Wang [38] had a similar understanding about KC effect generated in business groups, which is interrelated with four factors, namely subject A, object O, medium M and circumstances C. Then the KC effect in a business group can be expressed as:

$$P = F(A, O, M, C) \quad (1-2)$$

These studies have discussed the elements and the function of KC effect, but they are too qualitative and conceptual. Many problems haven't been noticed and put forward in research, such as the characteristic of add-value, the measurement method of add-value, how to stimulate the add-value creating, and so on. Thus the mechanism of KC should be analyzed in depth and the research design should be innovated.

2.2.2 Knowledge collaboration performance model

In KC performance, previous research mainly focused on the effect of or relationship between knowledge management, knowledge sharing, knowledge transfer and knowledge collaboration, etc. on organizational level, such as enterprise performance, team performance, management performance or innovative performance [33, 43, 47]. In fact, KC is a complex process which includes knowledge sharing, knowledge transfer and knowledge creation. From the literature, empirical research on the measurement and influencing factors of KC performance is rare. Current studies on the performance of knowledge only focus on the performance of knowledge sharing and effect of knowledge transfer and seldom address the performance, result or efficiency measurement issues in KC.

2.3 Brief summary

Although there are many literatures discussing the problems related to knowledge management of virtual teams, currently

there's no sufficient research on the performance of KC in virtual teams. It is a dynamic process including knowledge transfer, sharing, and innovation. Although it may contain many stages, the performance of any single stage is unable to represent the overall performance of KC. Hence, this paper will focus on the measurement of the performance of KC in virtual teams, and analyze the main factors which influence the performance of KC from social network characteristics, individual attributes and team attributes.

3 KC and add-value from enterprise capital

KC is an efficient cooperation status in which all those factors are active in the same rhythm. Its focal point is 'exact and just' in micro-layer and add-value in macro-layer. Different from knowledge transfer or sharing, KC has four significant characteristics as follow:

Integration, which means the knowledge subject, object, time and their environment should be integrated as a whole process.

Accuracy, which means knowledge or information should be transferred just in time and exactly for the special problem.

Dynamic, which means the collaboration process is highly associated with time.

Add-value, which means the KC process has the goal to create new knowledge, and make add-value for social capital and intellectual capital at the same time.

In general, capital add-value for KC comes from the add-value of social capital and intellectual capital, also from the accuracy and timeliness of KC. Therefore, this paper will discuss the performance evaluation of KC from the following three aspects.

3.1 KC and social capital

The concept of Social Capital has been proposed by Bourdieu [4] and defined as a capability of individual to obtain external resource through social relationship network. Soon it was extended to other domain or layers. Ke et al. [16] pointed out that no matter in micro- or macro-layer, the capability of resources employment and social network cohesion are two key characteristics of social capital. Accordingly, this paper argues that the social capital of virtual team is a collection of resources which come from, is embedded in and is obtained through social relationship network of team members.

KC aims at the creation of new knowledge, which essentially is a socialization process. In the classical SECI model, three phases of knowledge-creation, as Socialization, Externalization and Combination, all contain social interactions. Social interactions among individuals lead to

social network creation naturally and knowledge created is based on the network. Furthermore, Social capital is the benefit, value or assets produced by social link and interaction. Many empirical studies about knowledge creation often begin with the affect study of social capital [1].

Virtual team members should constantly get social capital via their social network to create new knowledge so that they can overcome the obstacles from its team member structure. It can be seen that KC enhances the old connection or helps to create new link in social network; in other words, it adds the value of social capital.

3.2 KC and intellectual capital

Intellectual capital is the capital asset of knowledge or capability controlled by an enterprise. It has positive relations to enterprise performance [9]. Usually, intellectual capital can be divided into explicit and tacit knowledge assets. To be convenient, this paper adopts this dichotomy of intellectual capital.

Intellectual capital contains all those assets created by intellectual activities, such as knowledge achievement, innovation and construction of valuable linkage. In the process of KC, knowledge workers promoted their ability, new knowledge had been produced and extended, business process and culture had been improved, and relationship with customers had been strengthened. All of these are about the add-value of intellectual capital.

From the existing literature, it can be seen the relationship between KC and intellectual capital has not drawn attention. Therefore, it is essential to do more on the promotion mechanism of intellectual capital by KC in different ways. In addition, because of the characteristic of knowledge-intensive in virtue team, KC performance has obvious effects on the accumulation and add-value of intellectual capital, especially for tacit knowledge asset. Thus, it is valuable to study on how to measure KC performance through intellectual capital.

3.3 Efficiency of knowledge cooperation and KC

3.3.1 Efficiency of knowledge cooperation

Due to the characteristics of the outsourcing virtual team, members should obtain inner knowledge effectively through frequent social interactivities and communications, shared language and goals. An effective cooperation statue will be formed, basing on two key variables of *who knows what*, *who knows who*. With such an understanding, the characteristic *exact/just* and *add-value* of KC are the same as the effective situation of *who knows what*, *who knows who* in their natural meanings. These are determined mostly by interplay of social capital and intellectual capital.

Based on System theory, KC is the order parameter of knowledge systems, in which involve very-large scale mini-transfer activities. The timeliness and accuracy of knowledge cooperation determine the macro statue of knowledge system. In enterprise systems with stable knowledge flow, timeliness and accuracy of KC are two opposite targets and couldn't exist at the same time. Increasing numbers of paths and layers in knowledge transfer can effectively improve accuracy, but it increases difficulty of searching paths and puts off knowledge flow as a result. Improving timeliness of knowledge transfer means lowered accuracy. Accordingly, these two factors should be taken into account simultaneously.

3.3.2 Intellectual capital, social capital and knowledge cooperation efficiency

It has shown that social capitals have significant positive relation to knowledge acquisition/sharing in an enterprise [21]. Conversely, knowledge activities enhance the relationships among individuals, and they can get more trust from each other and put forward the shared recognition. Thus we can infer that intellectual capital has significant positive relation to social capital.

The two key indexes, timeliness and accuracy of knowledge flows, commonly determine the efficiency of KC. Intellectual capitals contain the quality and quantity of knowledge object. Social capitals pose the path and layer of knowledge flows. Either of them affects knowledge workers to obtain right knowledge in limited time, thus affects timeliness and accuracy of knowledge transfer. Just as a learning curve, timeliness and accuracy of knowledge transfer will be improved with the increasing of intellectual and social capital; and when the growth of these two capitals reaches to a certain level, the cost of knowledge searching/identifying increases so fast that KC efficiency will get worse.

3.4 Effectiveness and efficiency of KC

It can be realized that the performance of KC not only expresses the effectiveness of collaboration (add-value of social/intellectual capital) but also the efficiency of cooperation (improving of timeliness and accuracy of knowledge flow). Then the performance evaluation framework of KC has been proposed as shown in Fig. 1.

3.5 Evaluation index of KC performance

3.5.1 Effectiveness measurement of KC

Effectiveness of KC should be measured in two aspects, add-value of social capital and intellectual capital.

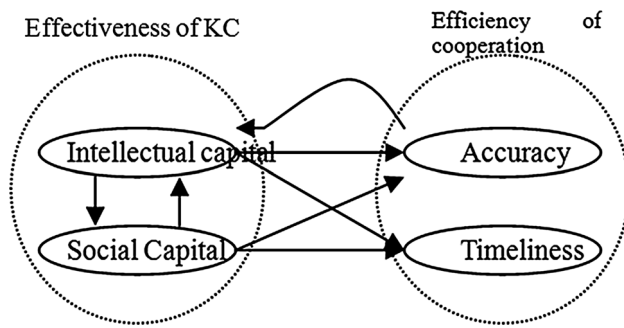


Fig. 1 Evaluation framework of KC

a. Add-value measurement of intellectual capital

As knowledge has the characteristics of intangible, easy-sharing and no-loss, the knowledge creation process can deliver knowledge products in an explicit form and get add-value of intellectual capital as tacit knowledge at the same time. From the knowledge classification model of Hedlund and Nonaka [13], to measure the increased value of explicit intellectual assets, all of these knowledge achievements produced by KC should be contained, such as patent, technologies and regulations. To measure the increased value of tacit intellectual assets, tacit knowledge produced in the collaboration should be counted, such as the increase of individual experience and technical skills, the promotion of group capabilities, the improvement of organization culture, and so on.

b. Add-value measurement of social capital

Nahapiet and Ghoshal [27] suggest that social capital should be considered in terms of three clusters: structural, relational, and cognitive. In KC process, the structural dimension of social capital is related to the more frequent relationship and the increase of link number. The relational dimension focuses on the enhancement of trust, reciprocity and respect, converging of language, position and point of view. The cognitive dimension means rules and norms tend to be clearer. All of these increases mean the add-value of social capital amount. Hence, to measure social capital's add-value, all of these three dimensions, social interaction, trust and shared cognitive, should be measured simultaneously [22].

3.5.2 Efficiency measurement of KC

Cao et al. [5] studied effect measurement of tacit knowledge transfer and proposed that efficiency of tacit knowledge transfer is primarily affected by platform. In addition, they found that the effectiveness of knowledge acquisition (KA) mainly depended on aspiration of knowledge source, knowledge accessibility and attraction ability. Knowledge accessibility is mainly affected by connectivity of knowledge network. Knowledge attraction ability mainly relies

on correlation degree [44]. To obtain knowledge efficiently, richness and correlation degree of knowledge resource, cooperation times of problem resolving should be considered in accuracy aspect. And for timeliness, searching and transfer times, as well as technology reliability should be considered.

In summary, we proposed a performance evaluation system of KC as shown in Table 1.

4 Factors influencing KC performance

Evaluation index of KC performance includes two aspects: effectiveness of collaboration and efficiency of cooperation. However, what factors influence the performance of KC? By the definition and characteristics of KC, we notice that the main factors affecting the performance of KC not only come from individual attributes of knowledge owner such as motivation, will, and ability, but also come from team attributes such as atmosphere, cultural, motivator, etc. At the same time, the structure and the inner relationship within a social network involving team members also have direct impact on efficiency and effectiveness of KC. Therefore, in this paper, we will elaborate the factors that affect KC performance from social network characteristics, individual attributes and team attributes.

4.1 Social network characteristics and KC performance

Many researches have focused on the influence of social network characteristics on knowledge sharing and knowledge transfer. Therefore, social network characteristics will be an indispensable factor in the research of KC performance in virtual team.

4.1.1 Network density

Network density shows the structural index of social network, which refers to the ratio of numbers of actual connections and possible connections among the network. It describes the degree of the closeness of the link between network nodes. McFadyen and Cannella [25] believes that the node relations are conducive to form the strong trust mechanism, which has the positive function to form knowledge innovation and cooperation relations.

Network density has an important influence on individual knowledge [10]. In virtual team, each node is an independent knowledge carrier, among which network structure is established in a flexible manner beyond time and space. The higher the network density is, the closer the relationship between individuals is, and therefore it is easier to form the trusted transfer channel.

Table 1 Performance evaluation system of KC

Construct	Variable	Dimensions and description	References
Effectiveness of collaboration	Add-value of social capital	Strengthen social interactive: stronger ties, new ties created Enhancement trust: more trust, acceptance, belongingness More sharing recognition: common language, goals and viewpoint	Liu et al. [22]
	Add-value of intellectual capital	Increase of Explicit knowledge assets: new patent/technology/process, reused modules/patterns/cases Increase of tacit knowledge assets: new experience/skill of individual, promotion of group capacity, improvement of organization of process/routine/culture	
Efficiency of cooperation	Accuracy	Accessibility, richness and correlation of knowledge resource	Cao et al. [5], Zhang and Jing [44]
	Timeliness	Cooperation times of problem resolving Knowledge searching/transferring times, technology reliability	

4.1.2 Connection strength

The earliest research on network strength is Granovetter [12]. He measured connection strength between nodes in four aspects, namely amount of time, emotional intensity, intimacy and reciprocal, and divided connection strength and classified them by strong ties and weak ties. Some other scholars considered contact frequency and duration in measuring connection strength [2, 29]. This study argues that connection strength represents the embeddedness of collaborative subject in the network, and it pays more attention to members' depth of interaction over a period of time. It can be measured from recognizing duration, interact frequency, emotional intensity and intimacy.

According to Granovetter, weak ties are more conducive to promote enterprise innovation. But many subsequent studies show that strong ties play a positive role in the knowledge transfer process [30, 36]. When connection strength is high, it not only improves the depth of communication between members, but also enhances the ability to absorb tacit knowledge, and finally improves the accuracy and timeliness of KC, as well as member's social capital and intellectual capital.

In summary, we assume that:

H1a Social network characteristics are positively related to efficiency of KC.

H1b Social network characteristics are positively related to effectiveness of KC.

4.2 Individual attributes and KC

4.2.1 Collaborative intention

As a kind of driving factors, collaborative intention can reflect team member's initiative in KC. It is the precondition for the successful achievement of KC [41]. If collaborative intention is strong, it will yield few cost and easy to improve KC performance [39]. In this paper, collaborative intention refers to whether the team members are willing to share knowledge and how much they want to share their own knowledge. Team members often have different backgrounds and play different roles. Only if the virtual team is based on deep understanding of the essence of KC, can these team members make a positive contribution and constantly absorb knowledge to achieve innovation. Therefore, individual collaborative intention will exert great influence on knowledge sharing, transfer, and innovation, so as to influence KC performance correspondingly.

4.2.2 Collaborative capacity

Individual collaborative capacity is another important factor affecting the collaboration behaviors. It includes two aspects: the capability of accurately assessing their own and partner's needs, and the capability of knowledge output and absorbing knowledge [48]. These collaborative capabilities may partly be the result of their own talents, but mostly they are affected by postnatal environment. When

team members have good collaborative capacities, the quantity, quality, speed and effectiveness of knowledge transforming will be greatly improved. The promotion of KC performance will be therefore more remarkable.

In summary, we assume that:

H2a Individual attributes and efficiency of knowledge cooperation have a positive correlation.

H2b Individual attributes and effectiveness of knowledge cooperation have a positive correlation.

4.3 Team attributes and KC

4.3.1 Collaborative atmosphere

Sveiby and Simons [34] pointed out that collaborative atmosphere is the valuation, or belief that influences knowledge sharing and creation behavior. They conducted measurements from employee attitude, work group support, direct manager, and the organizational culture. In the collaborative process, the innovation can be achieved through collaborative effects. In such atmosphere of information sharing, mutual respect and trust, team members are more willing to share their own talent and experience. Communication and cooperation will facilitate the search, transfer and creation of knowledge, increase intellectual and social capital, and then improve KC performance.

4.3.2 Collaborative culture

Collaborative culture is about value system, mutual recognition, and behavioral norms that are formed in the organizational learning process. It is a kind of intangible asset formed through constant accumulation in the long term practice process, which has a binding effect on team member's behavior and consciousness. López et al. [23] and Li et al. [18] all found that collaborative culture had a significant positive correlation to organizational performance and knowledge sharing. Now we believe that relaxed and harmonious collaborative culture will help team members exchange knowledge and share resources, new ideas and thoughts, and promote KC performance ultimately.

4.3.3 Motivator

We think that motivator is a process that can stimulate motive to generate a specific behavior. In the team collaboration process, motivator could not only promote members' knowledge capability, but also advance them with sustainable power and core competition advantages [42]. In KC process, it is necessary to build scientific and effective incentive mechanism to improve KC performance. By giving spiritual and material rewards to the

contribution of the team members promptly, and giving abundant financial support, team members will be encouraged to share and create knowledge with each other, and improve the performance of KC in the end.

In summary, we put forward the following hypothesis:

H3a Team attributes have a positive correlation with efficiency of knowledge cooperation.

H3b Team attributes have a positive correlation with effectiveness of knowledge cooperation.

Based on the above analysis, the theoretical model of this paper is shown in Fig. 2.

5 Research design

5.1 Design of scale and questionnaire

Based on the existing literature, we designed the structural questionnaire which is combined with KC characteristics of Chinese service outsourcing enterprises. At the same time, we adjusted and amended the questionnaire via interviews and pre-examination, and the final questionnaire includes 35 items. Measuring dimension and description of variables are shown in Table 2.

5.2 Survey sample

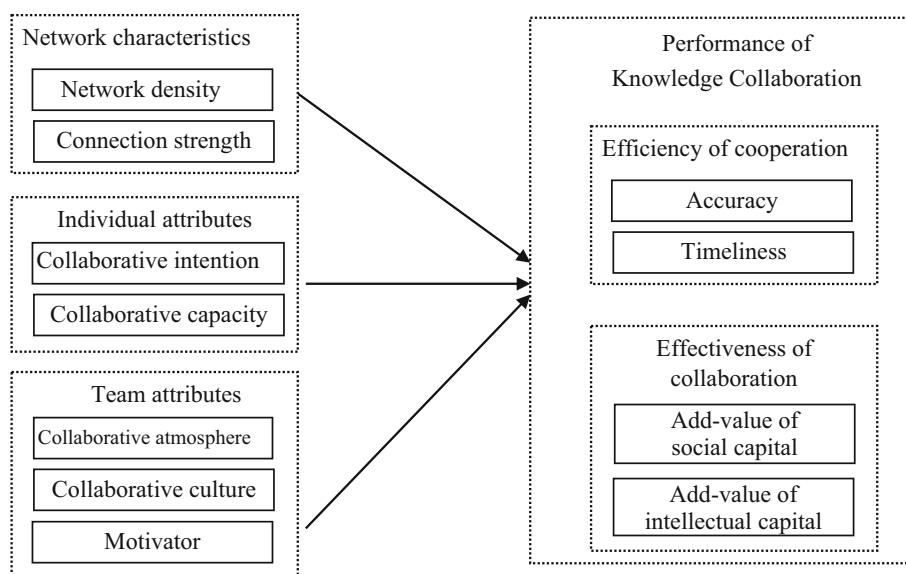
In this research, we selected 54 IT service outsourcing companies in China as the research subject. In the survey, 378 valid questionnaires were collected. The results of descriptive statistics are shown in Table 3. There are 98.4 % of respondents aged 40 or less. 90.3 % of respondents have a bachelor degree or higher, which is in line with the characteristics of IT practitioners. The respondents that belong to R&D team accounted for 46.1 %, belonging to services team accounted for 42.3 %; and 92.2 % of the team size is less than 50 people.

Respondents' positions distributed more widely, in which CEO, senior manager and supervisors accounted for about 20 %; R&D engineers accounted for about 30 %; testing staff accounted for about 10 %; operation, training, marketing staff etc. accounted for about 30 %, and researchers and other staff accounted for 10 %.

6 Data analysis and hypothesis test

6.1 Reliability and validity test

Reliability of variables or factors is tested with Cronbach's α coefficient and the results are shown in Table 4. The

Fig. 2 Theoretical model**Table 2** Variables measuring dimensions

Variables	Dimension	Dimensions and description	References
Network characteristics	Network density	Actual connections and possible connections among the network, emphasis on the extent of contact: connected number and tightness between team member	Zhu [48], Zhu et al. [49]
	Connection strength	Embeddedness of collaborative subject in the network, emphasis on depth of interaction over a period of time: recognizing duration, interact frequency, emotional intensity and intimacy	Benassi et al. [2], Granovetter [12], Marsden and Campbell [24]
Individual attributes	Collaborative intention	Whether the team members are willing to share knowledge and how much they want to share their own knowledge	Zhu [48]
	Collaborative capacity	The capability of accurately assessing their own and partner's needs, and the capability of output and absorbing knowledge.	
Team attributes	Collaborative atmosphere	Emphasis on trust and sharing among team members	Shen et al. [31]
	Collaborative culture	Value system, mutual recognition, and behavioral norms: understanding, identity and consistency	Xie [42]
	Motivator	Spiritual and material rewards, abundant financial support	

values of Cronbach's α are all more than 0.7, indicating that the scale has a good reliability. In the aspect of validity, we use confirmatory factor analysis (CFA) to examine the structure validity of scales in this paper. The results are given in Table 4. KMO values of network characteristics, individual attributes, team attributes, efficiency of cooperation and effectiveness of collaboration are more than the minimum level of 0.5, which are all significant. Factors loading of each item are all more than 0.5, indicating that factors have a good explanation for the corresponding latent variables. Therefore the questionnaire has good structure validity.

6.2 Structural equation analysis

We will use structural equation model (SEM) to study the relationship between variables. The path diagram is shown in Fig. 3.

Since SEM used the maximum likelihood method, the data should be in compliance with the assumption of multivariate normality, otherwise Chi-square estimates will swell and the model fit will become deteriorated. Therefore, we firstly performed normality test to study whether the data met the assumption of multivariate normality. The results are given in Table 5.

Table 3 Descriptive statistics

Variables	Item	Percent (%)
Gender	Man	56.3
	Woman	43.7
Age	≤30	58.5
	30–40	39.9
	40–50	1.3
	≥50	0.3
Education	College and below	9.7
	Bachelor degree	76.5
	Master degree and above	13.8
Team type	R&D team	46.1
	Services team	42.3
	research team	5.3
	Other non-task-based cooperative team	6.3
Team size	≤10	33.5
	10–30	43.6
	30–50	15.1
	50–100	6.3
	≥100	1.5

In Table 5, multivariate kurtosis is equal to 31.412 and critical value is 17.449. Wu [40] pointed out that if the absolute value of kurtosis is less than 10, or critical value is less than 5, the data is not significantly different from normal distribution. Because these values exceed the threshold value, we believe that the data does not meet the assumption of multivariate normality. According to Bollen and Stine [3], we use Bootstrap method to estimate when data is a non-multivariate normal distribution.

In the specific operation, we set the 2000 bootstrap samples in Bollen–Stine Bootstrap and reach the convergence in 20 iterations. The results show that the model has

a good fit in 1859 bootstrap samples, and poor fit in 141 bootstrap samples. The significant probability of Bollen–Stine Bootstrap is 0.071. Accordingly, although the data does not fit the assumption of multivariate normal distribution, we can still use Bollen–Stine to re-estimate the goodness of fit. The results are shown in Table 6.

From Table 6, we find that absolute fit index χ^2/df is equal to 3.774, greater than 3, RMSEA is 0.089, more than 0.08; relative fit index NFI is 0.878, IFI is 0.923, CFI is 0.922. Not all these indexes meet the corresponding requirements. In order to improve model fitness, we use the modified index (MI) to adjust the model. By adding the error covariance in “stre ~ inte”, “stre ~ capa”, we receive the following results (see Table 7; Fig. 4).

As shown in Table 7, the modified fitting indexes are improved and all reached the standard. Results show that the structural model can better fit the data. Therefore, according to the path coefficient, we can test the research hypothesis proposed in this paper. The results are given in Table 8.

As shown in Table 8, path coefficient of network characteristics impacting on efficiency of cooperation is 0.163 and its significance level is less than 0.1, so H1a is partially supported. Similarly, significance level of network characteristics impacting on effectiveness of collaboration is 0.072 less than 0.1, H1b is also partially supported. KC is the process of combining different resources to create new knowledge, and its innovation performance depends on knowledge heterogeneity [8]. Most scholars believe that knowledge heterogeneity will affect the performance of knowledge innovation of enterprises, and the relationship between them can be described with inverted U-shaped [14, 28, 37]. When there is higher knowledge heterogeneity, the opportunity for team members to contact external knowledge heterogeneity becomes bigger. The staff is

Table 4 Validity and reliability of the scale

Variable	Dimensions and items		Factor loading	KMO	Cronbach's α
Network characteristics	Network density	dens_1 ~ dens_3	0.731 ~ 0.863	0.755	0.716
	Connection strength	stre_1 ~ stre_5	0.598 ~ 0.783		
Individual attributes	Collaborative intention	inten_1 ~ inten_4	0.769 ~ 0.815	0.797	0.759
	Collaborative capacity	capa_1 ~ capa_4	0.672 ~ 0.794		
Team attributes	Collaborative atmosphere	atmo_1 ~ atmoi_4	0.681 ~ 0.792	0.855	0.816
	Collaborative culture	cult_1 ~ cult_4	0.676 ~ 0.747		
	Motivator	moti_1 ~ moti_4	0.765 ~ 0.812		
Efficiency of cooperation	Accuracy	accu_1 ~ accu_5	0.640 ~ 0.758	0.838	0.832
	Timeliness	time_1 ~ time_5	0.601 ~ 0.767		
Effectiveness of collaboration	Add-value of social capital	soci_1 ~ soci_5	0.622 ~ 0.728	0.849	0.822
	Add-value of intellectual capital	intel_1 ~ intel_5	0.676 ~ 0.841		

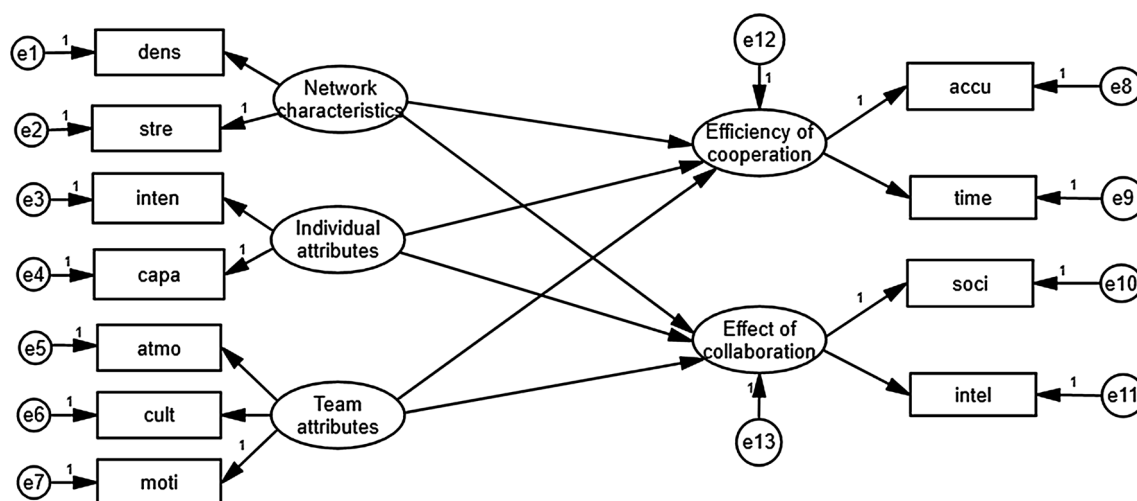


Fig. 3 Path diagram

Table 5 Joint normal distribution test results

Index	Kurtosis	Critical value
Multivariate	31.412	17.449

Table 6 Bollen–Stine Bootstrap Estimates

Fit index	χ^2/df	GFI	RMSEA	RMR	NFI	IFI	CFI
Value	3.774	0.936	0.089	0.029	0.878	0.923	0.922

Table 7 Revised Model fitting Index

Fit index	χ^2/df	GFI	RMSEA	RMR	NFI	IFI	CFI
Value	2.800	0.952	0.072	0.019	0.929	0.953	0.952

more likely to carry out knowledge collaboration. With the increasing of network density and strength, it will be prone to more knowledge innovation. But, when the network density and connection strength are too high, the cost of KC may exceed the benefits of knowledge heterogeneity, and the performance of KC will decline. This is why it shows the partly positive correlation between the network characteristics and performance of KC (efficiency of cooperation and effectiveness of collaboration).

For individual attributes, we know that it has a significant positive function on both efficiency of cooperation ($P = 0.003$) and effectiveness of collaboration ($P = 0.002$). So hypothesis 2a and hypothesis 2b are both proven. In a similar way, team attributes also have a significant positive impact on efficiency of cooperation and effectiveness of collaboration. Hypothesis 3a and hypothesis 3b are confirmed.

Fig. 4 Final path diagram.

* $p < 0.05$; ** $p < 0.001$;

*** $p < 0.001$

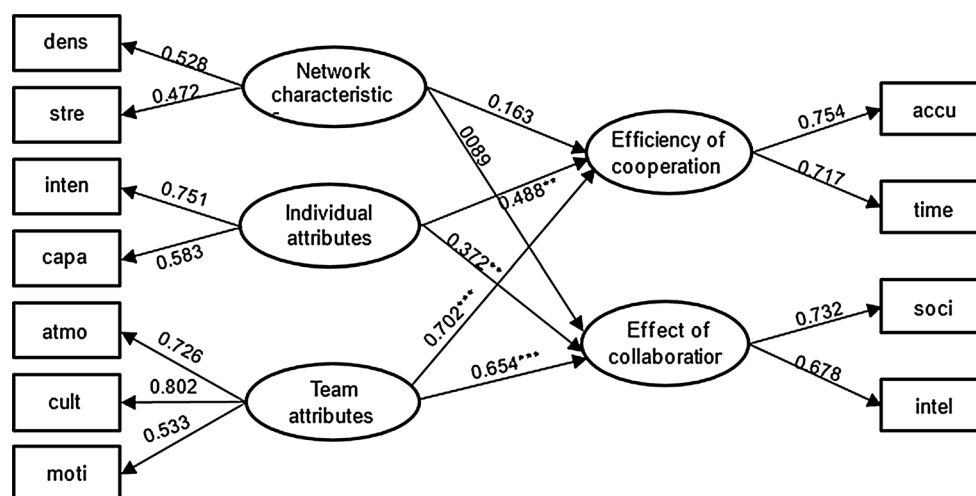


Table 8 Path Assumptions and Hypothesis Testing

Hypothesis	Path hypothesis	Path coefficient	<i>p</i> value	Test results
H1a	Network characteristics → Efficiency of cooperation	0.163	0.063	Support
H1b	Network characteristics → Effectiveness of collaboration	0.089	0.072	Support
H2a	Individual attributes → Efficiency of cooperation	0.488	0.003	Support
H2b	Individual attributes → Effectiveness of collaboration	0.372	0.002	Support
H3a	Team attributes → Efficiency of cooperation	0.702	0.000	Support
H3b	Team attributes → Effectiveness of collaboration	0.654	0.000	Support

Path coefficients are standardized coefficients

7 Conclusions and implications

7.1 Conclusions

In summary, the paper presents a performance evaluation model of KC which takes add-value of social capital and intellectual capital as the core in a virtual team. At the same time, the empirical study confirms that social network characteristics, individual attributes and team attributes have correlations with KC performance through efficiency of cooperation and effectiveness of collaboration. The results show that network density and connection strength of social network, willingness and capacity of individual attributes, team attributes have positive relations to efficiency of cooperation and effectiveness of KC. Thus there is a positive correlation with add-value of social and intellectual capital.

At present, virtual team is becoming an important organizational form of knowledge creation in many fields, especially in the IT outsourcing industry. Creating a virtual team, establishing an efficient mechanism of collaboration to call collective wisdom into full play, and creating new knowledge, new technology and new products, these are the goals that a lot of innovative enterprises pursue. However, the traditional performance evaluation based on project quality, cost and customer satisfaction cannot effectively motivate collaboration and knowledge innovation in virtual teams.

Different from other researches, this paper puts forward KC performance evaluation from the social and intellectual capital add-value perspective according to the characteristics of knowledge products, breaking the traditional performance measurement on project level.

7.2 Managerial and practical implications

Implications for strategic management practice are as follows. First of all, the traditional performance measurement based on only a single project, is only beneficial to the promotion of quality improvement, cost savings, but ignores the growth effect of intellectual capital on long-

term competitions of enterprises. Secondly, there are lots of KC implemented by knowledge individuals in the production process of knowledge, which will further help gain trusts between the members, so as to lay a foundation for more knowledge collaboration. This means that the accumulation of social capital will assist enterprises to obtain long-term competitive advantages. Thirdly, the positive correlation of individual, team attributes on KC performance should be linear, while the effect of individual network density, intensity on KC performance is not. Therefore, we need to find the most suitable network parameters to ensure the optimal cooperative performance.

From the result of this study, we also get some practical implications for virtual teams in IT outsourcing industry as shown below.

- (1) Establish performance evaluation metrics based on capital appreciation in virtual team.

Traditional performance evaluation evaluates team performance from cost efficiency. Although this method improves project quality and customer satisfaction, it ignores the accumulation of knowledge assets and also lacks knowledge innovation. Evaluating KC performance from add-value of social capital and intellectual capital in virtual teams helps the accumulation of knowledge and collaborative innovation, and it is also beneficial to increase organizational competitiveness and achieve strategic objectives.

- (2) Actively promote the formation and development of social networks in virtual team.

Team's collaborative culture, atmosphere and motivator are all positively correlated with the formation and development of social networks. A successful virtual team requires a good collaborative culture and atmosphere. It also needs an effective incentive mechanism established to encourage interactions among members, efficient network connection and mutual understanding, which will lead to a successful KC.

- (3) Pay more attention to use advanced technology to inspire KC

Virtual team members should focus on using advanced technology such as Web 2.0 to build a collaborative work platform. For example, in a Web 2.0 environment, the process of knowledge exchange, knowledge achievements are recorded and stored in digital forms. Based on this platform, connection strength and number of connections between employees, problem solving efficiency, as well as stock and increment of knowledge documents can be measured. It can partially solve the calculation problem of measuring intellectual capital and social capital appreciation and calculating timeliness and accuracy of KC.

7.3 Limitation and future direction

First of all, the paper has not yet been able to analyze the specific nonlinear relationship between social network factors and KC performance in depth, therefore the study is lack of a theoretical basis that network elements can promote the performance of KC. Although the main research conclusions have been verified, the specific management methods and practice strategy needs to be further strengthened. Another limitation is that the perspective of capital appreciation needs to be supported by practical cases. Further studies are therefore needed to increase the generalizability of our findings. The research team will further strengthen the combination of theory and practice to complement the theory of KC, and improve the efficiency of knowledge management in a virtual team.

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