Empirical study on relationship between knowledge attributes and innovation performance

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Abstract
This paper constructs the theoretical model of knowledge attributes, capacities involved in cooperative innovation process which include knowledge-absorbing capacity and knowledge-transferring capacity, and innovation performance. By analyzing data which come from 377 firms in Wanjiang economic zone, it reveals that knowledge attributes has significantly positive effect on these variables.

Keywords: knowledge intensive firms, knowledge attribute, innovation performance

Introduction
Recently, the studies on knowledge intensive industry have been focused significantly. Compared with the previous studies on other industries, knowledge intensive industry takes more emphasis on innovation activities, and it mainly showed on the activities as knowledge sharing and exchange. The idea of knowledge intensive industry, proposed by Miles in 2005 firstly, is regarded as the companies and organizations which mainly need the professional knowledge, and the main business of these organizations is to provide knowledge-based products or service for their customers (Miles, 2005). Knowledge intensive industry plays a
very important and proactive role in the knowledge-based market. Therefore, in this study, we choose knowledge intensive firms as our research objective because they are the companies who really need knowledge and produce knowledge.

As what Peter F. Drucker, the father of management, said that “knowledge is the only meaningful resource today” to gain advantages in competitions (Khan, 2009). In the increasingly rapid development of the knowledge economy era, the role of knowledge can not only be used to solve technical problems for enterprises. The ability of an enterprise to use a variety of knowledge is what can help enterprise to be unique and to produce unique resource (Yanying C. and Ruiwen C., 2005). Based on the theoretical and practical research on knowledge-based theory, it can be found that knowledge is an endogenous performance of one firm’s competitive advantage. Therefore, the innovation activities which resulted from competition have been significantly related with the knowledge an enterprise owns. However, with the development of information technology and knowledge economy, enterprise seems to be difficult to survive under the long-term competition by itself. Then, to face the uncertainty of market and risk of innovation activities, more and more enterprises choose cooperative innovation. Cooperative innovation is a crucial strategy to help enterprise reduce risk and cost in innovation researches, and it is also an important way for enterprise to obtain external knowledge and capacity (Zhong W. and Ruihu H., 2006).

However, firms who choose to cooperate with others may face an inevitable problem that is how to gain others’ knowledge resource as well as how to protect its own knowledge resource. Knowledge attributes, as the elements of knowledge resource, play a crucial role in the process of cooperative innovation. Currently, there are some studies did research on knowledge attributes, but most of them are based on the knowledge management but not on innovation performance and not on the process of cooperative process (Jianyuan Y. and Wenfeng X., 2010; Bruce H. and Jack A. N., 2002; Clyde W. Holsapple, 2004). In this study, based on the previous researches, we try to construct a concept model between knowledge attributes, knowledge absorbing capacity and knowledge transferring capacity, and innovation performance, then to get the data from questionnaires and do analysis through AMOS to analyze how knowledge attributes influence knowledge intensive firms’ innovation performance.

Model and hypotheses

Knowledge attributes and dimensions
Knowledge attributes are regarded as basic natures of the knowledge involved in a firm’s innovation, production and exchange. The attributes include three dimensions: tacit-ness, complexity and teach-ability.

Tacit-ness
In essence, knowledge refers to two types, one is implicit and another is explicit (Polanyi, 1962). Nonaka proposed in 1994 that tacit knowledge can be regarded as the know-how which obtained through personal experience. Therefore, tacit knowledge is difficult to be codified. In addition, tacit knowledge is hard to be expressed, discussed and used when there is no one knows that know-how is on the scene. In the enterprise, tacit knowledge is one of the most important intangible assets. Most of the designs, producing technologies, processes and management rules involved in the production are the explicit knowledge of enterprise,
and they are easy to be gained by external. Compared with the explicit knowledge, tacit knowledge such as ideological source of designs, social network of customers, and etc., they are difficult to be found and described by words. The transfer of tacit knowledge needs more face-to-face and longer personnel contact between two or more companies (Von Hippel, 1994; Teece, 1981; Farok J. C. and Wonchan Ra, 2002). That is tacit knowledge, which will have impact on the development of a firm directly.

**Complexity**

The complexity of knowledge is generally regarded as the large amounts of independent procedures, processes, employees, technologies and resources a firm owns because of particular knowledge or assets (Simonin, 1999). Kogut and Zander (2002) found that the more complicated a firm’s knowledge is, the more possible the firm extend its business. That is to say, complexity of knowledge increases the difficulty for other firms to find out, to learn and to imitate its knowledge resources. And correspondingly, the more complex the knowledge is, the more valuable of the knowledge is, and the more valuable innovation performance based on it.

**Teach-ability**

The teach-ability of knowledge can also refer to the observability of knowledge or can be seen this knowledge resource is easy to be imitated. In generally, the easy the knowledge can be observed, it is easier to be imitated and it is easier to be taught (Kogut and Zander, 1993). It is no doubt that the teachability of knowledge not only means it is easy to be observed and learned, the high teachable knowledge is more convenient to be transferred, it needs less personal contacts and it is harder to be bounded by contracts. What’s more, such knowledge resource only needs a little time to transfer, therefore, firms who own high teachable knowledge requires more protection on knowledge transfer, or it will cause a big lost.

**Capacities in cooperative innovation process**

Knowledge intensive firms refer to a group of organizations who has similar attributes as “high knowledge, high innovation, high technology and high interaction”(Jiang W., 2007). Such knowledge intensive firm needs to improve his capability to innovate, so that it can get the dominance and gain sustainable competitive advantage. Therefore, knowledge is what perfectly significant strategic resource, and it’s also the foundation of innovation. For an enterprise, whether it can obtain advantage in competition or not mainly reply on its abilities of knowledge creation, knowledge accumulation and knowledge application. Previous researches demonstrated that knowledge sharing should be the focus of cooperative innovation, and these studies paid more attention on the level of a single enterprise. However, we also can draw a lesson from the knowledge level to analyze problem, just like what Larry E. Westphal(1981), Seven Muller(1988) and Nonaka(1995) have done in their researches. To sum up, this paper makes an emphasis on the capacities involved in cooperative innovation process. And the two dimensions we divide here are knowledge absorbing capacity and knowledge transferring capacity. Here, the knowledge absorbing capacity not only means get external knowledge resource, but also the whole process to accumulate knowledge as well as keep it into use. Therefore, the knowledge absorbing capacity includes two capacities, one is absorbing and another is application.
Innovation performance
Because of the complexity and variety of the process of innovation and innovation output, till now, we cannot find a consistent concept to express what innovation performance is. The innovation performance which is formed through inter-firms cooperation may need a measurement which is more appropriate. In related research, some researchers used the amount of patent as the measurement on innovation performance. Some others measured the innovation performance of high-techs by R&D, number of applied patent, number of cited patent and number of new products (Hagedoom and Cloodt, 2003). Based on the previous researches and considered on the characteristics of innovation network as knowledge spillovers and knowledge sharing, in this paper, we measured innovation performance by three indexes, including the number of patent, the number of new products (including experiment report, designed drawings and etc.) and innovation efficiency.

Hypotheses
To sum up, we construct a four variables conceptual model (see figure 1 below). The four variables are knowledge attributes, knowledge absorbing capacity, knowledge transferring capacity and innovation performance. The hypotheses we proposed are as following:

H1: Knowledge attributes has positive impact on firm’s knowledge absorbing capacity.
H2: Knowledge attributes has positive impact on firm’s knowledge transferring capacity.
H3: Knowledge absorbing capacity has positive impact on innovation performance.
H4: Knowledge transferring capacity has positive impact on innovation performance.

Figure 1--conceptual framework

Methodology and data
Variables, validity and reliability
The four variables in the concept model are knowledge attributes, knowledge absorbing capacity, knowledge transferring capacity and innovation performance. And the validity and reliability of every variable are shown in table 1. The questionnaire we used for this paper applied the 5 level Likert-type and it was designed based on the previous studies and little revision are made to fit the Chinese reading habits.
Shown as the table 1, we can find that all the coefficient of Cronbach’s a are more than 0.7, which meet the requirements of internal consistency test very well. There is no doubt that the analysis on validity and reliability is so important for the model construction. Therefore, except examine Cronbach’s a, we also test the reliability by confirmatory factor analysis (CFA). From table 1, all results of confirmatory factor analysis can be accepted respectively.

**Sample and data collection**

Wanjiang economic zone refers to an emerging economic zone of central China. Because of its competitive advantages like central location, low human cost and significant supporting capacities, it develops rapidly in recent years. In addition, since its advancing strategic policy support, this economic zone attracts more and more investment and development. The main target companies of this survey are located in 12 cities and counties in Wanjiang economic zone, which including Hefei city, Tongling city, Wuhu city and etc. 430 of 470 questionnaires has been delivered back via email. And in these 430 questionnaires, there are 53 haven’t met our requirements on investigated firms. Among these, 17 companies are low-technology, which is without cooperative innovation or innovation performance, and 36 companies haven’t finished their questionnaires completely. Thus, we finally got 377 valid questionnaires and the effective rate is 80.21%. Which should be mentioned is that all the questionnaires should be answered by technical directors or senior managers of the enterprises.

**Results and analysis**

**Descriptive statistics analysis**

By SPSS16.0, we get the descriptive statistics analysis on these data. Table 2 shows the results of means, standard deviation and Pearson correlation analysis. It can be found from the results of means and standard deviation that the data are normal distributed, and this is the
prerequisite for further examine. For the Pearson correlation analysis, if the correlation coefficient is more than 0.9, these two variables could be combined. In our test, the results of Pearson correlation analysis suggest that there is significant linear relationship between each variable.

Table 2--results of descriptive statistics analysis and Pearson correlation analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Means</th>
<th>SD</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
<th>$\delta$</th>
<th>$\epsilon$</th>
<th>$\zeta$</th>
<th>$\eta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_t$</td>
<td>12.69</td>
<td>2.85</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\theta_y$</td>
<td>23.22</td>
<td>3.02</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\theta_x$</td>
<td>9.40</td>
<td>2.18</td>
<td>0.38</td>
<td>0.83</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\theta_k$</td>
<td>18.56</td>
<td>2.51</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>$\theta_l$</td>
<td>11.45</td>
<td>2.05</td>
<td>0.45</td>
<td>0.00</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>8.02</td>
<td>4.25</td>
<td>0.51</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Structural equation modeling analysis

Further examine on research hypotheses has been done based on structural equation modeling (SEM) analysis by software “AMOS 17.0”. In general, there should be a minimum requirement on sample, it should be no less than 100 (Minglong W., 2003; Boomsma, 1982). In this paper, the number of sample is 377 meets the requirement very well.

To examine whether the knowledge absorbing capacity and knowledge transferring capacity play mediating roles in the model, we applied the way Baron and Kenny used in 1986 to exam the mediator of the model. By using this method, we set three different models, which is model X, model Y and model Z to be checked here. Model X is the saturated model, model Y is the direct model and model Z is indirect model. Then, the result of structural equation modeling analysis can be seen in table 3. From what we can see in the table 3, some fitting indices of direct model and the saturated model haven’t met the significant requirements. Therefore, according to the principle of optimality, the model Z becomes the optimal model here.

Table 3--results of nested model analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>$X^2$</th>
<th>$X^2/df(5,&lt;0.1)$</th>
<th>RMSEA (&lt;0.05)</th>
<th>IFI (0.90)</th>
<th>TLI (0.90)</th>
<th>CFI (0.90)</th>
<th>IFI (0.90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>281.57</td>
<td>3.27</td>
<td>0.064</td>
<td>0.695</td>
<td>0.365</td>
<td>0.543</td>
<td>0.951</td>
</tr>
<tr>
<td>Y</td>
<td>182.23</td>
<td>2.00</td>
<td>0.056</td>
<td>0.900</td>
<td>0.935</td>
<td>0.900</td>
<td>0.913</td>
</tr>
<tr>
<td>Z</td>
<td>197.41</td>
<td>2.45</td>
<td>0.023</td>
<td>0.945</td>
<td>0.995</td>
<td>0.923</td>
<td>0.910</td>
</tr>
</tbody>
</table>

Table 4--path analysis on knowledge attributes, knowledge absorbing capacity, knowledge transferring capacity and innovation performance

<table>
<thead>
<tr>
<th>Path</th>
<th>Relationship</th>
<th>Model X</th>
<th>Model Y</th>
<th>Model Z</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>knowledge attributes $\rightarrow$ knowledge absorbing capacity</td>
<td>0.62***</td>
<td>0.59**</td>
<td>0.67**</td>
<td>H1 Support</td>
</tr>
<tr>
<td>R2</td>
<td>knowledge attributes $\rightarrow$ knowledge transferring capacity</td>
<td>0.34***</td>
<td>0.30***</td>
<td>0.54**</td>
<td>H2 Support</td>
</tr>
<tr>
<td>R3</td>
<td>knowledge attributes $\rightarrow$ innovation performance</td>
<td>0.40***</td>
<td>0.65***</td>
<td>0.40**</td>
<td>H3 Support</td>
</tr>
<tr>
<td>B1</td>
<td>knowledge absorbing capacity $\rightarrow$ innovation performance</td>
<td>0.44***</td>
<td>0.50***</td>
<td>0.50***</td>
<td>H4 Support</td>
</tr>
<tr>
<td>B2</td>
<td>knowledge absorbing capacity $\rightarrow$ innovation performance</td>
<td>0.59***</td>
<td>0.50***</td>
<td>0.50***</td>
<td>H5 Support</td>
</tr>
</tbody>
</table>

*** means $p<0.001$.  

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*** means $p<0.001$.
Table 4 shows that based on the model X, Y and Z, the path analysis on the relationship of knowledge attributes, knowledge absorbing capacity, knowledge transferring capacity, and innovation performance. To sum up, the mediating role of knowledge absorbing capacity and knowledge transferring role has been proven. That is to say, the influence of knowledge attributes on innovation performance is mediated by knowledge absorbing and transferring capacity. The analyses are shown as following:

Firstly, it is proven statistically that knowledge attributes has significantly positive effect on knowledge absorbing and transferring capacity (R1=0.67, p<0.001, and R2=0.54, p<0.001). Knowledge absorbing and transferring capacity has significantly positive effect on innovation performance (R4=0.89, p<0.001, and R5=0.32, p<0.001). In addition, since the knowledge attributes in model Y has positive impact on innovation performance, while the knowledge attributes in model X has no significant impact on innovation performance. We can get the conclusion that the influence of knowledge attributes on innovation performance is mediated by knowledge absorbing and transferring capacity.

In model Z, the change of knowledge attributes can significantly explain the change of knowledge absorbing capacity and knowledge transferring capacity respectively (for KA, it can explain 0.67, and for KT, it can explain 0.54). For the explanation on the change of innovation performance, knowledge attribute explain it through mediating effect (it equals to 0.67*0.89+0.54*0.32=0.7691). In addition, the change of knowledge absorbing capacity and knowledge transferring capacity can explain the change of innovation performance respectively (for KA, it can explain 0.89, and for KT, it can explain 0.32).

**Discussions and conclusions**

**Discussions**

By making surveys through Wanjiang economic zone of China, this paper got a conclusion that knowledge attributes have a significant direct impact on knowledge intensive firm’s knowledge absorbing and transferring capacity. And based on the structural equation modeling analysis, it is suggested that firm’s knowledge absorbing and transferring capacity can be the mediator in the relationship between knowledge attributes and innovation performance. The hypotheses are all supported by this research and the practical implications of this paper are as following:

1) Knowledge attributes has significant influence on firm’s capacities involved in cooperative innovation process, and knowledge absorbing and transferring capacity play mediating role in the relationship between knowledge attributes and innovation performance. That is to say, firms will promote its innovation performance if it makes improvement on its knowledge absorbing and transferring capacity as well as knowledge attributes. Therefore, through its improvement, the knowledge intensive firm may have a further development on knowledge obtaining, knowledge transferring, knowledge absorbing and knowledge application. This implies that better utilization of knowledge attributes and capacities can assist firms in better utilizing external sources. And when a firm has a further development on knowledge accumulation and application, it will be a good premise for firm it cooperates with. So the knowledge intensive firms which are can get more valuable knowledge resources from cooperative innovation and develops soon itself and the cooperative company.
(2) High knowledge absorbing and transferring capacity can help firm achieve high innovation performance. It helps to regulate the influence of knowledge attributes on innovation. With high knowledge absorbing and transferring capacity, firm can obtain more valuable knowledge resource quickly and improve the other capacity more easily, therefore, it help firm get more innovation performance and win the advantage in business competition. This finding suggests that knowledge intensive firm should pay attention on how to strengthen its knowledge absorbing and transferring capacity.

Contributions and limitations
This study contributes to the growing interest in integrating empirical approach in studying knowledge attributes, knowledge absorbing capacity, knowledge transferring capacity and innovation performance, which has not been fully investigated in the prior literature. And as noted earlier, for the evaluation of innovation performance, this study makes a summary and improvement based on the previous researches. However, this study is also subjected to several limitations that provide room for future research. First, the data were gathered from a single answer in each sample firm. The underlying assumption behind this method is that technical directors or senior managers who can provide ideas and right answers that reflect the company's knowledge and innovation behavior. Though all the validity and reliability tests examined in this study show there may have no serious problem, a multiple informant approach could be adopted in further research. Secondly, the data we used in this study are cross-sectional data. Although it may be enough to identify the relationships among each variable, however, to improve on our study, further studies can try to use multiple cross-sectional analysis.

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