Research on the Influence of Enterprise Innovation Network on Its Technology Innovation Performance-A Case in Electronic Information Listed Enterprises

Baohua Qi, Changqing Ding

School of Business, Hohai University, Nanjing 210000, Jiangsu, China

Abstract

From the perspective of Social Network, a firm’s innovation network is deemed as the integration of both internal and external relations of a company. Those two relations play a pivotal role in the process of technology innovation. Based on the analysis of literature, the hypothesis on the influence of innovation network on enterprise innovation performance is put forward from the two dimensions of internal network and external network. Via an empirical study with data from electronic information listed enterprises in Shenzhen, it has been proved that both internal and external relations of companies have exerted a positive impact on their companies’ performance.

Keywords: innovation network, technology innovation performance.

1. INTRODUCTION

Under the circumstance of knowledge economy, innovation is a significant means for enterprises to survive, develop and sustain its competitive advantages (Brow and Eisenhardt, 1995). Innovation may be a consequence from a firm’s own strengths. But more importantly, it derives from the resources and information exchange from external parts. With the increasing complexity and market competition of firms’ technology innovation, it is an effective way to solve the problem by constructing innovation network so as to access innovation resources, to share innovation risks and to reduce exchange costs. When it comes to electronic information companies, the technology innovation seems to be the most important effect on the survival and development of a firm and on the improvement of its performance. Compared with traditional enterprises, electronic information enterprises have features like speedily updated technology, high risks, being much professional, clear categories, and so on. Therefore, electronic information enterprises have put much more emphasis on external technology innovation and network innovation than any other industries. Tichy introduced the concept of social network in enterprise organization, thinking that firm’s network is the integration of both company’s internal and external relations (Ren et al., 2011; Chen, 2002; Tichy et al., 1979). Network is regarded as a means of resource allocation. Many scholars think that firm network has a positive impact on its technology innovation performance. While some scholars reckon that such influence is uncertain. In recent years, lots of scholars have researched in this field with the majority of qualitative analysis. And the quantitative analysis most gets data from questionnaire (Yue and Yao, 2015). Therefore, studies on influence on company technology performance exerted by firm network are really rare. According to the company category by Sina Finance and Economics, the samples are chosen from small and medium board electronic information listed enterprises in Shenzhen City. The data is collected from annual reports of 65 companies and the empirical study has been conducted to test the influence on technology innovation performance by firm network relations.

2. THEORY AND RESEARCH HYPOTHESES

In recent years, scholars from home and abroad have studied on firm’s technology innovation performance from the perspective of social network. And firm innovation network has been regarded as an integration of both internal and external relations of firms. Gulati believes that the enterprise network is a collection of various relationships that are formed during the process of cooperation, which is helpful to the information exchange and resource sharing between enterprises. Enterprise innovation network is a special form of enterprise network, which is to obtain innovative resources between enterprises and improve their technological innovation performance (Granovetter, 1985). Freeman thinks that the innovation network is a basic system arrangement to
deal with the system innovation, the main link mechanism of the network structure is the innovation cooperation relationship between enterprises. At present, Because of the difference in research perspective, the domestic and foreign research on the innovation network is not formed the concept of universal acceptance. Gai Wenqi believes that the enterprise innovation network is the subject of action (enterprises, scientific research institutions, intermediary organizations and individuals) formed a variety of formal or informal relatively stable relationship in the process of innovation, relations based on cooperation and communication. This article is in favor of Nonaka and Takeuchi on the definition of innovation network. He thinks that enterprise innovation network is the entire process involved in innovation activities of various subjects, including suppliers, customers, government institutions, intermediaries and other stakeholders involved the products R & D, design, manufacturing, sales and the formation of the enterprise network, formed the Corporate networks by mutual blending (Tan and Tan, 2009; Perven and Alam, 2015). This paper has followed Collins’ classification of firm network with internal and external parts (Collins and Clark, 2003). Firm’s external relation is a bridge linking the firm with its outside organization in business, which is a platform for firms and potential beneficiaries to communicate with each other. It also sets the stage for firms, suppliers, clients, governments, and so on to collaborate together so as to achieve resources that can not be gained in markets. Firm’s internal relations involve the network of research and development part, production, marketing and management departments, which integrate resources during the process of innovation and play a pivotal role in such process. In 1998, Tsai and Ghoshal have utilized Structural Equation Modeling to study on the influence on technology innovation performance by firm network and they have come to the conclusion that firm network has a positive effect on resource exchanges among enterprises, thus contributing to product innovation of enterprises (Tsai and Ghoshal, 1998). Gao Jian surveyed firm technology innovation activities in China and found that the contributing factors of achieving technology innovation success can be divided into two parts, namely, internal factors and external factors (Gao, 1997). No matter it is in internal or external relation, the collaborative relation has always done good to firms’ technology innovation activities. We can know from literature review that the external network is the significant origin for firm innovation. Not only can a firm acquire innovation resources from clients and suppliers from external network, but it can also acquire the information about customers’ needs and prices, dramatically reducing exchange fees and costs of companies. With a good knowledge of market information, the risk of innovation can be constrained so that it can do good to firm technology innovation. Consequently, a hypothesis has been put up with here, namely, H1: Through external relations, benign relations with suppliers, clients, and governments can be constructed so that such relations exert a positive effect on firm technology performance.

The external relation is an important propelling factor of firm technology innovation, and the important source to obtain enterprises innovative knowledge. And it interacts with internal relation to make innovation. The internal relation embraces the network of a firm’s research and development department, production department, and marketing division with human capital, material capital and innovation ability involved. Internal relation contributes to firm technology innovation activities through access to resources, configurations, and the ability to integration utility. Therefore, we come to H2: Firm’s internal network relation can enhance material and human capital and it can improve firm’s technology innovation ability so as to achieve better technology innovation performance.

Based on H1 and H2, we can easily assume a H3: Firm innovation network exerts a positive impact on technology innovation performance. How external and internal relations can impact on firm technology innovation performance is elaborated in great detail as the following Figure 1

Figure 1. The influence of enterprise network on its technology innovation performance
3. **EMPIRICAL ANALYSIS**

### 3.1 The Selection Of Samples And Industry

Listed companies are role models, who have advanced technology innovation levels and research capabilities. However, there are big differences in terms of innovation capability and innovation significance (Xu, 2013). Overall, the innovation ability of high-tech industry and technology-intense industry is much better than that of traditional industries. Electronic information enterprise technology update is fast, the characteristics of network innovation is obvious, therefore we have chosen electronic information enterprises as the sample with annual report from small and medium board electronic information enterprises in Shenzhen City in 2013 and 2014. The innovation patents data is collected from patents index from State Intellectual Property Office of China. Annual reports are acquired from websites such as cninf, resset, and NTES economics.

### 3.2 Variable design

On the basis of previous Chinese study and research on listed companies, the variables are made to measure firm internal and external networks.

#### 3.2.1 Variables Of Firm External Network

Considering accuracy and availability of data, this paper has taken supplier relationship, customer relations, and government relations as independent variables. According to the requirements of China Securities Regulatory Commission, listed companies have to list the first five suppliers and purchasers. This research has used the ratio of the total volume of the first five purchasers to cost of major business as the variable of measuring the relation of firm with suppliers. Besides, the ratio of the total volume of sales with first five customers to major business income is utilized as the variable to measure the relation of firm with customers and the higher the rate is, the closer the relation will be. Next is the relation between a firm and the government. The good relation between those two would ensure the company to have favorable policy and resources support. In addition, the government can change opportunity and markets through political policies. Having referred to Bian Yanjie and Qiu Haixiong’s researches, this paper has made a variable of CEOs or general managers who once worked as a member of the National People’s Congress or who are in Chinese People’s Political Consultative Conference, government, army, or state banks. Those who meet the previous condition are marked as 1 and those who do not are marked as 0. The relation between entrepreneurs and government can be found in the board members information of listed companies.

#### 3.2.2 Variables Of Firm Internal Network

Firm internal network refers to the combination of firm production network and research and development network, which use material and human resources to achieve knowledge. The methods of Gao Suying and Qiuyuanyuan have been reviewed to choose firm internal network variables and the firm material capital, human capital, and innovation ability are set as measures of firm internal network (Gao et al., 2011). The firm material capital is made through this formula: \( \frac{\text{earnings before interest + financial expenses + staff salary}}{\text{Total assets - total liabilities}} \). The measure of firm human resources is done through this formula: \( \frac{\text{number of doctors} \times 22 + \text{number of master} \times 19 + \text{number of undergraduates} \times 16 + \text{number of graduates from senior high} \times 12}{\text{the total number of staff}} \). The measure of innovation ability is made via the ratio of number of researcher and developers to the number of all staff.

#### 3.2.3 Variables Of Technology Innovation Performance

Technology innovation performance is set as a dependent variable. Although for a long time there is a growing body of researches in technology innovation, there is no agreed worldwide measure index for technology innovation performance. Some took single indicator like research input, the number of patents, the number of new products and so on. Some took two or more. Considering the availability and accuracy of sources of data, this paper has used objectively the number of patents as the indicator of technology innovation performance. Via national intellectual property web, we can find the data concerning number of patents of 65 small and medium board electronic information listed enterprises in Shenzhen City.
Table 1 Variable description

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation performance</td>
<td>The number of patents</td>
</tr>
<tr>
<td>The material capital</td>
<td>Earnings before interest + financial expenses + staff salary)/(Total assets - total liabilities</td>
</tr>
<tr>
<td>Human capital</td>
<td>(Number of doctors<em>22 + number of master <em>19 + number of undergraduates</em>16 + number of graduates from senior high</em>12)/the total number of staff.</td>
</tr>
<tr>
<td>Innovation ability</td>
<td>The ratio of number of researcher and developers to the number of all staff.</td>
</tr>
<tr>
<td>Supplier relationship</td>
<td>The ratio of the total volume of the first five purchasers to cost of major business</td>
</tr>
<tr>
<td>Customer relations</td>
<td>The ratio of the total volume of sales with first five customers to major business income</td>
</tr>
<tr>
<td>Government relations</td>
<td>CEOs or general managers who once worked as a member of the National People’s Congress or who are in Chinese People’s Political Consultative Conference, government, army, or state banks</td>
</tr>
</tbody>
</table>

3.3 Model setting

To test the empirical hypothesis, this article set the following mode to analysis, the first place to verify the influence of external relations within the network of innovative performance. We set the model:

\[ Y = f (IV, DV) \] (1)

\[ Y = f(IV, DV) \] (2)

\[ Y \] represents innovation performance; IV and DV represent independent variables and dummy variables.

3.4 Analysis of data and results

This paper has employed Excel 2003 and SPSS 19.0 to process data. The preprocessing is achieved through Excel 2003 and the correlation analysis and regression analysis are made by SPSS 19.0.

3.4.1 Descriptive statistical analysis of various variables of internal network external network.

In general, we use the minimum, maximum, mean and standard deviation to descriptive statistical analysis of a set of data

Mean value formula

\[ \bar{X} = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{\sum_{i=1}^{n} x_i}{n} \] (3)

Standard deviation

\[ \sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{N} (X_i - \mu)^2} \] (4)
Table 2 Descriptive statistics of Enterprise network and Innovation performance

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>maximum</th>
<th>(M±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External network</td>
<td>0.15</td>
<td>2.97</td>
<td>1.228±0.650</td>
</tr>
<tr>
<td>Internal network</td>
<td>12.81</td>
<td>17.54</td>
<td>15.894±1.247</td>
</tr>
<tr>
<td>Enterprise network</td>
<td>14.14</td>
<td>20.17</td>
<td>17.122±1.466</td>
</tr>
<tr>
<td>Innovation performance</td>
<td>0.09</td>
<td>226.23</td>
<td>28.237±43.279</td>
</tr>
</tbody>
</table>

Notice: M is for mean, SD is for Standard deviation

Descriptive statistical analysis of the survey data of 62 listed enterprises, the main contents include the enterprise external network, internal network, and relationship network, innovation performance. Statistical analysis results are shown in table 2. It can be seen from table 2. Enterprise external network, internal network, enterprise network relationship score 1.228±0.650, 15.894±1.247 and 17.122±1.466, respectively.

3.4.2 Correlation analysis

Correlation coefficient is an indicator of the objective existence of the phenomenon, and the correlation coefficient between the two groups is more deeply than the graph to describe the correlation between the observed values.

Correlation coefficient

\[ r_{xy} = \frac{\sum z_x z_y}{N} \]

\[ = \frac{\sum (X-\bar{X})(Y-\bar{Y})}{N} \]

\[ = \frac{\sum (X-\bar{X})(Y-\bar{Y})}{N} \]

\[ = \sum \frac{(x-\bar{x})(y-\bar{y})}{N*S_x*S_y} \]

\[ = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{N\left(\frac{1}{n}\sum^n_{i=1}(X_i-\bar{X})^2\right)^{\frac{1}{2}}\left(\frac{1}{n}\sum^n_{i=1}(Y_i-\bar{Y})^2\right)^{\frac{1}{2}}} \]

\[ R = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum(X_i-\bar{X})^2} \sqrt{\sum(Y_i-\bar{Y})^2}} \]

Or

\[ R = \frac{n \sum xy - \sum x \sum y}{\sqrt{n \sum x^2 - (\sum x)^2} \sqrt{n \sum y^2 - (\sum y)^2}} \]

In the formula, \( \bar{X} = \frac{1}{n} \sum^n_{i=1} X_i \) and \( \bar{Y} = \frac{1}{n} \sum^n_{i=1} Y_i \) as the mean.
This paper has used correlation analysis to depict the close relation among different variables and the correlated coefficients are used to picture the relations of different variables. And correlated coefficients are used to show whether they are significantly related or not. In order to know the relations among different variables, Pearson product-moment correlation has been utilized to analyze the relation between firm network and innovation performance. And the result is shown as Table 3. Using spss19.0 data analysis software to obtain the correlation coefficient is as follows:

Table 3 Correlation analysis of firm network and innovation performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>SP</th>
<th>CR</th>
<th>GR</th>
<th>PC</th>
<th>HC</th>
<th>IA</th>
<th>IP</th>
<th>EN</th>
<th>IER</th>
<th>RN</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CR</td>
<td>0.275*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GR</td>
<td>0.178</td>
<td>0.214</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>0.088</td>
<td>0.014</td>
<td>-0.067</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HC</td>
<td>0.236</td>
<td>0.359**</td>
<td>0.135</td>
<td>0.068</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IA</td>
<td>0.223</td>
<td>0.114</td>
<td>0.187</td>
<td>0.161</td>
<td>0.688**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP</td>
<td>-0.048*</td>
<td>0.111*</td>
<td>0.099*</td>
<td>0.021**</td>
<td>0.193**</td>
<td>0.260**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN</td>
<td>0.669**</td>
<td>0.321*</td>
<td>0.774**</td>
<td>0.010</td>
<td>0.082</td>
<td>0.200</td>
<td>0.106*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRN</td>
<td>0.258*</td>
<td>0.326**</td>
<td>0.143*</td>
<td>0.178</td>
<td>0.985**</td>
<td>0.785**</td>
<td>0.215**</td>
<td>0.106*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RN</td>
<td>0.516**</td>
<td>0.139</td>
<td>0.465**</td>
<td>0.147</td>
<td>0.874**</td>
<td>0.757**</td>
<td>0.230**</td>
<td>0.534**</td>
<td>0.898**</td>
<td>1</td>
</tr>
</tbody>
</table>

Notice: *p<0.05, **p<0.01, SP is for service provider; CR is for customer relation; GR is for government relation; PC is for physical capital; HC is for human capital; IA is for innovation ability; EN is for external relation; IRN is for internal relation network; IP is for innovation performance; RN is for relation network.

From Table 3, we can easily see that there is a significantly positive correlation between relation network and innovation performance. And external network is positively correlated to innovation performance. Besides, both customer relation and government relation have a significantly positive relation with innovation performance. Internal relation is also significantly positive with innovation performance. From Table 3, human capital, physical capital and innovation ability is positively correlated with innovation performance.

3.4.3 Regression analysis

There is a significant correlation between relation network and innovation performance. In order to further explore the predictable function by relation network on innovation performance, regression analysis is done as follows.

Two dimensions, internal network and external network, are set as independent variables and innovation performance is made as dependent variable. And multivariate regression analysis is done with the following results.

Table 4 Regression analysis of relation network and innovation

<table>
<thead>
<tr>
<th>Non-standardized</th>
<th>Coefficients</th>
<th>Standardized</th>
<th>Coefficients</th>
<th>Co linearity</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>SE</td>
<td>Beta</td>
<td>t</td>
<td>sig</td>
</tr>
<tr>
<td>constants</td>
<td>144.016</td>
<td>63.799</td>
<td>2.257</td>
<td>0.028</td>
</tr>
<tr>
<td>RN</td>
<td>6.788</td>
<td>3.713</td>
<td>0.230</td>
<td>1.828</td>
</tr>
<tr>
<td>R</td>
<td>0.230</td>
<td>0.037</td>
<td>F</td>
<td>3.343</td>
</tr>
<tr>
<td>R2</td>
<td>0.053</td>
<td>Std</td>
<td>E</td>
<td>42.52</td>
</tr>
</tbody>
</table>

Predictor: (constants), RN; Dependent variable: IP

In the regression model, R=0.230. The adjusted coefficient is 0.037. F = 3.343 and p= 0.042(p<0.05), which mean that the overall variables have become significantly different and the regression result is excellent. The value of D-W is 1.692 which belongs to the range from 1.2 to 2.8 and this shows that this model is acceptable.

Table 4 shows that the regressive coefficient of influence by internal relation on innovation performance is 6.788, and p is 0.042, which is below 0.05 and is a positive number. Thus, it is safe to say that internal relation exerts a positively predictable function on innovation performance.
From table 4, T is over 0.1, and VIF is below 5, which mean that there is no problem of multicollinearity. The probability of constant term is about 0.028, showing that it is not a standardized regression equation, which is as follows.

A linear regression model is

$$y_i = a + bx_i + u_i \quad (11)$$

$$b = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{n \sum x_i^2 - (\sum x_i)^2} \quad (12)$$

We get the regression equation by spass statistical software

$$IP = 144.016 + 6.788 \cdot RW \quad (13)$$

In order to classify dimensions of functions by relation network on innovation performance, the study is made on relation network and innovation performance, which is shown as Table 5

**Table 5 Regression analysis of internal network, external network and innovation performance**

<table>
<thead>
<tr>
<th>Non-standardized coefficients</th>
<th>Standardized coefficients</th>
<th>Co linearity</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>SE</td>
<td>Beta</td>
</tr>
<tr>
<td>Constants</td>
<td>148.239</td>
<td>70.221</td>
</tr>
<tr>
<td>EN</td>
<td>5.645</td>
<td>8.491</td>
</tr>
<tr>
<td>IN</td>
<td>7.142</td>
<td>4.426</td>
</tr>
<tr>
<td>R</td>
<td>0.231</td>
<td>R2</td>
</tr>
<tr>
<td>R2</td>
<td>0.053</td>
<td>Std</td>
</tr>
</tbody>
</table>

Predictor: (constants), EN, IN

$$R^2 = 1 - \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} \quad (14)$$

$$= \frac{\sum(y - \bar{y})^2 - \sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} = \frac{SSR}{SST} \rightarrow SSR accounts for the proportion of SST \quad (15)$$

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \quad (16)$$

$$R^2$$ the greater the degree of fitting the better, $$R^2$$ the smaller the $$R^2$$, the worse the fitting.

In the model of regression of relation networks on innovation performance, multiple correlation coefficient $$R=0.231$$ and coefficient of determination $$R^2 = 0.053$$. And adjusted coefficient of determination is 0.021. In this model, $$F = 1.655$$ and $$p = 0.025(p<0.05)$$, which mean that there is a significant difference and the regression result is excellent. The value of D-Wis 1.694, which is in the range from 1.2 to 2.8 and therefore, the result is accepted.

From the results of Table 5, the regressive coefficients of ER and IR on IP are 5.645 and 7.142 respectively with 0.034 and 0.038 of p, which are both positive numbers. In other words, relation network exerts a positively predictable function on innovation performance.

As can be seen from Table 5, T is less than 0.1, and VIF is below 5, which indicate that there is no multicollinearity.
\[ VIF = \frac{1}{1-R_i^2} \] (17)

The probability of constant term is about 0.039, indicating that it is not a standardized regression equation, which is as follows.

\[ IP = 148.239 + 5.645 \times EN + 7.142 \times IN \] (18)

Seen from the overall regression coefficients, RN has a positive effect on IP. Therefore, H3 is proved true. To be more specifically speaking, both EN and IN have a positive impact on IP, thus H1 and H2 are proved true too. In addition, IN exerts a more important influence than EN does.

4. CONCLUSION

This paper has conducted an empirical study on the influence by firm relation network on innovation performance from the perspective of social network. From data, we can see that both internal relation and external relation have a positive effect on technology innovation. Furthermore, internal relation exerts a much more significant effect than external relation does. Consequently, firms must lay more emphasis on relation network during the process of technology innovation from a strategic point of view. Firms should make appropriate management and plan maintenance to protect network innovation so as to overcome its drawbacks. Compared with the internal network and external network, the influence of enterprise internal relationship network on enterprise technological innovation performance is greater. Therefore, enterprises should pay more attention to the role of internal network, strengthen internal coordination and communication to enhance the ability of digestion and absorption and independent innovation. The study results not only provide empirical evidence to demonstrate that firm relation network has a positive influence on technology innovation performance and some related theories of relation network are enriched too.

5. DISCUSSION

Although there are some meaningful conclusions achieved, there are unavoidably several limitations. Small and medium board electronic information listed enterprises in Shenzhen City are selected as samples. However, whether the results are feasible to a larger sample is still unclear. Besides, the data only shows conditions from 2013 to 2014. And some variables may not be exactly appropriate, which needs to be further tested. We can study from the following two aspects of the in-depth study in future. 1. This paper analyzes the influence of internal network external network of electronic information enterprise on enterprise technology innovation performance, but also the lack of research on the interactive relationship between the two of them. 2, this paper is to study the static analysis on the impact of technological innovation network and innovation performance, the dynamic evolution of enterprise innovation network and the relationship with the different innovation modes are worth further research.

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