Effects of R&D Cooperation to Innovation Performance in Open Innovation Environment

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ARTICLE INFO

Available Online May 2014
Key words:
Collaboration;
Innovation;
Performance;
Open Innovation.

ABSTRACT

Dynamic nonlinear characteristics of internal and external environment in modern organization shows up increasingly, which make innovative research breakthrough organizational boundaries and present a pattern of open mode, the traditional mode of innovation is facing huge challenges like increasing innovation cycle, huge R&D input and inefficient knowledge transfer. And cooperation with external organizations to implement R&D is definitely a possibility to solve the open innovation environment challenge. Since organizations often have multiple dimensions of cooperation with different types of organization for research and development for the influence of organizational innovation performance or for exploring cooperation at the same time in different areas, and in different types of institutions. This paper studied the innovation performance of relevant government agencies except such innovation organization as enterprises, universities, and research institutions for the first time. This paper tracked on a survey of China's national engineering technology research center in related situation from 2002 to 2011 and collected related data to research and development cooperation and innovation performance for empirical research. Study found that universities have advantages in richness, in knowledge itself and knowledge accessible extent, cooperation with university in R&D is the best choice to promote the innovation performance of the organization. While cooperating with domestic universities and domestic enterprises to carry out research and development has bad effect in organizational innovation performance; while cooperation with domestic institutions and foreign institutions in the research and development plays a positive role in promoting innovation.

1. Introduction

In the 1980s, the National Science Foundation of American has established the Engineering Research Center (Engineering Research Center, ERC) relying on the university to promote the relationship of "university - industry" and strengthen the interdisciplinary cooperation (Wang, 2010). China started construction of National Engineering Research Center (NERC, National Engineering Research Center) in 1992, by the end of 2011, the total number has reached 294, the NERCs distributed in the field of electronic information technology, new materials, advanced manufacturing technology, energy and environmental protection, medicine and biology and agriculture and other fields, which become an important platform for industrial generic technology development and industrialization of scientific and technological achievements.

Henry Chesbrough (2003) put forward the open innovation that is, using the inflows and outflows of knowledge to accelerate the innovation of the organization and realizing the value of innovation through internal and external market with purpose. Theory of open innovation has absorbed and integrated a lot of previous theories and thoughts such as cooperative innovation, strategic alliance, innovation network and virtual network. Henry Chesbrough (2006) argued that the management of knowledge and technology in the organization is not closed motionless, but to make full use of its value by promoting the communication of knowledge and technology among different organizations actively. The enterprise must establish extensive contact with the outside world to realize the complementary advantages in knowledge dissemination and sharing.

The cooperation with outside organizations, which is considered to have a positive impact to innovation in our organization, can provide the organization with resources lacked, especially the innovation knowledge.

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Many literature has analyzed the influence of a single type of cooperation for innovation (e.g., Dittrich and Duysters, 2007; Kaufman, Wood, and Theyel, 2000; Sherwood and Covin, 2008; Song and Di Benedetto, 2008; van Echtelt et al., 2008; von Hippel, 1988), but does not take some organizations working with different types of external institutions existed at the same time into account (e.g., Belderbos, Carree, and Lokshin, 2006; Belderbos, Carree, Diederen, et al., 2004; Das and Teng, 2002).

Kenneth G. (2010) argued that organizational innovations in China are mainly concentrated in the following institutions: private enterprise, individual, university, the state - owned enterprise, public research institute, the state - owned institute, hospital. In addition, the enterprises, universities, research institutions are recognized as the major institutional innovation, Kenneth G. (2010) argued that related studies underestimated the function and capacity of government institutions in the role of innovation, since the relevant agencies of governments applies and accredits a large number of patents every year. National Engineering Technology Research Center is a related institution of government, it is also an important part of national innovation base and national innovation system, it aims at exploring a new way of combining technology and the economic and strengthening the center of the link forcing scientific and technological achievements into productive, improving maturity, compatibility, and the level of engineering on scientific and technological achievements, to provide technical innovation support for national economic and social development under the condition of socialist market economy(Zhou Yu, and He, 2013), since the organization could not supply the required knowledge for innovation, open innovation is helpful to obtain a new, complementary knowledge (Chesbrough, 2003).In order to solve the challenge and meet the needs of time development, the Engineering Center cooperates with external agencies actively and sets up a partnership with a number of external institutions in 2002-2011.（see the figure 1）

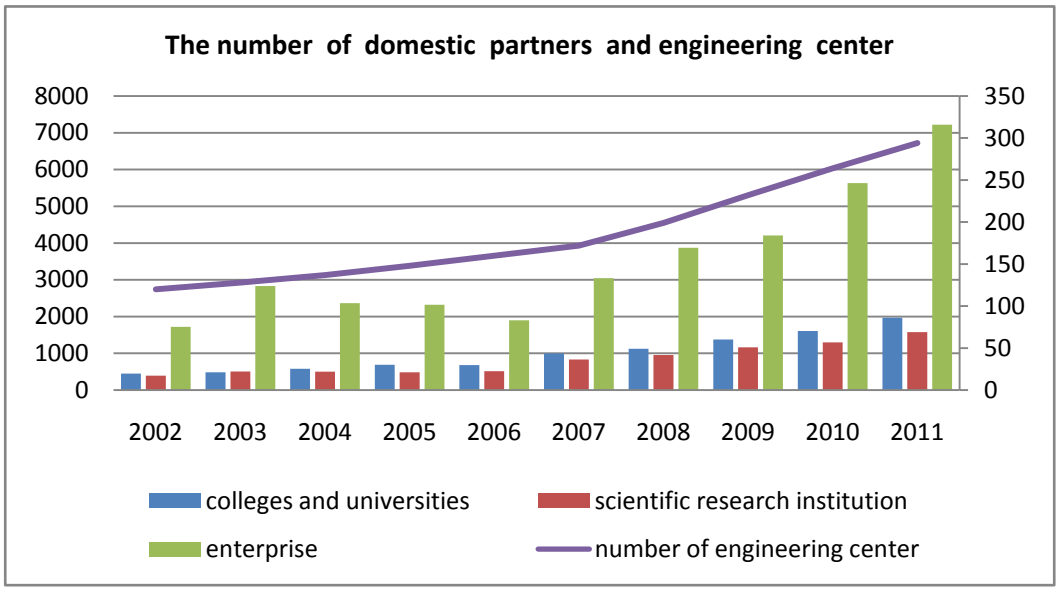

Figure 1. The number of NERC and domestic partners from 2002 to 2011

In order to explain the effects of R&D cooperation to innovation performance effectively, this paper based on the conception of "knowledge basement" (e.g., Grant, 1996; unrealistic expectations and Zander, 1992; Nonaka, 1994; Grant and Spender, 1996), which analyzed the effects of R&D cooperation to innovation performance of by using knowledge acquisition and the abundance of knowledge itself. First of all, the organization innovation requires rich knowledge as the basis, multiple disciplines is helpful to improve the innovation performance in different dimensions. Different types of research and development cooperation exist differences in degree of knowledge itself, which have different influence on organizational innovation performance. Therefore, assuming that all other conditions being equal, doing research and development cooperation with institutions of high degree of knowledge will be more likely to improve organizational innovation performance, because a variety of knowledge are more likely to be combined with internal knowledge and promote the innovation performance of the organization.

Secondly, the organizational innovation performance benefits by research and development partners who are more likely to acquire knowledge. Across organizational boundaries, and even acquiring knowledge within the organization, which is usually very difficult (unrealistic expectations and Zander, 1992; Szulanski, 1996; the Un, 2008); People need incentives, right mind-set and shared environment that help to promote the transfer of knowledge. Therefore cooperating with research and development institutions of easy access to knowledge, the easier to integrate with the enterprise internal knowledge, the more helpful to promote the innovation performance of the organization.

Table 1 Classification of R&D collaboration by richness of knowledge and ease of accessing knowledge for innovation performance

		The ease of knowledge acquisition		
		high	middle	low
The abundance of knowledge itself	high	R&D cooperation with domestic university		R&D cooperation with foreign universities
	middle		R&D cooperation with domestic scientific research institutions	R&D cooperation with foreign scientific research institutions
	low		R&D cooperation with domestic enterprises	R&D cooperation with foreign enterprises

Due to the tremendous amount of different partners of knowledge itself and the ease of knowledge acquisition, each type of cooperation have a different impact on innovation performance. Based on the two dimensions of each type of research and development cooperation, can be positioned into a matrix (Table 1).

2. Theory and Hypotheses

2.1 R&D collaboration with single institute and innovation performance

Cooperation with domestic institutions focused on: cooperation with domestic universities, research institutions and domestic enterprises. Similarly, research and development cooperation with foreign institutions, mainly concentrated in: research and development cooperation with foreign universities, foreign research institutions and foreign enterprises.

These three types of cooperation help to improve the performance of organizational innovation, and research and development cooperation with the universities are the best able to improve the organizational innovation performance, because no matter from the abundance of knowledge itself or from the ease of knowledge acquisition, it is the highest.

Comparing with the other two types of research and development cooperation, cooperation with the university can provide more abundant knowledge, thus more conducive to improve the innovation performance. There is a widespread belief in research and development collaboration with the university concerned more in the foundation, precompetitive research (Arora and Gambardella, 1990; Mowery and Rosenberg, 1989), therefore, that is a driving force for basic research and university cooperation (Lewis, 1990), it is not very useful for direct industrial use (Cohen, Nelson, and Walsh, 2002). However, the universities gradually focus on enterprise requirements from basic research (Santoro and Chakrabarti, 1999). Henard and McFadyen (2006), thought the universities have a wider range of ideas and multi-disciplinary perspective than other organizations, therefore, the potential ability for universities implementing multidisciplinary research project is greater.

Universities have proper system and mechanism for complex knowledge, so as to make it easier for the cooperation with organization in research and development to improve organizational innovation performance and acquire knowledge. Comparing with the other two types of agencies, obstacle to acquire knowledge from university is smaller. Study from Agrawal and Henderson (2002), Henard and McFadyen (2006) found that the brief exchange among researchers, to attend the meeting, graduate internships, and other kinds of innovation mechanism, made organization of university and the knowledge connect and exchange in a mutually beneficial relationship.

These arguments support the following assumptions:
H1: R&D cooperation between organization and domestic universities has more positive effect than research and development cooperation between domestic scientific research institutions and domestic enterprises.
H2: R&D cooperation between organization and foreign universities has more positive effect than research and development cooperation between foreign research institutions and foreign enterprises.

2.2 The Joint Impact of Different Institute and Innovation Performance

Batheltet al. (2004) discussed complementary assumptions scientifically. The joint impact of different regional and different institute's R&D collaboration on innovation performance exists. There are three possibilities, namely independent, substitute, and complementary. If the first possibility exists, R&D cooperation of different institutions in different regions is independent of the innovation performance, which means no interaction effect. If the second possibility exists, R&D cooperation of different institutions in different regions of the world is irreplaceable for innovation performance, which means the improvement of innovation performance thanks to a particular type of organization so as to avoid other types of research and development cooperation partners of other areas. It shows that R&D cooperation of different institutions in different regions of the world has negative effect for the interaction of innovation performance. If the third possibility exists, research and development cooperation of different institutions in different regions is complementary, which shows that R&D cooperation of different institutions in different regions of the world has a positive interaction effect for innovation performance.

We think doing research and development cooperation with different institutions in different regions of the world at the same time has a positive influence on innovation performance. First, there are qualitative differences among different regional institutions, so as to make the organization gain heterogeneous, complementary knowledge by the research and development cooperation with these institutions and improve organizational innovation performance, which are difficult to be imitated by all other competitors (He & Wong, 2012).Secondly, doing research and development cooperation between domestic and foreign institutions at the same time can overcome the limitation of space and has a vital role in preventing local network failure. We believe that the research and development cooperation with foreign institutions is more of an exploratory, and cooperation with domestic institutions is more of a exploitative (Drejer & Vinding, 2007), so, cooperation with domestic institutions and foreign institutions at the same time, the organization will receive the highest innovation performance, because many studies have found that exploration and exploitation work helps to improve innovation (e.g., He & Wong, 2004; Smith & Tushman, 2005). Involved in an interwork between strong relationship and a weak relationship.

However, cooperation with many domestic institutions at the same time may lead to "the ties that bind into the ties that blinds" (Grabher, 1993, p. 24), what's more, the unrestrained imitation of the local process, choice and homogeneity may make the dynamic hot spot of industrial clusters become a blind spot (Pouder & St John, 1996); excessive R&D cooperation with domestic institutions, ignoring the foreign institutions, will cause the R&D cooperation network in organizations too closed and rigid, which means that lacks flexibility ,newest ideas and consciousness about the development abroad when dealing with the new threat or opportunity. Cooperating with many domestic institutions at the same time may also makes the organization sink into a cycle, namely obtaining the same knowledge according to cooperation with the domestic institutions repeatedly (Zaheer & George, 2004), which resulted in waste of knowledge. Research and development cooperation with foreign institutions solves the locking problems in institutions and the level of regional space (Batheltet al., 2004; Boschma & Ter a Wal, 2007). Different stimuli and ideas injected into the research and development network in the organization through the research and development cooperation with foreign institutions, so as to prevent the knowledge-based organizations become rigid (made et al., 2009).In addition, some novel stimuli and ideas from foreign institutions can also have "catfish effect" on the domestic institutions.(Problems and advice in Chinese and foreign scientific and technological cooperation R&D management,2010-4, Technical Management Research).

Therefore, doing research and development cooperation with many domestic institutions at the same time may has a negative impact on organizational innovation performance, but doing research and development cooperation with domestic institutions and foreign institutions at the same time has a positive impact on organizational innovation performance.
H3: Impact of cooperation with domestic universities and research institutions on organizational innovation performance is negative.
H4: Impact of research and development cooperation with domestic universities and domestic enterprises on organizational innovation performance is negative.

H5: Impact of research and development cooperation with domestic and foreign universities on organizational innovation performance is positive.
H6: Impact of research and development cooperation with domestic universities and foreign research institutions on organizational innovation performance is positive.
H7: Impact of research and development cooperation with domestic universities and foreign enterprises at the same time on organizational innovation performance is positive.

3. Data and Methods

These assumptions described the effect of the organization to do research and development cooperation with individual institutions or with two scientific research institutions at the same time on the innovation performance. Data came from the 2002-2011 statistical report of National Engineering Technology Research Center.

Arguments about different types of research and development cooperation, we used the joint research between National Engineering Technology Research Center and the different types of institutions as a research and development cooperation, we take the number of R&D cooperation in between the National Engineering Technology Research Center and domestic universities, research institutions, companies, foreign universities, foreign scientific research institutions and foreign enterprise in 2002-2011 as independent variables, in which influence of research and development cooperation between research organization and institutions on innovation performance, taking the six separate units of R&D cooperation as the six independent variables; and when research organization cooperates with different types of institutions in different areas at the same time, we will use the product of domestic universities and domestic research institutions, domestic enterprises, foreign universities and research institutions, the number of R&D cooperation in foreign enterprises respectively as five independent variables which have common influence on innovation performance. In addition, we take the size of the organization (indicated by the number of centers used), the scale of the organization (indicated by the number of the workers) and the input of organization (indicated by investments completed actually) as control variables.

In this paper, we study the effects of R&D cooperation to organizational innovation performances, therefore, innovation performance is the only dependent variable in this paper. And innovation output is varied, including patent application, patenting, publishing scientific books and so on, in this paper we use the patent application, application of an invention patent patenting, awarding an invention patent, publishing scientific books or science and technology thesis as 6 indicators, using the factor analysis of SPSS analysis method, which is a multi-dimensional statistical method using the method of multivariate analysis. First of all, doing KMO and the spherical Bartlett test of the six indicators related with the innovation output of National Engineering Technology Research Centering in 2002-2011. Following table gives the results of KMO factor analysis and spherical Bartlett test. The value of Bartlett sphericity test probability p is 0.000, so the hypothesis is rejected, that is to say, it can be thought that correlation coefficient matrix is different significantly from the matrix .Meanwhile, KMO value is 0.795, according to the KMO measure standard, the original variables are suitable for factor analysis.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.795
Bartlett's Test of Sphericity	Approx. Chi-Square	51.909
	df	6
	Sig.	.000

Innovation performance= 0.987* Granted patents +0.981*Application for Patent +0.970* scientific and technical papers+0.858* Published works of science and technology, which can be calculated the innovation performance of national engineering technology research center from 2002 to 2011. See the table below.

Table 2 The innovation performance of national engineering technology research Center from 2002 to 2011

	2002	2003	2004	2005	2006
Innovation Performance	4329.99	5760.73	7890.61	8109.18	9719.65
	2007	2008	2009	2010	2011
Innovation Performance	13338.68	17029.54	19369.96	22284.15	27038.01

4. Results

Table 3 The frequency of R&D cooperation

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
R&D collaboration/cooperation	37.53	31.93	35.96	38.41	48.42	46.39	42.49	44.36	44.58	44.16
R&D cooperation with domestic universities	28.15	28.26	30.25	30.33	33.86	30.73	29.63	30.78	28.53	28.44
R&D cooperation with domestic scientific research institutions	24.66	25.56	25.82	23.80	25.24	24.51	26.39	24.88	23.08	23.50
R&D cooperation with domestic enterprises	33.12	32.76	30.11	30.27	26.70	30.93	29.73	31.74	36.10	36.31
R&D cooperation with foreign universities	4.88	4.95	4.58	6.13	4.61	4.86	5.17	5.06	4.97	4.43
R&D cooperation with foreign scientific research institutions	5.06	4.27	4.95	6.07	5.16	4.94	4.61	4.07	3.98	4.05
R&D cooperation with foreign enterprises	4.14	4.20	4.29	3.40	4.61	4.03	4.47	3.47	3.34	3.27

R&D: *research and development. All table value in percent.*

Before we discuss the hypothesis testing, we should analyze the frequency of R&D cooperation first. Summarized in table 3. Ways of cooperation between National Engineering Technology Research Center and external agencies are various, in addition to the research and development cooperation, we also have processing production, advisory services and other types. Percentage of R&D cooperation of all types has been below 40% during 2002 to 2005, but after 2006, it has been in more than 40%.

Similarly, percentage of research and development cooperation between National Engineering Technology Research Center and domestic institutions accounts about 85% of all, of which foreign institutions is only about 15%. In the research and development cooperation with three different types of institutions, the specific details are shown in figure 1, the number of cooperation with universities, scientific research institutions is far less than the number of cooperation with enterprises, and as we can see, the cooperation with universities, scientific research institutions mainly focuses on research and development cooperation while the cooperation with enterprises mainly concentrated in the processing production and consulting services, but the difference between the number of research and development cooperation with enterprises and the number of R&D cooperation with universities and research institutions is not very big due to the base of cooperation with enterprises.

Next we study effects of each type of R&D cooperation has on innovation performance; and the common impact of different types of research and development cooperation in different areas have on innovation performance. Table 4 provides the results of the analysis. Model 1 shows only the control variable has influence on innovation performance; Model 2 is used to analyze different influences of research and development cooperation that the three control variables and three domestic institutions have on innovation performance; Model 3 is used to analyze different influence of research and development cooperation that the three control variables and three foreign institutions have on innovation performance; Model 4 is used to analyze the combined impact of research and development cooperation that the three control variables and those of different types in different regions have on innovation performance. Model 2,

3 and 4 are used to test the seven assumptions.

These results supported the H1 H4, H5 and H7,but didn't support H2, H3, H6.The correlation coefficient between research and development cooperation with domestic universities and innovation performance is positive, statistically significant, while this is bigger than the correlation coefficient of domestic scientific research institutions and the domestic enterprises, which suggests that research and development cooperation with domestic universities has the biggest impact on innovation performance comparing with domestic scientific research institutions and enterprises, fully supporting the H1. The correlation coefficient between R&D cooperation with foreign universities and organizational innovation performance is not significant in statistics, H2 is not supported. The correlation coefficient between doing R&D cooperation with domestic university, domestic research institutions at the same time and organizational innovation performance is not significant by statistics, which does not support the H3. While the correlation coefficient between doing research and development cooperation with domestic universities, domestic enterprises and organizational innovation performance is statistically significant, and negative, which fully support the H4. At the same time the correlation coefficient between doing research and development cooperation with domestic universities and foreign research institutions and organizational innovation performance is statistically significant, and it is positive, fully support the H5. While even the correlation coefficient between doing research and development cooperation with domestic universities and foreign enterprises at the same time and organizational innovation performance is statistically significant, it is negative, and do not support H6.But the correlation coefficient between doing research and development cooperation with domestic universities and foreign enterprises at the same time is statistically significant, and it is positive, fully support the H7.

Table 4 Results of the analysis of R&D collaboration on innovation performance
Dependent variable: innovation performance

	Model 1	Model 2	Model 3	Model 4
Number of center	0.633 （0.411）	-0.066 （0.224）	0.387 （0.235）	-0.925** （0.137）
Number of Employees	0.892 （0.574）	0.921** （0.250）	0.637 （0.323）	-0.249 （0.094）
Actual completed investment	-0.536 （0.358）	-0.726*** （0.160）	-0.372 （0.202）	1.865** （0.211）
Domestic university		0.862*** （0.167）		
Domestic research institutions		0.599** （0.017）		
Domestic enterprise		0.130 （0.707）		
Foreign university			-0.180 （0.612）	
Foreign research institutions			0.346 （0.123）	
Foreign enterprise			0.351** （0.012）	
Domestic university* Domestic research institutions				0.480 （0.230）
Domestic university* Domestic enterprise				-2.797*** （0.196）
Domestic university* Foreign university				2.509*** （0.235）
Domestic university* Foreign research institutions				-0.690 （0.127）
Domestic university* Foreign enterprise				1.233*** （0.084）

*Note:*P<0.10;**P<0.05;***P<0.01, two-tailed test, standard error in parentheses*

5. Discussion and Conclusion

These findings do have great contributions to research and innovation performance. Model 2 and model 3 show that national engineering technology research center cooperate with external institutions, especially with domestic universities, research institutions, foreign enterprises on innovation performance which has a positive significant influence. No matter the richness in knowledge itself and the ease of knowledge acquisition of the domestic universities is higher than that of the domestic scientific research institutions and enterprises, therefore, the correlation coefficient of the former than the latter two correlation coefficients. As the matter of the fact, there are few cooperated research cases which were cooperated between national engineering technology research center and foreign universities and foreign scientific research institutions, so that did not reach statistical significance.

This article studies the innovation performance of relevant government institutions except enterprises, universities, research institutions for the first time. National engineering technology research center is not only one of the relevant government institutions but also a key national innovation base and an important part of national innovation system as well. Under the condition of the socialist market economy, to explore the new way of combining the science technology with the economic, to strength the link between scientific and technological achievements and productivity, if the national engineering technology research center cooperate with two domestic institutions at the same time, which obstructs the development of the innovation performance. The correlation coefficient is negative, which we can find it clearly from the statistics, it further validated Grabher's thought (1993) that cooperating with several domestic institutions would lead the organizations fall into a bad circle, namely repeating cooperation with the domestic institutions and obtain the same knowledge, which cause the network of research and development too closed and rigid, this means the organizations lack of flexibility, when face the new threats or opportunities. However doing research and development cooperation with domestic institutions and foreign institutions at the same time has a positive role in promoting innovation, except for the correlation coefficient of the domestic universities and foreign scientific research institutions have on the innovation performance is not significant, the correlation coefficient of domestic universities and foreign universities, domestic universities and foreign enterprises have on innovation performance are both positive, which are also significant statistically. Further proves doing research and development cooperation with foreign institutions solved the locking problems in institutions and regional levels of space, which was proposed by Batheltet al. and Boschma & TerWal; Whittingtonet al thought different stimuli and ideas could be injected into the research and development network of the organization by doing research and development cooperation with foreign institutions, so as to prevent the knowledge-based organizations becoming rigid and to promote the innovation performance of the organization. Faems, Van Looy, and Debackere (2005) thought establishing a multi-dimensional cooperation with multiple agencies at the same time is helpful to obtain different innovation knowledge, but in this paper, the study found that establishing a multi-dimensional research and development cooperation with multiple agencies can be a challenge for managers, which needs to select the type of partner carefully, not all multidimensional development cooperation could promote innovation performance, instead it could be obstacles.

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