A Study on the Modes of Open Innovation Matched With Firms' Internal Capabilities

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Abstract--**The open innovation paradigm coined by Henry Chesbrough offers a new way of thinking and managing about innovation. But it's still unknown that how to manage open innovation efficiently. This paper analyzes key innovation resources owned by outside organizations. Based on the essential characteristics of open innovation, this paper establishes the modes of open innovation matched with firms' internal capabilities. The research manifests that openness do improve performance of innovation, and furthermore there are interactions between internal capabilities and modes of openness. This leads to the suggestion that firms should select suitable modes matched with their internal capabilities. Specifically, it is suggested that different types firms should adopt different matching strategies. For instance, for firms with intensive internal R&D activities and strong internal R&D capabilities, collaboration with science-based partners is preferable. But, for firms with good R&D capabilities and medium manufacturing capabilities, collaboration with horizontal connections will be an optimal option. Meanwhile, for firms with medium R&D capabilities, collaboration with technology related organizations and value chain partners will achieve better innovation performance. In sum, this paper states that it is important for firms to decide whether they can access to complementary resources which is beneficial for innovation from the openness.**

I. INTRODUCTION

Along with the rapid change pace and complexity of technology, the shorter product life cycles and global competitive environment, the importance of external innovation resources in innovation was acknowledged by many researchers and practitioners [3] [11] [12] [15] [16] [33] [42]. Exploiting external innovation resources to advance innovation got a renewed interest after Chesbrough's seminal work on open innovation [4]. The benefits of external technology acquisition for innovation have been emphasized in extant literature [19] [41]. Many innovative firms have changed the way they search for new ideas, adopting open search strategies that involve in the use of a wide range of external sources to strengthen and speed up their innovation processes.

In the extant literature, the empirical analyses about the impact of open search strategy on innovation performance mainly focused on the positive aspect [5] [26]. And only a few scholars offer a more critical perspective on openness [24]. They discussed that with increasing degree of openness in the process of innovation, the product development projects were slower and higher cost than the norm in the industry and the firm's usual projects. Sofka & Grimpe [37] pointed out that being open for innovation generally pays off, however the direction of search strategies influences innovation performance.

Open innovation has the advantage of free flow of innovation resources. Open innovation provides a good opportunity for firms to acquire the resources needed for innovation from the outside. Searching for external knowledge has frequently been characterized as crucial input for firms' success in innovation. But openness of the process of innovation will take some costs. Williamson [44] considered that external joining need opportunity costs and financial costs. There will be the costs of searching for information and innovation resources, transaction costs and management costs of inter-organizational cooperation if firms adopt open innovation strategies. Excessive searching and access to external innovation resources would adversely affect innovation performance [25]. Too much external ideas and external innovation resources will cause the problem of attention allocation on management [34], and thus overload what the firm can respond to. Moreover, the greatest danger of openness is the leakage of knowledge to external partners [26]. When working with potential competitors, the leakage of key technology is the most serious problem. For the non-competitive cooperation between firms, sensitive business information and technologies may also leak to competitors by a common supplier or user [1]. This offers some challenges for management and research of open innovation.

The existence of abundant external innovation resources will increase the complexity of innovation management for firms. How to manage open innovation becomes a hot research topic. Open innovation has dynamic characteristics. The modes of managing open innovation in different firms will be related with the status in the innovation system and the stage of technology development [9]. Through an in-depth case study, Chiaroni, Chiesa & Frattini [6] [7] analyzed the changes of organizational structure and management system which firms had undergone to move from a closed to an open innovation paradigm. Bianchi et al. [2] explored the organizational modes of open innovation and partners selection in firms in the bio-pharmaceutical industry at different stages of drug development and drug discovery. Existing studies have provided important ideas and theoretical basis for a better understanding of open innovation, but recent research mainly focus on exploring for a single issue such as partner selection, organizational structure change and usually through the case study. Therefore it is important to conduct some further empirical research on modes of managing open innovation and to support the theoretical assumptions. It is also necessary to provide suggestions for practioners.

The implementation of open innovation cannot automatically happen and also external innovation resources cannot flow into firms automatically. Why there are

differences about the effects of open innovation among different firms? How to organize the open practice in order to achieve optimum utilization of this innovative paradigm? In fact, there are significant differences in the stage of development, internal resources, market conditions and absorptive capacity in different firms. Internal resources and capabilities will affect the results of open behavior. Therefore, how to select the right partnership? What is the best organizational mode matched with firm's internal capabilities? Those are very important for guiding firms to implement open innovation efficiently.

This paper analyzes the innovation resources owned by different types of outside innovation agents. And it also analyzes the key external innovation resources needed in the process of innovation in different firms. Based on the essential characteristics of open innovation, this paper furthermore explores the modes of open innovation matched with firm's peculiarities. This paper will provide guidance for firms to utilize external innovation resources efficiently based on their own innovation resources so as to eventually improve innovation performance.

The remainder of this paper is organised as follows. The following section presents theory analysis and hypotheses development. The third section introduces the data and sample, and variables we use in this study. It is then followed by the results section. The fifth section is the section of discussion and conclusion.

II. THEORY AND HYPOTHESES

A. The connotation of open innovation

Open innovation means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well [4]. Open innovation means that firms can and should leverage internal and external resources simultaneously to achieve innovation. The essence of open innovation is to access and use of external knowledge in the process of innovation.

1. Open innovation emphasize the use of external innovation resources

Open innovation emphasizes the full use of external resources including technology and market information. Useful knowledge and innovative supports from outside might be different external agents such as lead users, suppliers, design firms, even competitors. Open innovation emphasizes active collaborations with outside organizations to improve the efficiency of innovation through a wide use of external innovation resources and external marketing channels.

2. Open innovation emphasizes the complementarity and synergy between internal and external innovation resources

The open innovation paradigm is not simply an approach emphasizing the use of external technologies for innovation. Open innovation is also to search for and access ideas and resources which are complementary with internal R&D projects. Put differently, open innovation essentially emphasizes the complementarity and synergy between internal and external innovation resources. Firms access complementary resources by opening to the outside organizations in the innovation process. The synergistic effects based on heterogeneous resources make firms improve their core competencies. In the open innovation paradigm, internal resources still play a critical role for innovation. External innovation resources are complementary with internal resources, rather than be substitute for. There is a significant positive correlation between internal resources and external searching. The state of the internal resources will affect the capability to access and exploit external resources.

3. The integration of internal and external innovation resources is the key to success for innovation

In a bountiful external knowledge landscape, a firm organizes its internal R&D to identify, understand, select from and connect to the wealth of available external knowledge. A firm organizes its internal R&D to integrate internal and external knowledge to form more complex combinations of technologies to create new systems and architectures [4]. In the open innovation paradigm, a firm must improve the capability of monitoring, evaluation, absorption and exploitation of external knowledge, which is similar to the concept of absorptive capacity [11]. Internal R&D capabilities will determine the capability of searching, identification, absorption and exploitation of external source of innovation. Therefore open innovation must be more intensive in internal R&D activities which acts as a precondition in implementing open innovation approach. Internal R&D departments have new function of searching and integration resources. In this way, an innovator can be defined as an integrator of internal and external resources.

Henderson & Clark [21] proposed that new product developments require two kinds of knowledge: component knowledge and architecture knowledge. Component knowledge is knowledge about the components of the core design concepts. Architecture knowledge means the integration of various components and connecting into an overall knowledge. In the process of innovation, components knowledge can come from inside or outside the firm, integrating a variety of technological resources by opening product constructions and setting interaction with outside organizations, while the architecture knowledge must come from internally. In the open innovation paradigm, to maintain the competitive advantage firms should have two types of competence, core competence [36] and background competence [17]. Firms overcome the technological problems in some core areas and access external technologies in other wide areas. Only when firms have enough background competence can they acquire, absorb and integrate external knowledge well [8].

B. The key innovation resources owned by different types of outside agents

Identifying the key innovation resources owned by different types of external innovation agents and to decide which knowledge is required for firm's innovation become increasingly important for practioners. We state it will be beneficial for firms to select outside partners in different stages of innovation.

1. Stakeholders on product value chain

International research on innovation and the innovation practices show that close contact with users is good for accurate understanding market demand. Von Hippel [42] thus emphasised the role of lead users for bringing forward new solutions and product concepts. Firms can invite users to participate in the new product development (NPD) process directly through the application of toolkits for user innovation and design in order to quickly obtain new ideas and new product definitions[14] [43]. Through close interactions with innovative users, manufactures can absorb radically new product concepts and select the most promising prototype versions. Therefore, firms can accelerate the innovation process and reduce the risks of commercialisation [42] [43]. Furthermore, interactions with users enable firms to acquire new technological skills, learn about relevant technological trends, and extend their innovation and technology-related networks [27].

Firms can accelerate innovation and reduce costs by facilitating the participation of suppliers in the design and development process [10] [32]. Establishing iterative and long-term contact with suppliers ensures the full use of external resources and establishes a more flexible NPD process. Nowadays, more and more firms engage in strategic supplier relationships exploiting the full potential of their relation in order to benefit from shared intellectual resources, harnessed capabilities, and innovative jointly developed products and technologies.

2. Competitors and firms in other industries

With the fast pace of technology, it is difficult for a single firm to keep advanced research in all kinds of research areas. Even the most innovative companies with the most extensive internal capabilities cannot undertake technological innovation activities on their own [38]. Great technology and ideas can be found in companies of all sizes [4]. R&D cooperation is considered as a mechanism to maximise a company's value by effectively combining its own resources with the complementary resources of its partners [13] [20] [29] [38]. Firms may set up collaborations with competitors to learn more about technologies that are difficult, time-consuming, and costly for internal development. Competitors also collaborate when they face common technological problems or wish to set technological standards [39]. Competitors in local industry clusters often stimulate each other's innovations. Competitors may also be attractive partners with whom to team up and exploit complementary R&D resources to develop new products and reduce costs and risks [28].

After the stage of dominant design of NPDs, complementary assets become a key factor in successful innovation [38]. Firms in other industries, though they do not develop and produce the same products, based on mutual need for complementary competences, the resource advantages of one firm happens to be another's weakness [22]. Partnerships have developed in particular between high-tech start-ups and larger incumbents [28]. High-tech start-ups are willing to set collaborations with incumbents to promote the application of new technologies and commercialization. And incumbents may collaborate with high-tech start-ups to enter new product areas or technological fields [18] [35].

3. Universities and research institutes

Universities and other public research institutes are important sources of new scientific and technological knowledge for firms pursuing radical innovations or nascent technologies [1]. Industry-science collaborations make firms access to new knowledge and increase their understanding of emerging scientific developments [1] [23]. Linking scientific knowledge is especially important for firms to advance innovation in the fast developing technologies [30] [40].

4. Intellectual property organizations and other technology agencies

Close contact with intellectual property organizations and other technology agencies is a valid way for firms to access to external technologies. Firms can expand their knowledge base with limited investments through technology purchasing. Intellectual property organizations and technology agencies may play a bridging role that enables firms to search and acquire external knowledge economically and quickly.

Firms may also cooperate with venture capital enterprises to get funding to support innovation. As an equity financing, venture capital, is one kind of special capital, which combines technology, management experience and entrepreneurship, etc.. Venture capital not only solves the problem of financing of technological innovation, but also brings valuable market information and technological information with the involvement in management and control by professional venture capitalists.

C. Hypotheses

Openness cannot directly improve innovation performance. The aim of openness to outside organizations is to obtain innovation resources that are complementary to firm's internal R&D. For the exploitation of external innovation resources efficiently, firms must have corresponding internal absorptive capacity, to promote the integration of internal and external resources.

The state of the internal resources will affect the capability to access and use external resources. If a firm wants to access to lead scientific knowledge through

collaboration with universities or research institutes, the firm should have strong R&D capabilities and absorptive capacity to absorb and exploit scientific knowledge as a precondition.

Cooperation with competitors and firms in other industries are effective channel to obtain complementary resources. Because of the leakage of knowledge, firms with intensive R&D activities seldom open to competitors for the control of R&D spillovers. Most firms concern about their competitors very much just to trace technological developments and market dynamics. On the other hand, without certain internal capabilities a firm cannot become an attractive partner[31], and also cannot fully benefit from external knowledge sources [41]. For this reason, firms with strong or weak R&D capabilities will seldom open to competitors. Firms with medium internal R&D capabilities can access to complementary resources through collaborations with horizontal connections. Firms may seek breakthrough innovative solutions through collaborations with firms in other industries on key technologies and core technologies.

Partners in the value chain, users and suppliers, can provide market information and advanced accessories for firms. Thereby improve the quality of new products and improve the efficiency of innovation. But there is still a problem of the information leakage. Sensitive business information and technological knowledge might be leaked to competitors by a common supplier or user. In the open innovation paradigm, intellectual property organizations, technology agencies are all important agents for acquiring external innovation resources. Working closely with technology-related organizations can promote innovation performance efficiently.

Open innovation emphasizes complementarity and synergy between internal and external innovation resources. Open innovation emphasizes the integration of internal and external resources to advance innovation. Based on the essence of open innovation we can formulate the following hypotheses:

H1: Firms with intensive internal R&D activities, collaboration with universities or research institutes will improve innovation performance.

H2: Firms with good R&D capabilities and medium manufacturing capabilities, close collaboration with horizontal connections will achieve better innovation performance.

H3: Firms with medium R&D capabilities, strong manufacturing capabilities and marketing capabilities, close cooperation with technology-related organizations will improve innovation performance.

H4: Firms with medium R&D capabilities, ordinary manufacturing capabilities and marketing capabilities, the close cooperation with value chain partners will improve innovation performance.

H5: Firms with weak R&D capabilities, manufacturing capabilities and marketing capabilities usually make less contact with outside organizations and gain relatively low innovation performance.

III. DATA AND VARIABLES

A. data

Data for the analysis was obtained from questionnaires sent to innovative firms in China. We sent 515 questionnaires to the heads of R&D centres in firms that have a national or provincial R&D centre in Zhejiang. Of the 243 questionnaires we collected in total, 34 were subsequently eliminated as invalid. We therefore had 209 valid questionnaires.

The questionnaire was structured into four parts. The first part contained some general information about the surveyed firms. The second part asked for firms' internal capabilities including R&D, manufacturing and marketing. The third part concentrated on firm's external linkages and the acquisition of external knowledge from users, suppliers, competitors, universities and other outside organizations. And the last part was about the information of firm's innovative performance. In the questionnaire, we used a seven-point Likert scale to measure the importance of each item.

Table 1 provides an overview of the distribution of respondents over nine industries.

This paper uses the indicator annual sales to reflect firm's scale. In our sample collected in this research, there are 3 firms with annual sales less than 100 million Yuan, 37 firms with annual sales between 100 million Yuan to 500 million Yuan, 77 firms with annual sales between 500 million Yuan to 5 billion Yuan, 48 firms with annual sales between 5 billion Yuan to 10 billion Yuan, 33 firms with annual sales between 10 billion 20 billion, and 11 firms with annual sales more than 20 billion Yuan.

Therefore, the industry distribution of the sample across various business sectors, and firm size is widespread, indicating that the sample have a good representation.

TABLE 1: OVERVIEW OF SAMPLE BY INDUSTRY

Industry	Frequency	Percent (%)
Pharmaceuticals	22	10.53
Materials and chemicals	27	12.92
Electrical and communications equipment	29	13.88
Metallic mineral products	12	5.74
Machine manufacturing	60	28.71
Car manufacturing	10	4.78
Textile and clothing	18	8.61
Paper and furniture	17	8.13
Food	14	6.70
Total	209	100

B. Variables

For measuring the internal capabilities of innovative firms we included ten aspects in the survey: R&D inputs, R&D employees, R&D equipments, qualified technical workers, manufacturing equipments, proficiency level of workers, qualified salesman, network of marketing, post-sale service and exploitation of new market (see Table 2). The level of capabilities about these aspects is based on the scores of the respondents answering the question 'Compare with domestic competitors, how about the following description of your firm's resources?' Respondents could answer on a seven-point Likert scale: higher scores indicate that the level of capability is advantaged for the respondent firm. The Cronbach's alpha coefficient of ten internal capabilities is 0.819 meaning that ten items have a high degree of internal consistency and the reliability of the questionnaire is quite good.

For measuring the linkages with external organizations we included nine types of potential partners in the survey: lead users, major clients, suppliers, competitors, firms in other industries, universities and research institutes, technology agencies, intellectual property organisations, and venture capital funds (see Table 2). The degree of exploitation of external sources is based on the scores of the respondents answering the question 'what is the importance of co-operation with the following external partners in your firm's innovation activities?' Respondents could answer on a seven-point Likert scale: higher scores indicate that the innovation partner type is more important for a firm's innovative performance. The Cronbach's alpha coefficient of nine external sources is 0.888 meaning that nine items have a high degree of internal consistency and the reliability of the questionnaire is quite good.

Innovative performance is measured by six items: number of new products; the ratio of new products sales to total sales; the speed of new product developments; the success ratio of innovation projects; the number of patent applications; and the number of industry standards. We used a seven-point Likert scale to measure the condition of each item. Respondents were asked to compare their firm's performance vis-à-vis competitors in the same industry. High (low) scores on the Likert scale indicate that the firm's innovative performance is strong (weak) compared with competitors. We took the average of the scores on these six items to evaluate the innovative performance as a synthetic 'innovative performance' indicator. Cronbach's alpha coefficient for the six items is 0.795 which represents a high degree of internal consistency.

IV. RESULTS OF EMPIRICAL ANALYSIS

A. Descriptive statistics of internal capabilities and external linkages

Table 2 shows the descriptive statistics of internal capabilities of the respondent firms and importance of external sources in the process of innovation.

By Table 2, we find that the manufacturing capabilities are high for the most of Chinese innovative firms. The R&D resources and technological knowledge are the weakness for innovation. Therefore acquiring and exploiting external resources to complement with internal technological knowledge through the openness of the process of innovation is more important for Chinese firms.

TABLE 2 DESCRIPTIVE STATISTICS OF INTERNAL CAPABILITIES AND EXTERNAL INNOVATION AGENTS

	item	Mean	Variance	Cronbach α
internal capabilities	R&D inputs	4.7377	1.4720	0.819
	R&D employees	4.5967	1.5751	
	R&D equipments	5.0813	1.2752	
	Qualified technical workers	5.0254	1.0855	
	Manufacturing equipments	5.6364	0.9078	
	Proficiency level of workers	5.7033	0.8734	
	Qualified salesman	5.4211	0.9082	
	Network of marketing	5.2967	0.8153	
	Post-sale service	5.5550	0.8251	
	Exploitation of new market	5.2919	1.1120	
external innovation agents	Lead users	4.5455	2.5762	0.888
	Major users	4.2249	2.5983	
	Suppliers	4.1770	2.4646	
	Competitors	4.1675	2.3712	
	Firms in other industries	2.7847	1.7372	
	Universities and research institutes	3.6005	1.8551	
	Technology agencies	2.7751	1.9831	
	Intellectual property organisations	2.9713	2.3554	
	Venture capital funds	2.3397	2.2830	

By table 2, we find that collaboration with users and suppliers are frequently mentioned by the respondents as important external sources of innovation. It is remarkable that many respondents mention competitors as a source of innovation. It is not possible to determine from the survey whether firms learn from competitors through information leakage, or from employees who are hired away from competitors, or whether they establish formal technology alliances with competitors to undertake joint R&D. Collaboration with firms in other industries is only practiced by a minority of the respondents. Cooperation with universities and research institutes is somewhat less popular as external source of technologies. The role of technology agencies, intellectual property organizations, and venture capitalists is rather marginal. In sum, Table 2 shows that Chinese innovative firms adopt relatively few innovation relationships with external partners, especially when it comes to ties with specialized companies such as technology agencies, intellectual property organizations, and venture capital funds.

B. Factor analysis of internal capabilities and external innovation resources

To show the internal and external innovation resources clearly, we ran a factor analysis for firm's internal capabilities and different types of external sources respectively.

For internal capabilities, the KMO (0.869) and the chi-square for Bartlett's test of sphericity (544.794) were highly significant ($p < 0.001$). Therefore, we can conclude that factor analysis is suitable for this data. Three factors will be retained according to the criteria of extraction with eigenvalues higher than 1. Three factors reflect 60.84% of the variance in the original data. Then we regrouped the internal capabilities and labelled each of the three factors according to the rotated factor loadings with varimax orthogonal rotation. The results are presented in Table 3.

Table 3 shows internal capabilities can be categorised into three groups: R&D capabilities, manufacturing capabilities, and marketing capabilities. The scores of these three factors will be used as the variables to reflect the determinant of internal capabilities on innovative performance for firms.

Similarly, for external sources, the KMO (0.877) and the chi-square for Bartlett's test of sphericity (934.67) were highly significant ($p<0.001$). Therefore, we can conclude that factor analysis is suitable for this data. Four factors will be retained according to the cumulative proportions of variance. Four factors reflect 80.63% of the variance in the original data. Then we regrouped the external sources and labelled each of the four factors according to the rotated factor loadings with varimax orthogonal rotation. The results are presented in Table 4.

TABLE 3 ROTATED FACTOR LOADINGS OF FIRMS' INTERNAL CAPABILITIES

	loadings			Name of the factor
	1	2	3	
R&D inputs	**0.801**	0.206	0.129	R&D capabilities
R&D employees	**0.748**	0.220	0.056	
R&D equipments	**0.783**	0.183	0.051	
Qualified technical workers	**0.734**	0.121	0.035	
Manufacturing equipments	0.333	0.067	**0.664**	Manufacturing capabilities
Proficiency level of workers	0.055	0.172	**0.821**	
Qualified salesman	0.245	**0.627**	0.276	Marketing capabilities
Network of marketing	0.209	**0.704**	-0.025	
Post-sale service	0.104	**0.784**	0.015	
Exploitation of new market	0.313	**0.713**	0.058	

TABLE 4 ROTATED FACTOR LOADINGS OF THE IMPORTANCE OF EXTERNAL SOURCES

	loadings				Name of the factor
	1	2	3	4	
Lead users (LU)	**0.819**	0.160	0.188	0.276	Value chain partners
Major users (MU)	**0.859**	0.182	0.091	0.162	
Suppliers (S)	**0.639**	0.447	0.367	0.041	
Competitors (C)	0.480	**0.704**	0.214	-0.063	Horizontal connections
Firms in other industries (OE)	0.156	**0.784**	0.256	0.416	
Technology agencies (TM)	0.074	0.137	**0.799**	0.354	Technology related organisations
Intellectual property organisations (IP)	0.217	0.237	**0.789**	0.211	
Venture capital enterprises (VC)	0.195	0.162	**0.857**	0.001	
Universities and research institutes (UNI)	0.332	0.159	0.302	**0.815**	Science-based partners

Table 4 shows external sources can be categorised into four groups: value chain partners, horizontal connections, technology-related organisations and science-based partners. The scores of these four factors will be used as the variables to reflect the importance of four types of external partners on innovative performance.

C. Cluster analysis

For the comparative analysis of different modes of open innovation, this paper uses cluster analysis with four types of external sources "value chain partners", "horizontal connections", "technology-related organizations" and "science-based partners" as the clustering variables. We used two method, hierarchical clustering method of Ward and K-means clustering method. The results are consistent by two methods. The sample of 209 firms can be categorized into five groups. The descriptive statistics of external sources and internal capabilities of five clusters are shown in Tables 5 and 6.

The first group, the mean of "science-based partners" values 1.1657, most firms select universities or research institutes as partners and access to advanced scientific knowledge to promote innovation. The mean of "value chain partners" values 0.3697, more firms cooperated with lead users and suppliers and access to market information and suppliers' advanced technologies. The means of "horizontal connections" and "technology-related organizations" are negative. Correspondingly, by Table 6, comparing the values of internal capabilities and innovation performance of this group, we can find that the mean on "R&D capabilities" values 0.4156, it is the greatest value. While the means on "manufacturing capabilities" and "marketing capabilities" are less. With strong R&D capabilities, firms have intensive internal R&D activities, and therefore have strong absorptive capacity to acquire and absorb scientific knowledge from cooperation with universities or research institutes. Firms in the first group usually have good innovation performance. Thus H1 is supported.

The second group, the mean of "horizontal connections" values 1.4177, most firms select competitors and firms in other industries as partners to access to complementary resources for innovation. The mean of "science-based partners" and "technology-related organizations" values 0.4344 and 0.3990 respectively, more firms cooperated with universities or research institutes and technology agencies to access to new scientific knowledge. The means of "value chain partners" values -0.0211. Few firms cooperated with users and suppliers. Correspondingly, by Table 6, comparing the values of internal capabilities and innovation performance of this group, we can find that R&D capabilities are weaker than firms in the first group. The mean on "R&D capabilities" values 0.2450, it is the greatest value. And the means on "marketing capabilities" and "manufacturing capabilities" are less, values 0.2116 and -0.0514 respectively. With good R&D capabilities and marketing capabilities, but insufficient manufacturing capabilities, firms cooperated with horizontal connections to acquire complementary resources. Though internal R&D capabilities are weaker than firms in the first group, by using outside knowledge firms achieve better innovation performance. Thus H2 is supported.

TABLE 5 THE VALUES OF MEAN AND STD. DEVIATION OF EXTERNAL PARTNERSHIP

	Number of cases		Value chain partners	horizontal connections	science-based partners	technology-related organizations
cluster 1	35	Mean	0.3697	-0.4193	**1.1657**	-0.6924
		S.D.	0.6716	0.8052	0.6926	0.5860
cluster 2	32	Mean	-0.0211	**1.4177**	0.4334	0.3990
		S.D.	0.4838	0.5566	0.7561	0.8626
cluster 3	31	Mean	0.3169	-0.3460	0.3801	**1.5486**
		S.D.	0.7879	0.6609	0.9082	0.5903
cluster 4	56	Mean	**0.8035**	0.0114	-0.8745	-0.4299
		S.D.	0.6426	0.9434	0.5957	0.7280
cluster 5	55	Mean	-1.2197	-0.3746	-0.3178	-0.2266
		S.D.	0.5804	0.7745	0.6565	0.6704

TABLE 6 THE VALUES OF MEAN AND STD. DEVIATION OF INTERNAL CAPABILITIES

	Number of cases		R&D capabilities	Manufacturing capabilities	Marketing capabilities	Innovation performance
cluster 1	35	Mean	**0.4156**	0.1361	-0.0427	**5.3038**
		S.D.	0.9381	1.0067	1.05305	0.8234
cluster 2	32	Mean	**0.2450**	-0.0514	**0.2116**	**5.3698**
		S.D.	0.9252	1.1241	0.7754	0.5816
cluster 3	31	Mean	0.0821	**0.4294**	**0.3960**	**5.4570**
		S.D.	0.6832	0.6532	0.7330	0.7888
cluster 4	56	Mean	0.0545	0.0419	-0.1234	5.0685
		S.D.	0.9048	0.9887	1.0275	0.9681
cluster 5	55	Mean	-0.5088	-0.1118	-0.1934	4.3606
		S.D.	1.1380	1.0794	1.1238	0.8126

The third group, the mean of "technology-related organizations" values 1.5486. Most firms select intellectual property organizations and technology agencies as partners, to purchase advanced technologies for promoting innovation. The mean of "value chain partners" and "science-based partners" values 0.3169 and 0.3801 respectively, some firms cooperated with users and suppliers to acquire market information and new technologies. And some firms cooperated with universities to access to new scientific knowledge. The means of "horizontal connections" values -0.3460. Correspondingly, by Table 6, comparing the values of internal capabilities and innovation performance of this group, we can find that the mean on "manufacturing capabilities" and "marketing capabilities" values greater, values 0.4294 and 0.3960 respectively. And the mean on "R&D capabilities" values 0.0821. With good manufacturing capabilities and marketing capabilities, but medium R&D capabilities, without intensive internal R&D activities, firms cooperated with technology-related organizations to purchase new technology. Though internal R&D capabilities are weaker than firms in the first two groups, firms access to external technological resources to complement with internal deficiencies through openness, their innovation performance are better. Thus H3 is supported.

The fourth group, the mean of "value chain partners" values 0.8035, the mean of "horizontal connections" values 0.0114, while the mean of "science-based partners" and "technology-related organizations" below average, values -0.8748 and -0.4299 respectively. Most firms select users and suppliers as partners. Correspondingly, by Table 6, comparing the values of internal capabilities and innovation performance of this group, we can find that firms in this group have medium R&D capabilities and manufacturing capabilities, while the mean on "marketing capabilities" values -0.1234, below the average level. Firms cooperated with users and suppliers to acquire market information to complement with internal deficiencies in marketing capabilities. Innovation performances of firms in this group are below the first three groups. Thus H4 is supported.

The fifth group, the means on four external sources value negative all. Correspondingly, by Table 6, the means on internal "R&D capabilities", "manufacturing capabilities" and "marketing capabilities" are all negative either. The results show that internal capabilities in firms are lower than average and they do not open to outside in the process of innovation so innovation performance is the lowest. Thus H5 is supported.

D. Multivariate analysis of variance (MANOVA)

To further compare the interactions between four types of open innovation modes and internal R&D capabilities, this paper use multivariate analysis of variance. We analyze the impact of different open innovation modes (OI modes), internal R&D capabilities, and their interactions on innovation performance. The results are shown in Table 7.

TABLE7 TESTS OF BETWEEN-SUBJECTS EFFECTS (MANOVA)

Source	Sum of Squares	df	Mean Square	F	Sig.
OI modes	21.958	4	5.490	8.997	0.000
Internal R&D capabilities capabilities	6.705	2	3.352	5.494	0.005
OI modes * Internal R&D	8.882	8	1.110	1.819	0.075
Error	118.375	194	0.634		
Total	155.920	208			

TABLE8 MULTIPLE COMPARISONS BETWEEN 4 OI MODES AND INNOVATION PERFORMANCE

comparison	(I) OI mode	(J) OI mode	Mean Difference (I-J)	Std. Error	Sig.
LSD	Open to science-based partners	Open to horizontal connections	-0.1460	0.19469	0.454
		technology-related organizations开放	-0.2332	0.19632	0.236
		Open to value chain partners	0.1554	0.17151	0.366
		closed	0.8632**	0.17211	0.000
	Open to horizontal connections	technology-related organizations开放	-0.0872	0.20059	0.664
		Open to value chain partners	0.3013*	0.17639	0.089
		closed	1.0092**	0.17697	0.000
	Open to technology-related organizations	Open to value chain partners	0.3885*	0.17819	0.030
		closed	1.0964**	0.17877	0.000
	Open to value chain partners	closed	0.7078**	0.15111	0.000

*. The mean difference is significant at the 0.05 level

**. The mean difference is significant at the 0.01 level

By Table 7, open innovation modes (OI modes) have significant impact on innovation performance, internal R&D

capabilities have significant impact on innovation performance, interactions between R&D capabilities and OI modes are significant too.

To show the differences between the impacts of four OI modes on innovation performance more clearly we use LSD-test to distinguish the pairwise difference. The results are shown in Table 8.

By Table 8, the results of LSD test show that the impacts of different OI modes on innovation performance have significantly differences. External knowledge sourcing has a strong impact on firms' innovation performance. However, the impact of opening to value chain partners on innovation performance have significant difference with opening to horizontal connections and technology-related organizations in the 0.1 level of significance.

To further show the interaction of internal R&D capabilities and OI modes clearly, the diagram of interactions on innovation performance are shown in Figure 1.

Fig. 1 shows that there is a significant interaction between internal R&D capabilities and OI models. When firms have strong internal R&D capabilities, setting close cooperation with "science-based partners", "horizontal connections" and "technology-related organizations" would promote innovation performance greatly. H1 and H2 are supported. When firms have medium internal R&D capabilities, the impact of cooperation with science-based partners on innovation performance is insignificant. It is because firms do not have corresponding absorptive capacity to absorb and apply nascent scientific knowledge in new products developments. Therefore firms cannot take full advantage of universities' lead scientific knowledge. While setting close cooperation with "technology-related organizations" and "value chain partners" can promote innovation performance greatly. H3 and H4 are supported. When firms have weak internal R&D capabilities, setting close cooperation with "technology-related organizations" can promote innovation performance greatly. Figure 1 shows that firms do not adopt an open innovation model, with the same internal R&D capabilities, but innovation performance is the lowest. H5 is supported.

V. CONCLUSIONS

More and more firms adopt open innovation strategy to speed up and improve their innovation performance. But firms do not have enough time and attention to maintain close contact with all types of outside organizations. To achieve higher efficiency of openness firms should select suitable OI modes matched with their internal capabilities.

(1) In the process of innovation, firms can significantly improve their innovation performance by opening to outside organizations, interaction with outside organization and leveraging technology discoveries and complementary resources developed by others.

(2) There are a variety of open innovation modes aimed at different type of outside organizations as the main partners. The impact of different modes on innovation performance is diverse.

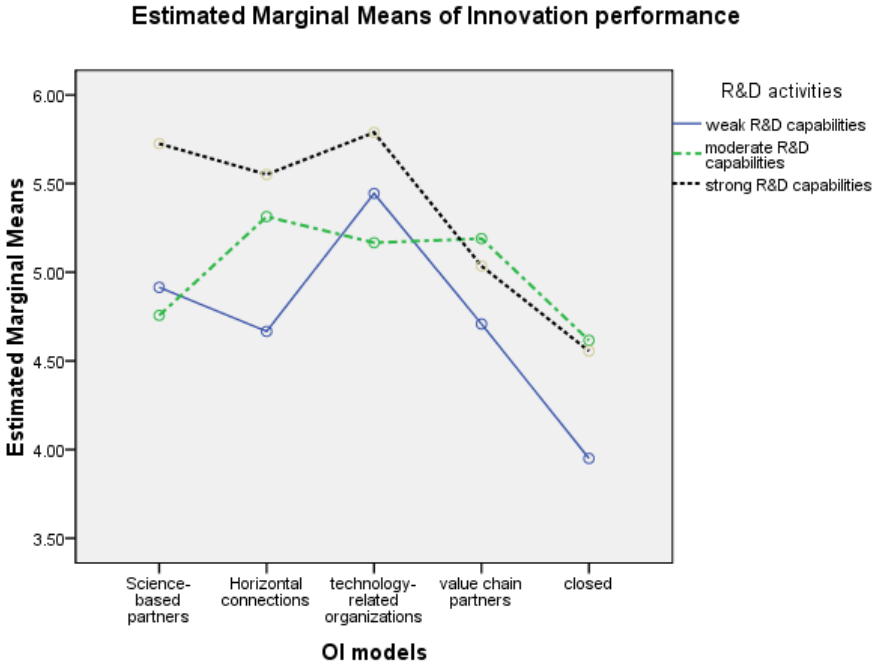

Figure1 The interactions between internal R&D and OI modes

External knowledge sources are categorised into four groups: value chain partners; horizontal connections;

science-based partners; and technology related organizations. Using the importance of these four types of outside organizations in firms' innovation practice as the clustering variables, this paper does the clustering analysis of the sample firms. The results show that there are five groups with different partners as the main goal of open innovation organizational mode. They are collaboration with "science-based partners", "value chain partners", "horizontal connections", "technology-related organizations", as well as closed. The results of analysis of variance show that different types of innovative organizational modes have a significant impact on innovation performance.

(3) There are interactions between internal capabilities and different open innovation modes

For firms having close contact with science-based partners, they usually have intensive internal R&D activities, and have strong R&D capabilities. They have strong absorptive capacity to acquire and absorb advanced scientific knowledge from cooperation with universities or research institutes. Therefore opening to science-based partners improve their innovation performance greatly. Those firms having close contact with horizontal connections, they have good R&D capabilities and marketing capabilities, but insufficient manufacturing capabilities. Firms select competitors and firms in other industries as partners to access to complementary resources to promote innovation. For firms which have close contact with technology-related organizations, they usually have good manufacturing capabilities and marketing capabilities, but medium R&D capabilities. Without intensive internal R&D activities, firms cooperated with technology-related organizations to buy external technologies to complement with deficiencies and therefore improve innovation performance. Those firms having close contact with value chain partners, they usually have medium R&D capabilities and manufacturing capabilities, while their marketing capabilities are below average. Firms cooperated with users and suppliers to acquire market information to complement with deficiencies in marketing capabilities. Those firms don't adopt open strategy, their internal capabilities are lower than average and their innovation performance is the lowest too.

(4) Firms should select suitable open innovation modes matched with their own internal capabilities

Firms with strong internal R&D capabilities set close relationship with science-based partners can improve innovation performance greatly. Firms with good internal R&D capabilities and medium manufacturing capabilities, cooperation with horizontal connections is beneficial for innovation. Firms with medium internal R&D capabilities, set close collaboration with technology related organizations and value chain partners can significantly improve the innovation performance. Firms cannot blindly open to outside organizations. How to select the suitable partners? It is important for firms to decide whether they can access to complementary resources which is beneficial for innovation from the openness.

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