A study on mechanism of environmental protection industry innovation under open innovation - the intermediary effect based on the enterprise network dynamic capability

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Abstract

In the dynamically changing external environment, it is the core issue of enterprise innovation strategy that how enterprises maintain a sustained level of innovation by creating their own capabilities. In addition, the open innovation proposed by Chesbrough provides a new way of thought for innovation management. This essay constructs conceptual models of several sets of variables relationships between environmental protection industry innovation performance and external innovation resources, which is based on 85 environmental protection enterprises as the questionnaire objects and a path analysis of the model is conducted. The results show that the cooperation with horizontal and vertical enterprises can significantly affect innovation performance only by virtue of the intermediary effect of the enterprise network dynamic capability, and government-industry-academy-research cooperation can directly improve innovation performance. Mechanistic study not only reveals that the joint action by external innovation resources and network dynamic capabilities can influence the innovation and motivation of environmental protection enterprises, but also reflects that a major source of environmental protection innovation is the internal resources. This provides theoretical guidance for enterprises to effectively implement the open innovation strategy in the innovation practice.

Keywords: open innovation, environmental protection industry, innovation performance, network dynamic capability

1 Introduction

In the knowledge innovation era, technical innovation is the key to enterprises' sustainable development. However, the market requirements and high uncertainty of the environment gradually make the innovation a complexity activity, and this urges the transformation from the traditional closed innovation model to a new open innovation model. Under the current situation of the global innovation, technical innovation of environmental protection (hereinafter referred to as EP) enterprises is facing opportunities and challenges. With the gradually increasing national focus on environmental pollution, ecological destruction and comprehensive utilization of resources, EP enterprises also introduce more new technologies, new products and new concept to satisfy the requirements of the country and the society for environmental protection, which greatly promotes the technical innovation level of EP enterprises. However, there are still many problems in such enterprises' technical innovation. Most EP enterprises are not capable to take the initiative for high-level innovation. Compared with other enterprises, internal research and development of such environmental protection enterprises are of more uncertainty mainly in: uncertainty of the achievement of the R &D goals, uncertainty of the business application of final products, skills and technologies, uncertainty of the project profitability. For the purpose of solving these problems, this essay adopts the Chesbrough open innovation theory based on strategical alliance theory [1], that is, to obtain innovation resources outside the enterprises to make up for the inadequacy of innovation resources and capability, to decrease the uncertainty in R & D process and of the results, so as to enhance the enterprises' innovation level.

Open innovation comprehensively utilizes the marketed channels inside and outside enterprises to serve the innovation activities and coordinates the internal and external resources to create innovation ideas, so as to realize the innovation activities in the shortest time and at the least cost. Therefore, open innovation is a dynamic process of synergy, interaction and integration of various elements. Open innovation model means that the enterprises will carry out little independent innovation, but cooperate with horizontal enterprises and vertical enterprises and base on the government-industry-academy-research cooperation to obtain new products, skills, technologies and ideas. Meanwhile, acquisition and integration of external innovation elements require the enterprises to be equipped with some Internet dynamic capability. And the Internet dynamic capability requires a flexibly organization and cooperation by the enterprises. With the open innovation as a new model of enterprises innovation activities, the enterprises now can A more effectively integrate innovation resources among the social resources, without any needs to enter into formal.

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With the rapid development of national economy and increasing EP investment in our country, as well as policies and measures formulated by the country to encourage development of EP industry, the environmental protection industry experiences a rapid development. However, compared EP enterprises with other countries such as America, Japan and Finland, the EP enterprises in China are characterized by small size, insufficient R & D funds, low level of opening, weak capability of resource integration and lack of technical personnel, which are far from requirements of EP enterprises as the technology-intensive and capital-intensive enterprises and constrains the innovation level of EP industry. Research on innovation of EP industry in existing literature mainly focuses on policy and market. For example, Luo Jianhua proposes to promote innovation of EP industry from the aspect of policy [2]; Fu Tao indicates the swift of environmental technology innovation application from engineering, capitalization and marketization to industrialization [3]; Jiang Hongqiang and Zhang Jing proposes to promote the industrialization of EP high and new technology through the EP technology system combining industry, academy and research [4]; Dong Ying indicates that the government shall deeply understand regularity of R&D activities in EP industry and the confronting problems, establish virtuous investment mechanism for the industry innovation and gradually improve and gradually improve the Intermediate Organization of technology [5]. These researches are carried out rarely from the aspect of enterprises' micro-mechanism. EP industry has transited from the "government-led and regulations driven phase" and "mandatory institutional change and trying to utilize market mechanism phase" to "inducing institutional change and deepening development phase", therefore we should pay more attention on the independent innovation of enterprises in local markets. However, this is contradictory with the difficulty of EP enterprises to carry out independent innovation on their own, and Chesbrough open innovation model provides an idea for development of EP industry. This essay analyses the action mechanism of innovation performance of EP industry and provides theoretical guidance for EP enterprises to utilize internal and external innovation resources in accordance with their own network properties with external innovation resources as input variable, innovation performance as output variable, process from input variable to output variable as a black-box and based on the enterprise network dynamic capability as the intermediary.

2 Research model and hypothesis for open innovation mechanism

2.1 THEORETICAL MODEL

Through combing relevant domestic and foreign literature and documents and inspecting the EP enterprises' development practices, it is found that the innovation capability is the motive force for sustainable development of EP industry. With the increasing emphasis on environment protection by the country and the society, requirements for EP products and technology put increasing pressure on innovation. Insufficiency of fund and uncertainty of market profitability make the independent innovation increasingly difficult. Therefore it is necessary for EP enterprises to implement open innovation strategy to make up for the inadequate innovation capability. Open innovation emphasizes the utilization of external market-oriented channels and coordinates external innovation resources to achieve spill over of technology and knowledge through cooperation with horizontal enterprises and vertical enterprises and government-industry-academy-research cooperation, and absorb, allocate and integrate externally acquired resources with the aid of enterprise network dynamic capability, so as to accelerate the innovation of EP enterprises.

From the aspect of enterprise resource theory, discuss the role of enterprise network dynamic capability as an intermediary of external innovation resources and innovation performance. Thus, a resource meaning is attached to external innovation resources and enterprise network dynamic capability and innovation. External innovation resources are the main source of innovation elements of open innovation strategy and the efficiency of the absorption, allocation and integration of external resources by the enterprise relies on network dynamic capability. Network dynamic capability restricts the scope of external resources to be acquired by enterprises and intensity of inter-organizational exchange, which will necessarily affect the efficiency of innovation accumulation through external integration approach and then further affect the innovation performance [6]. However, for open innovation, during the process of acquiring external resources, the synergy with internal innovation resources should be emphasized. Lack of acquisition of external innovation resources makes closed innovation, while lack of cultivation of internal innovation resources makes it difficult for enterprises to own technologies and products of independent intellectual property rights. Therefore, during the research on the effect of innovation performance in EP industry under the open innovation, the innovation performance serves as the explained variable, cooperation with horizontal enterprises and vertical enterprises, government-industry-academy-research cooperation and internal resources as the explanatory variable, and enterprise network dynamic capability as the intermediary variable. Construct the

conceptual model under this essay in accordance with above analysis (see, Figure 1).

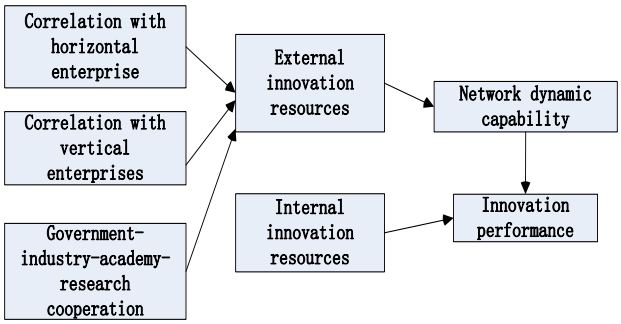

FIGURE 1 Conceptual model of open innovation mechanism and action path

2.2 HYPOTHESIS

2.2.1 Leading logic and hypothesis of external innovation resources and innovation performance

Enterprises' innovation not only needs to utilize internal resources, but also coordinate external resources. Enterprises searches for, identifies and absorbs innovation resources from outside and establishes the innovation relationship network with horizontal and vertical enterprises and government-industry-academy-research cooperation through the construction of external innovation resources searching mechanism, so as to acquire new resources, technologies, skills and concepts necessary for enterprises and ultimately promotes the improvement of innovation performance. Therefore, external innovation resources are the main channel for enterprises to acquire new technologies, markets and knowledge and the original point of innovation sources [7]. As to the dimension of external innovation, scholars divide, based on the prospective of innovation resources, the external innovation elements into horizontal cooperative enterprises, vertical cooperative enterprises, special technical organizations and other organizations which include government and venture capital enterprises [8]. EP industry is of the characteristics of special industry, and is the kind of industry form integrating policy-guiding, capital-intensive and technology-intensive. Thus government policies and measurements, venture capital enterprises and technical agencies are critical to EP enterprises. This essay divides the external innovation resources into horizontal enterprise cooperation, vertical enterprise cooperation and government-industry-academy-research cooperation in accordance with characteristics of external resources and the position in the industrial structure and based on the specialty of EP industry.

Many scholars analyse the impact of open innovation performance from the perspective of complementarities of specific cooperative object resources. Horizontally, Ritala uses game theory model to demonstrate that higher performance can be achieved by cooperation with competitive enterprises than simply by competition, and in high-tech industries, cooperation with competitors will create breaking through innovation and incremental innovation [9]. Hagedoorn believes cooperation with complementary enterprises will realize the sharing of complementary innovation resources and innovation risks and cost, so as to shorten innovation cycle and improve innovation performance [10]. Vertically, Clark points out that enterprises can improve innovation performance by integrating technologies and standard resources of upstream providers and market resources of downstream customers in the vertical industrial chain [11]. For government-industry-academy-research cooperation, Laursen & Salter point out that intermediary organizations are capable to effectively solve the problems of diseconomy and asymmetry of information in and out of markets, and reduce the information search cost and transaction expense in market, policy, technology, funds and others, so as to improve enterprises' motivation of innovation [12]. Based on above analysis, it is hypothesized as follows:

H1a: positive correlation between innovation performance and cooperation with horizontal enterprises;

H1b: positive correlation between innovation performance and cooperation with vertical enterprises;

H1c: positive correlation between innovation performance and government-industry-academy-research cooperation.

2.2.2 Leading logic and hypothesis of external innovation resources and enterprise network dynamic capability

Selection process of external innovation resources by enterprises is not static, but varying with the change of factors such as development phase, innovation awareness and innovation capability. Enterprise network dynamic capability requires that the network, resources and capabilities of enterprises shall be able to cope with the change of external innovation environment, so as to acquire favourable external resources. Tether believes enterprises are comparatively in the external innovation environment and innovation process persists throughout the innovation system consisting of several enterprises [13], which requires enterprises be equipped with the capability to manage and coordinate innovation resources outside enterprises, that is, enterprise network dynamic capability [14]. Therefore, network dynamic capability, in essence, is closely connected with dynamics of external innovation environment. This is further confirmed by Gulati who points out that constant changing of external innovation environment objectively enhances the cooperation of technologies, knowledge and ideas between enterprises and external organizations such as providers, users and competitors. Certian network dynamic capability is required for enterprises to transform the technical spillover generated by such cooperation into actual innovation performance [15]. It is hypothesized as follows based on above analysis:

H2a: positive correlation between enterprise network dynamic capability and cooperation with horizontal enterprises;

H2b: positive correlation between enterprise network dynamic capability and cooperation with vertical enterprises;

H2c: positive correlation between enterprise network dynamic capability and government-industry-academy-research cooperation.

2.2.3 Leading logic and hypothesis of enterprise network dynamic capability and impact of innovation performance

In the fiercely competitive environment, enterprises need introduce external innovation resources constantly to make up the shortage of internal resources to improve innovation capability. And the efficiency to acquire innovation resources from external environment depends on the network dynamic capability of enterprises. The network dynamic capability is utilized to acquire, integrate and reallocate internal and external resources and cope with rapidly changing environment. Therefore, competitive advantages of enterprises are derived from network dynamic capability. Only by rapidly acquiring external innovation resources based on development level, innovation level and market environment, can enterprises effectively develop new products to satisfy various market requirements [16]. It is hypothesized as follows based on above analysis:

H3a: positive correlation between enterprises innovation performance and network dynamic capability.

Combining the above 3 groups of correlation analysis of external innovation resources and innovation performance, external innovation resources and network dynamic capability, and network dynamic capability and innovation performance, it is hypothesized as follows:

H3b: Network dynamic capability plays an intermediary role in the process of external innovation resources' positive impact on innovation performance.

3 Research design

3.1 MEASUREMENT OF VARIABLES

In innovation performance correlation model of EP industry under open innovation, measurement of variables of cooperation with horizontal enterprises and vertical enterprises, government-industry-academy-research cooperation, network dynamic capability and innovation performance. As these variables cannot be objectively and quantifiably measured, the 5-Liked Scale is adopted for subjective scoring in this research. Score of 1-5 is used to refer to the level of compliance of items from complete non-compliance to complete compliance. Based on reference, expertise and on-site investigation and research, this research adopts several items of variables for measurement.

In this research, measurement of cooperation with horizontal enterprises in external innovation resources is mainly according to Dorsey's definition of horizontal enterprises as enterprises and organizations in the same link of market system [17] as well as Chen Yufen and Chen Jing's division of horizontal enterprises [8]. It is adjusted based on broad meaning of EP industry. Consequently, 2 items of cooperation with competitive enterprises and cooperation with complementary enterprises with total 6 sub-items are determined. For the measurement of cooperation with vertical enterprises, 2 items of providers and customers with total 6 sub-items are determined based on Harabi's verification by virtue of statistic data that 84% of emerging enterprises carry out cooperation and R&D with customers or providers in vertical industrial chain direction selection [18], Liu Wei's analysis of vertical dimension in external innovation resources [19] and empirical analysis. For measurement of government-industry-academy-research cooperation, 3 items of academy, government and intermediary organization with 9 sub-items are determined based on Kong Xianghao's "Four Wheel Driven" structure model of synergy innovation for government-industry-academy-research cooperation [20], Chen Hongxi's viewpoint that academy, industry and university relationships are the three helices of innovation network [21] with communication as its core during the analysis of government-industry-academy-research cooperation model and the development phase of EP industry.

Measurement of enterprise network dynamic capability refers to the division of enterprise network capability dimensions by Damanpour F & Gopalakrishnan [22], and is adjusted based on research by Xin Qing and Yang Huixing [23]. Acquirement of external innovation resources is derived from identification of new market requirements and cognition of new technical capability; screen and assess items based on the enterprises' own resources stock and innovation level, with the standards of assessment including that there are market requirements for innovation results, enterprises are capable to carry out innovation activities and the economic feasibility of the innovation process; after the screening, transform and integrate the external innovation resources inside the enterprises to obtain network dynamic capability and achieve the constant improvement of organizational innovation capability. Based on above analysis, this essay constructs the theoretical measurement scale of enterprise network dynamic capability from three dimensions of resources searching identification, screening and assessment and transformation with 9 sub-items.

As to the measurement of innovation performance, Lichtenthaler's two items of utilizing the chance to enter new market and improving enterprises' technical level are adopted to measure the open innovation performance [24]. Cai Ning and Yan Chun points out that innovation performance is a multi-dimension structure [25], however, assessment of innovation performance in current researches emphasizes on the financial perspective

excessively. Lichtenthaler advises that enterprises should take the factor of strategic motive which cannot be neglected into consideration besides material rewards during the implementation of open innovation strategy [26]. Based on above analysis, this essay identifies 6 sub-items to construct theoretical measurement scale of innovation performance, including success rate of new projects, quantity of new products, quantity of new patents, innovation culture, leading posture of innovation management capability and skills.

To verify the effectiveness of the scale, this research carries out a pre-research before the formal questionnaire. T test is performed for key variables (average) of pre-research and formal questionnaires, and there is no significant difference. Meanwhile, carry out correlation analysis of various indicators of pre-research and formal questionnaires, and the results show significant correlation, that is, the answers by objects of research are effective.

3.2 SAMPLING

This research is targeted at EP enterprises and distributes and collects questionnaires mainly through the following 3 channels. The first channel is to utilize social relationships to distribute questionnaires to 33 EP enterprises in 3 provinces of Zhejiang, Jiangsu and Guangdong and distribute 66 questionnaires to the targeted enterprises in the way of E-mail, 59 of which are collected, including 54 effective questionnaires. The second channel is to select 45 EP enterprises and related enterprises from the member list of China Environmental Protection Association during 2012 to 2013. In this way, totally 90 questionnaires are distributed, 43 of which are collected, including 36 effective questionnaires. The third channel is to visit 7 EP enterprises listed in the Demonstration Technical Category for National Advanced Pollution Control (in 2012), deeply interview the technical professionals and managers, and deliver 14 questionnaires on site, all of which are collected. Through above three channels, there are 170 questionnaires are distributed in this research, 116 of which are collected, achieving an overall collection rate of 68.2%. Taking out 12 ineffective questionnaires, there are 104 effective questionnaires suitable for subsequent research, making up 89.6% of the total questionnaires.

3.3 VERIFICATION OF RELIABILITY AND VALIDITY

Firstly, carry out descriptive statistic analysis of variables, including maximum and minimum value, average value and standard deviation (Table 1). For external innovation resources, the maximum average of government-industry-academy-research cooperation is 3.846, which is confirmed in research. EP industry is led by policy and the industrial development is closely related to the environmental protection of the government. As a capital-intensive industry, most enterprises in EP industry are of small size and shortage of funds, so they usually choose to cooperate with high schools and academies on innovation of products and technologies. Average of cooperation with vertical enterprises is also high (M=3.821), which is compliant with development tendency of EP industry, that is, beginning to pay attention to vertical industry integration strategy unifying EP technology, plan project, R&D, construction and operation, strengthening communication and cooperation among various links to effectively extend the industrial chain and obtain competitive advantages of value chain. The minimum average of cooperation with horizontal enterprises is lowest (M=3.519), that means, EP enterprises are usually reluctant to cooperate with competitive or complementary enterprises, so as to avoid the disclosure of core technology capability and consequently affect the competitive advantages. Average of enterprise network dynamic capability (M=3.789) is related to the low utilization of external innovation resources. Most enterprises have not realized the impact of open innovation on enterprises' innovation capability, and the core of enterprises is to introduce technologies, thus leading to high R&D expenses and failure to give consideration to external innovation resources. Average of innovation performance is 4.029, which means, the innovation performance is at a comparatively ideal position and the EP industry has developed from government-leading phase to combination of government and market phase. Polluters' requirements and demands for EP products are increasing which strengthens EP enterprises' motivation for investment and development.

This research studies the internal consistency reliability of the six sub-scales of cooperation with horizontal enterprises, cooperation with vertical enterprises, government-industry-academy-research cooperation, internal resources, network dynamic capability and innovation performance based on Cronbach's a standards. The results of reliability analysis are as follows: Corrected Item-Total Correlation (CITC) value falls within the scope of 0.412 ~ 0.848 and all CITC values are more than 0.35 as required; measurement variable consistency index （Cronbach's a）falls within the scope of 0.649 ~ 0.848, basically compliant with the requirements of Cronbach's alpha to be more than 0.7 [27]. Therefore, under open innovation, internal consistency is high among external innovation resources, network dynamic capability and innovation performance and the scale design complies with the requirements. The results generated in the way of principal components and factors analysis show: the factor load capacity of variables are all more than 0.5 and average KMO is more than 0.7, which show the scales are of comparatively high validity.

TABLE 1 Descriptive statistics and validity analysis of research variables

Variables	Innovation Performance	Cooperation with Horizontal Enterprises	Cooperation with Vertical Enterprises	Government-industry-academy-research Cooperation	Network Dynamic Capability	Internal Resources
Quantity of Sub-items	6	6	9	10	6	4
Minimum Value	3.000	2.330	3.000	2.000	2.670	3.000
Maximum Value	5.000	4.330	5.000	5.000	4.670	5.000
Average	4.077	3.519	3.821	3.846	3.789	4.029
Standard Deviation	0.383	0.440	0.548	0.531	0.415	0.453
CITC	0.724	0.412	0.500	0.591	0.848	0.584
Cronbach alpha	0.788	0.694	0.712	0.791	0.848	0.784
Factor Load Capacity	0.524	0.654	0.773	0.852	0.751	0.839
Effective N	104	104	104	104	104	104

Note: * refers to be significant at the level of 0.05 (both sides), ** refers to be significant at the level of 0.01 (both sides)

3.4 HYPOTHESIS TESTING

This essay adopts path analysis to test the conceptual model as shown in Figure 2. The variables in the model can be divided into three categories: endogenous variables, exogenous variables and unmeasured variables. Cooperation with horizontal enterprises (X_1), cooperation with vertical enterprises (X_2), government-industry-academy-research cooperation (X_3) and internal resources (X_5) are endogenous variables, as they will not be affected by other variables in the model. Network dynamic capability (X_4) and innovation performance (X_6) are exogenous variables as they will be affected by endogenous variables. At last, R_i represents the variables not appearing in the model. Path coefficient P_{ji} is used to show the relation among variables in the model, which is equivalent to the standard regression coefficient β.

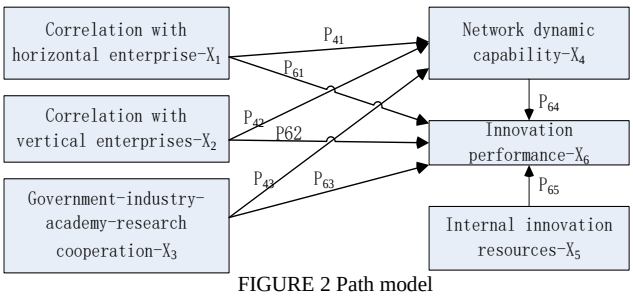

FIGURE 2 Path model

In the section of Hypothesis, we have clarified the impact of cooperation with horizontal enterprises, cooperation with vertical enterprises, government-industry-academy-research cooperation and network dynamic capability on innovation performance. The path coefficient P_{ij} represents the regression coefficient of No. j variable to No. i variable. To get the path coefficient P_{ij}, this essay constructs the following 5 equations in combination of SPSS 19.0 to calculate the adjacent correlation coefficient between paths of external resources acquisition and innovation performance action path and standard regression coefficient of other variables.

$$X_2 = P_{21}X_1 + P_{2u}R_1, \quad (1)$$

$$X_3 = P_{31}X_1 + P_{2v}R_2, \quad (2)$$

$$X_4 = P_{41}X_1 + P_{42}X_2 + P_{43}X_3 + P_{4w}R_3, \quad (3)$$

$$X_6 = P_{61}X_1 + P_{22}X_2 + P_{63}X_3 + P_{6x}R_4, \quad (4)$$

$$X_6 = P_{65}X_5 + P_{6y}R_5. \quad (5)$$

In the above equations, X_1 represents the cooperation with horizontal enterprises; X_2 represents the cooperation with vertical enterprises, X_3 represents government-industry-academy-research cooperation; X_4 represents enterprise network dynamic capability; X_5 represents internal resources; X_6 represents innovation performance; P_{ij} represents standard regression coefficient; R_i represents standard residual. The regression results are shown as follows:

TABLE 2 Regression results

Variables	Path Coefficient	Coefficient Value	*t* Value	Significance (*p* value)
Equation 1: $X_2 = P_{21}X_1 + P_{2u}R_1$				
X_1 Cooperation with Horizontal Enterprises	P_{21}	0.180	1.542	0.126
R-squared =0.023, Adjusted R-squared=0.013, p=0.126				
Equation 2: $X_3 = P_{31}X_1 + P_{2v}R_2$				
X_1 Cooperation with Horizontal Enterprises	P_{31}	0.027	0.266	0.791
X_2 Cooperation with Vertical Enterprises	P_{32}	0.234	2.740	0.007
R-squared =0.073, Adjusted R-squared=0.055, p=0.022				
Equation 3: $X_4 = P_{41}X_1 + P_{42}X_2 + P_{43}X_3 + P_{4w}R_3$				
X_1 Cooperation with Horizontal Enterprises	P_{41}	0.174	2.513	0.014
X_2 Cooperation with Vertical Enterprises	P_{42}	0.267	4.723	0.000
X_3 Government-industry-academy-research Cooperation	P_{43}	0.364	6.475	0.000
R-squared=0.534, Adjusted R-squared=0.520, p=0.000				
Equation 4: $X_6 = P_{61}X_1 + P_{22}X_2 + P_{63}X_3 + P_{6x}R_4$				
X_1 Cooperation with Horizontal Enterprises	P_{61}	0.078	1.183	0.240
X_2 Cooperation with Vertical Enterprises	P_{62}	0.086	1.388	0.168
X_3 Government-industry-academy-research Cooperation	P_{63}	0.167	2.154	0.034
X_4 Network Dynamic Capability	P_{64}	0.259	3.127	0.000
R-squared=0.528, Adjusted R-squared=0.505, p=0.000				
Equation 5: $X_6 = P_{65}X_5 + P_{6y}R_5$				
X_5 Internal Resources	P_{65}	0.507	7.907	0.000
R-squared=0.480, Adjusted R-squared=0.465, p=0.000				

From above table, there exists correlation between adjacent sequence in conceptual model, and such correlation may be the indirect factor to affect the interaction of variables in next link. Therefore, direct, indirect, implied, and unanalysed effect relationship and correction shall be comprehensively taken into consideration. The indirect impact coefficient in the model means the effect of the variable on other variables to impact innovation performance; implied correlation coefficient should refers to the direct effect of external innovation resources on innovation performance by the aid of network dynamic capability; unanalysed impact coefficient refers to the correlation between external innovation resources which act on network dynamic capability.

TABLE 3 Decomposition of relationship between variables

Variable Combination	Correlation Coefficient	Decomposition of Relationship				Total impact Coefficient
		Direct Impact Coefficient	*Indirect Impact Coefficient*	*Implied Correlation Coefficient*	*Unanalysed Impact Coefficient*	
$X_1 \rightarrow X_2$	R_{12}	P_{21}=0.180				0.180
$X_1 \rightarrow X_3$	R_{13}	P_{31}=0.027				0.027
$X_2 \rightarrow X_3$	R_{23}	P_{32}=0.234				0.234
$X_1 \rightarrow X_4$	R_{14}	P_{41}=0.164			$P_{42}R_{12} + P_{43}R_{13} = 0.058$	0.222
$X_2 \rightarrow X_4$	R_{24}	P_{42}=0.267			$P_{41}R_{12} + P_{43}R_{23} = 0.114$	0.381
$X_3 \rightarrow X_4$	R_{34}	P_{43}=0.364			$P_{41}R_{13} + P_{42}R_{23} = 0.064$	0.431
$X_1 \rightarrow X_6$	R_{16}	P_{61}=0.078	$P_{62}R_{12} + P_{63}R_{13} + P_{64}R_{14} = 0.076$			0.154
$X_2 \rightarrow X_6$	R_{26}	P_{62}=0.086	$P_{61}R_{12} + P_{63}R_{23} + P_{64}R_{24} = 0.116$			0.202
$X_3 \rightarrow X_6$	R_{36}	P_{63}=0.167	$P_{61}R_{13} + P_{62}R_{23} + P_{64}R_{34} = 0.134$			0.301
$X_4 \rightarrow X_6$	R_{46}	P_{64}=0.259		$P_{61}R_{14} + P_{62}R_{24} + P_{63}R_{34} = 0.122$		0.381

As to the verification of relationship between 3 dimensions of external innovation resources and innovation performance, based on the path analysis in Table 3, it is found that cooperation with horizontal and vertical enterprises have significant positive effect on innovation performance (R_{16}=0.154, R_{26}=0.202). However, the observed value consists of two parts, among which direct relationship with innovation performance is not significant (P_{61}=0.078, P_{62}=0.086). Therefore, it is assumed that 1a and 1b are false, that is, the cooperation with horizontal and vertical enterprises cannot directly improve the EP enterprises innovation performance. Government-industry-academy-research cooperation is significantly correlated with innovation performance (R_{26}=0.301, P<0.1) and also significantly correlated in direct relationship. Therefore, it is assumed that 1c passes the validation and government-industry-academy-research cooperation is beneficial to the improvement of innovation performance.

As to the verification of relationship between 3 dimensions of external innovation resources and enterprise network dynamic capability, based on the path analysis in Table 3, it is found that the direct correlation coefficients of cooperation with horizontal and vertical enterprises and

government-industry-academy-research cooperation and network dynamic capability are significant (P_{41}=0.164, P_{42}=0.267, P_{43}=0.364). Therefore, it is assumed that 2a, 2b and 2c are verified, that is, horizontal and vertical enterprises and government-industry-academy-research cooperation have direct positive effect on enterprise network dynamic capability.

As to the verification of relationship between 3 dimensions of external innovation resources and enterprise network dynamic capability, based on the path analysis in Table 3, it is found that enterprise network dynamic capability has significant effect on improvement of innovation performance (P_{64}=0.259, P<0.01). Therefore, it is assumed that 3a is verified.

Verification of enterprise network dynamic capability's intermediary effect in the relationship between external innovation resources and innovation performance: in the above relationship disposition of variables, it is found that indirect impact of cooperation with horizontal enterprises on innovation performance is achieved through the intermediary of network dynamic capability ($P_{64}R_{14}$=0.056). Similarly, indirect impact factors of network dynamic capability on cooperation with vertical enterprises and government-industry-academy-research cooperation are respectively 0.063 and 0.112. External innovation resources have significant positive effect on innovation performance by virtue of enterprise network dynamic capability. Therefore, it can be illustrated that integration levels of external innovation resources have indirect positive impact on innovation performance by improving the enterprise network dynamic capability. Therefore, H_{3b} is verified. Enterprise network dynamic capability plays an intermediary role for external innovation resources to improve innovation performance.

4 Research results and discussion

4.1 RESULT DISCUSSION FOR EXTERNAL INNOVATION RESOURCES AND ACTION MECHANISM OF INNOVATION PERFORMANCE OF ENTERPRISES

4.1.1 Dimension of cooperation with horizontal enterprises

Correlation coefficient between cooperation with horizontal enterprises and innovation performance is 0.154, in which the direct correlation coefficient is only 0.078. The significance probability is 240 > 0.1 and the path relationship is not obvious with path coefficient not significant even under the significance level of 0.1, which shows that there is no direct correlation between cooperation with horizontal enterprises and innovation performance. To test the action mechanism of external innovation resources to innovation performance, in line with research results in the documents at home and abroad, the intermediary variable of network dynamic capability is establishes in this essay. By the action of network dynamic capability, cooperation with horizontal enterprises obtains a significant correlation (R_{16}=0.154, P<0.01) with innovation performance, which shows cooperation with horizontal enterprises is beneficial for the improvement of innovation performance by the action of intermediary network dynamic capability. This conclusion is confirmed by many scholars. Bayona believes cooperation between horizontal enterprises can provide technical combination advantages to achieve coordination effect and R&D scale effect, so as to ultimately achieve the technology breakthrough [28]. Although the cooperation with horizontal enterprises promotes, to some degree, the innovation performance, such effect of promotion is the weakest compared with the effect of cooperation with vertical enterprises and government-industry-academy-research cooperation. This is confirmed by the empirical research. Under the co-effect of policy guidance and market coordination, EP industry has positive externality and polluters do not take the initiative to bear negative externality costs, consequently resulting in big potential demands and small real demands in domestic market. For capital-intensive and technology-intensive EP industry, because of big investment and long payback period, EP industry, in most cases, is not willing to make capital and personnel investment to develop new technologies and new products, but imitates and replicates the existing technologies and products of relevant enterprises, which makes decreasing communication between peers to avoid the disclosure of technologies, information and products.

4.1.2 Dimension of cooperation with vertical enterprises

Correlation coefficient between cooperation with vertical enterprises and innovation performance is 0.202, in which the direct correlation coefficient is only 0.086. The significance probability is 0.168>0.1and the path relationship is not obvious with path coefficient not significant even under the significance level of 0.1, which shows that there is no direct correlation between cooperation with vertical enterprises and innovation performance. However, by the action of network dynamic capability, cooperation with vertical enterprises can achieve an significant correlation (R_{26}=0.202, P<0.05) with innovation performance, which shows that under the open innovation strategy, enterprises will transform the knowledge and technical spillover into innovation elements by improving their own network dynamic capability, so as to maximize the acquisition of external resources and improve the innovation performance. This is confirmed by Deng Yingxiang and Zhu Guilong. They propose that cooperation with enterprises in vertical industrial chain can be beneficiary for the improvement of innovation performance, and network dynamic capability mostly directly acts on searching for, absorbing and integrating new knowledge in vertical industrial chain to be transformed into the innovation elements [29]. Based on the analyses in Table 3, the impact of cooperation with vertical enterprises on network dynamic capability and

innovation performance falls between the horizontal dimension and government-industry-academy-research dimension. It is found in field research that cooperation of EP enterprises and vertical enterprises is beneficiary for acquisition of market information, standards and technical resources, so as to achieve the innovation of incremental products and technologies.

4.1.3 Dimension of government-industry-academy-research

Correlation coefficient between government-industry-academy-research cooperation and innovation performance is 0.301, in which the direct correlation coefficient is only 0.259. The significance probability is 0.000<0.05 and the path relationship is not obvious with path coefficient not significant even under the significance level of 0.05, which shows that there is direct positive correlation between government-industry-academy-research cooperation and innovation performance. This primarily show that government-industry-academy-research cooperation acts directly on innovation, without any need of intermediary of network dynamic capability. This is compliant with the current development status of EP industry, that is, most EP enterprises don't have their own R&D departments due to small size or sufficient network dynamic capability to acquire external innovation resources, therefore in most cases, they will choose to cooperate with academies, designing institutions and public service platforms of government for technical innovation. Empirical results also show that, government-industry-academy-research plays a comparatively important role in innovation performance, mostly because industrialization of technical and scientific R&D and results is of high market risk, while most EP enterprises' low technical R&D makes low conversion ratio of industrialization of technical and scientific R&D results. Therefore, in most cases, EP enterprises will tend to choose government-industry-academy-research cooperation for innovation.

4.2 ANALYSIS OF INTERNAL RESOURCES' EFFECT ON INNOVATION PERFORMANCE

Internal innovation resources manly include R&D investment. A large quantity of empirical researches and the results prove that internal innovation resources have significant positive impact on innovation performance. It is found in this essay that, by the way of path analysis, acquisition of external innovation resources have significant positive correlation with innovation performance with a path coefficient of 0.381, while path coefficient between internal innovation resources and innovation performance is 0.507, which is bigger than that of external innovation resources and innovation performance. This is incompliant with Chesbrough's opinion that the external innovation resources share the same importance with internal resources. This shows that, EP enterprises still implement the open innovation strategy at a low level and make insufficient use of external innovation resources. Veugelers & Cassiman's research shows that, technology-intensive and capital-intensive enterprises are more likely tend to acquire external resources. Open innovation does not mean to give up internal R&D, but to effectively utilize and integrate internal resources of enterprises [30]. Therefore, enterprises not only need the external resources related to basic science, but also depend on their own R&D activities. It is also found in mechanism analysis that internal resources have significant correlation with network dynamic capability, which shows the structure of internal resources of EP enterprises affects the capability to acquire external resources and the improvement of network dynamic capability which can helps more effectively acquire the resources necessary for enterprises and enrich the enterprises' internal resources.

5 Political meaning

This essay constructs the conceptual models between cooperation with horizontal enterprises, cooperation with vertical enterprises, government-industry-academy-research cooperation and internal resources with innovation performance based on the deficiencies in current researches and in line with implementation of open innovation strategy by EP enterprises, and carry out empirical research on internal effect mechanism between variables by questionnaires to 85 EP enterprises. The results reveal that cooperation with horizontal and vertical enterprises require the EP enterprises to be equipped with certain network dynamic capability to improve innovation performance, while government-industry-academy-research cooperation can directly promote the improvement of enterprises' innovation capability. At the meantime, empirical researches also demonstrate that main factor for EP enterprises innovation is internal resources and external innovation resources act only as a supplementary to internal resources. Combing the above analysis results, we can summarize the idea of sustainable development for EP innovation as:

1) During the development process, EP enterprises shall lay emphasis on the construction of multi-layer network structure and can acquire resources from external innovation environment in accordance with different development phases and external environment and in line with their own requirements and capability, reduce the redundancy of network structure, and improve efficiency to absorb external innovation resources.

2) Constantly perfect innovation service system of EP enterprises by establishing new organizations or adjusting the service scope of existed service organizations. The system shall serve not only for the acquisition of external resources, but also for the R&D of internal technologies.

3) EP enterprises establish more extensive social relationship with horizontal competitors or partners, enterprises in vertical industrial chain, agencies,

academies, high schools, governments and financial institutions by establishing information platform.

4) The government can enhance the relations among EP enterprises and extend social network of informal communication by establishing agencies, such as environmental protection associations.

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