



R&D COOPERATION AND ENTERPRISE INNOVATION. ANALYSIS BASED ON CHINA'S MANUFACTURING INDUSTRY

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Abstract

In the context of open innovation, R&D cooperation is an important way to enhance the innovation performance of enterprises. Based on sample survey data from manufacturing production bases in western Shandong Province, China, this paper analyzes and researches on the impact of R&D cooperation on the innovation of Chinese manufacturing enterprises. The study shows that: R&D cooperation has a significant role in promoting the marginal benefit of organizational R&D investment; cooperation between enterprises and suppliers facilitates product innovation input and output, and has a positive role in promoting enterprise innovation; R&D cooperation between enterprises and customers promotes the investment in enterprise product innovation, which helps to improve product innovation to a certain extent; R&D cooperation between enterprises and universities or research institutes $i_{t-1/2}$ improves enterprise innovation performance; R&D cooperation between enterprises and universities or research institutes $i_{t-1/2}$ improves enterprise innovation performance. Improvement of enterprise innovation performance. The conclusion of the study is to emphasize that R&D cooperation is an important source of enterprise innovation, and enterprises should build effective cooperative relationships to achieve continuous innovation.

Keywords: R&D cooperation; innovation investment; firm innovation

1. Introduction

With the profound changes in the economic situation at home and abroad, enterprises need to strengthen R&D cooperation to achieve sustainable development, and the complexity of modern technology makes it necessary to require more knowledge and experience in enterprise R&D and innovation, which prompts enterprises and different organizations to establish R&D cooperation to achieve complementary advantages, benefit sharing, resource sharing and risk sharing. R&D cooperation can reduce the complexity of innovation, reduce costs and risks, increase the likelihood of success of innovation, and realize enterprise innovation as a common purpose of cooperative subjects.

Enterprise innovation is a transformation process from innovation input to innovation output, and the research on R&D cooperation and enterprise innovation is carried out from the following two aspects:

On the one hand, research on the impact of R&D cooperation on enterprise innovation input, enterprise innovation input mainly includes R&D investment, product innovation input and process innovation input, product innovation input includes the input of new product development, the input of existing product improvement, and process innovation input refers to the input of the improvement of production and manufacturing links. A large number of studies have shown that there is a significant positive correlation between R&D cooperation and R&D investment, the more enterprises involved in cooperation, the greater the R&D investment, and the diversified types of R&D cooperation, mainly between enterprises and suppliers, competitors, customers, universities, research institutions, etc. Most scholars pay more attention to the impact of different types of R&D cooperation on the innovation investment of enterprises.

On the other hand, the relationship between R&D cooperation and innovation output, the enterprise's innovation output mainly includes the product value brought by new products, low production cost and high labor productivity brought by process innovation. Becker and Dietz believe that the enterprise's R&D cooperation behavior enhances the provision of innovation output with a greater likelihood (Becker and Dietz, 2004); Ma Yanyan et al. point out that the breadth of R&D cooperation has an inverted U-shaped relationship with firms' new product output, while the depth of firms' R&D cooperation has a U-shaped relationship with new product output (Ma Yanyan et al., 2014); Wang Longwei et al. further point out that the role of R&D cooperation on innovation output is affected by different cooperative governance mechanisms among organizations (Wang Longwei et al., 2011), and similarly scholars have focused on the impact of the type of R&D cooperation on firms' innovation output. Aschhoff and Schmidt argue that cooperation between firms and competitors can reduce firms' production costs, and cooperation with universities can increase the output of product innovation (Aschhoff and Schmidt, 2008); Belderbos et al. show that firms' cooperation with suppliers and competitors can increase firms' labor productivity, and cooperation with universities and competitors can increase the share of sales of new products (Belderbos et al, 2004).

In short, some literatures directly study the relationship between R&D cooperation and innovation output, some literatures study the mechanism of R&D cooperation's impact on firms' innovation output, explore the impact of R&D cooperation on innovation inputs, and unravel how R&D cooperation affects innovation outputs, but do not explore the impact of R&D cooperation and its types on firms' innovation inputs and outputs. Given the shortcomings of related studies, this paper utilizes a sample of manufacturing firms to further explore the impact of R&D cooperation on firm innovation.

2. Methodology

This paper analyzes and discusses the impact of R&D cooperation on innovation input and innovation output of enterprises. The R&D cooperation of enterprises includes horizontal cooperation (including the cooperation between enterprises and competitors), vertical cooperation (including the cooperation between enterprises and suppliers and customers) and social

cooperation (including the cooperation between enterprises and colleges and universities and research institutions), and enterprises adopt different forms of R&D cooperation to produce different impacts on different types of innovation input and output. Therefore, the impact of the type of R&D cooperation on firms' innovation inputs and outputs is further explored.

This paper adopts a sample survey of manufacturing enterprises, selecting sample enterprises in the western special vehicle industry base of Shandong Province, sampling 90 surveyed enterprises, deleting 15 unqualified questionnaires, and finally obtaining 75 qualified samples. The detailed questionnaire in this paper, which contains a wealth of information about the enterprise, provides a better opportunity to study the R&D cooperation of the enterprise and enterprise innovation.

This questionnaire sets 2 topics from the perspective of R&D investment: (1) Do enterprises cooperate in R&D? (2) What is the ratio of enterprise R&D investment to sales? Setting 1 question from the perspective of the type of R&D cooperation: (3) What are the main types of enterprise R&D cooperation? Set 2 questions from the perspective of innovation input and innovation output of enterprise-supplier cooperation: (4) Does enterprise-supplier cooperation promote product innovation investment? (5) Does firm-supplier cooperation promote product innovation output? Innovation inputs and innovation outputs of firm-customer cooperation Setting 2 topics: (6) Does firm-customer cooperation promote product innovation inputs? (7) Does enterprise-customer cooperation promote product innovation output? Innovation inputs and innovation outputs of firms' cooperation with universities and research institutes set 2 topics: (8) Does firms' cooperation with universities and research institutes promote product innovation inputs? (9) Does cooperation between firms and universities and research institutions promote product innovation output?

2.1 Investment in R&D

(1) Frequency of whether firms collaborate on R&D

Table 1

Frequency of whether firms collaborate on R&D	Frequency	Percent	Effective percentage	percentage
Yes	64	85.3	85.3	85.3
No	9	14.7	14.7	100
Total	75	100.00	100.00	

As can be seen from the above table, the percentage frequency of R&D cooperation by enterprises is 85.3%, which shows that enterprises have recognized the current fierce market environment, it is increasingly difficult to improve enterprise innovation performance through independent R&D, and enterprises need to establish R&D cooperation relationships with different organizations.

Frequency of companies' R&D investment-to-sales ratio

Table 2

Frequency of corporate investment-to-sales ratios	Frequency	Percent	Effective percentage	percentage
More than 10%	2	2.7	2.7	2.7
8%-10%	47	62.7	62.7	65.4
6%-8%	12	16.0	16.0	81.4
3%-5%	6	8.0	8.0	89.4
Below 3%	8	10.6	10.6	100
Total	75	100	100	

From the above table, it can be seen that the ratio of enterprise R&D investment to sales accounted for more than 6% accounted for 81.4%, which shows that R&D cooperative enterprises are more willing to carry out R&D investment, and obtain more innovation output through R&D investment.

2.2 Types of corporate R&D cooperation

(1) Frequency of types of corporate R&D cooperation

Table 3

Frequency of types of corporate R&D collaborations	Frequency	Percent	Effective percentage	percentage
Cooperation with suppliers	26	28.9	28.9	28.9
Cooperation with customers	29	32.2	32.2	61.1
With universities and research institutes	35	38.9	38.9	100
Total	90	100.00	100.00	

As can be seen from the above table, the proportion of cooperation between enterprises and suppliers, enterprises and customers, and enterprises and universities and research institutes are comparable, respectively 28.9%, 32.2% and 38.9% are relatively large, and the same enterprise not only cooperates with the suppliers but also may cooperate with the customers or the universities and research institutes at the same time. This shows the diversification of enterprise R&D cooperation.

2.3 Firm-supplier cooperation

(1) Whether firm-supplier cooperation promotes the frequency of product innovation inputs

Table 4

Whether firm-supplier collaboration promotes the frequency of product innovation inputs	Frequency	Percent age	Effective percentage	percentage
Yes	24	92.3	92.3	92.3
No	2	7.7	7.7	100.00
Total	26	100.00	100.00	

As can be seen from the above table, it is believed that the cooperation between enterprises and suppliers to promote product innovation inputs accounted for 92.3%, which shows that the cooperation between enterprises and suppliers promotes the innovation of intermediate goods, and the innovation of intermediate goods drives the investment in product innovation of enterprises.

(2) Whether firms' cooperation with suppliers promotes the frequency of product innovation outputs

Table 5

Whether firms' cooperation with suppliers promotes the frequency of product innovation outputs	Frequency	Percent age	Effective percentage	percentage

Yes	23	88.5	88.5	88.5
No	3	11.5	11.5	100.00
Total	26	100.00	100.00	

As can be seen from the above table, the percentage of those who believe that the cooperation between enterprises and suppliers promotes the output of product innovation is 88.5%, which shows that in the process of innovation inputs, the possibility of product innovation is greatly increased by enterprises through "learning by doing", which further increases the output of product innovation.

2.4 Firm-Customer Collaboration

(1) Whether firm-customer collaboration promotes the frequency of product innovation inputs

Table 6

Whether customer collaboration promotes the frequency of product innovation inputs	firm-	Frequen	Percent	Effective	percentage
	cy	cy	age	percentage	
	the				
	of				
	product				
	innovation inputs				
Yes	27	27	93.1	93.1	93.1
No	2	2	6.9	6.9	100.0
Total	29	29	100.0	100.0	

From the above table, it can be seen that the frequency of the belief that the cooperation between the enterprise and the customer to promote the product innovation investment is 93.1%, which shows that the enterprise and the customer R & D cooperation reduces the learning behavior after the delivery of the enterprise, so that the cooperation between the enterprise and the customer is more usual, and increases the investment in product innovation.

(2) Whether firms work with customers to promote the frequency of product innovation outputs

Table 6

Whether firms work with customers to promote frequency of product innovation outputs	Frequency	Percent age	Effective percentage	percentage
Yes	25	86.2	86.2	86.2
No	4	13.8	13.8	100.0
Total	29	100.0	100.0	

As can be seen from the above table, it is believed that the frequency of cooperation between enterprises and customers to promote the output of product innovation accounted for 86.2%, which shows that the customer as the ultimate user of the enterprise's products, the customer understands its own needs, and the cooperation between the two reduces the risk of product innovation, enhances the recognition of the new product, and increases the share of sales.

2.5 Firms' cooperation with universities and research institutions

(1) Whether firms and universities and research institutions promote the frequency of product innovation inputs

Table 8

Whether firms and universities and research institutions promote the frequency of product innovation inputs	Frequency	Percent age	Effective percentage	percentage
Yes	29	82.9	82.9	82.9
No	6	17.1	17.1	100.0
Total	35	100.0	100.0	

From the above table, it can be seen that the frequency of the opinion that enterprises cooperate with universities and research institutes to promote product innovation inputs accounted for 82.9%, which shows that enterprises are the main body of scientific and technological innovation, and universities and research institutes are the main body of knowledge innovation, and that the two collaborate in research and development to promote the synergistic innovation of science and technology and knowledge.

(3) Whether firms' cooperation with universities and research institutes contributes to the frequency of product innovation outputs

Table 9

Whether firms' cooperation with universities and research institutes contributes to the frequency of product innovation outputs	Frequency	Percent	Effective percentage	percentage
Yes	28	80.0	80.0	80.0
No	7	20.0	20.0	100.0
Total	35	100.0	100.0	

As can be seen from the above table, the frequency of the belief that enterprises cooperate with universities and research institutes to promote the output of product innovation accounted for 80.0%, which shows that with the popularization and application of research results, universities and research institutes have to pay attention to the transformation of research results.

2. Results

Through the organization of the questionnaire, found that the percentage frequency of enterprises to carry out R & D cooperation is 85.3%, enterprise R & D investment and sales ratio accounted for more than 6% of the ratio of 81.4%, that enterprises and suppliers to promote cooperation in product innovation investment accounted for 92.3%, that enterprises and suppliers to promote cooperation in product innovation output accounted for 88.5%, that enterprises and customers to promote cooperation in product innovation investment of 93.1%, 86.2% that enterprises cooperate with customers to promote product innovation output, 82.9% that enterprises cooperate with universities and research institutes to promote product innovation input, and 80.0% that enterprises cooperate with universities and research institutes to promote product innovation output.

4. Discussion

A firm's R&D investment consists of the firm's expansion margin and its intensification margin, with the expansion margin being whether the firm invests in R&D and the intensification margin being how much the firm invests. R&D cooperation affects R&D investment through cost sharing, R&D investment promotes innovation, and corporate innovation is characterized by high risk, high cost, and high uncertainty; therefore, R&D investment generally occurs in large firms, and SMEs invest relatively little in R&D. If enterprises invest in R&D through cooperation, R&D costs will be shared and R&D risks will be dispersed, which will motivate enterprises to invest in R&D. Along with the deepening of cooperation, the cooperation governance mechanism will be improved, the problems of opportunistic behavior and transaction costs arising in the process of cooperation will be solved, and the level of R&D investment of enterprises will be improved. Therefore, compared with enterprises without R&D cooperation, enterprises with R&D cooperation are more likely to make R&D investment and the level of R&D investment of enterprises is higher.

Complementarity of advantages is an important driving force for R&D cooperation pursued in enterprise innovation, and the advantageous information of partners' products and processes is obtained by other partners through spillover effect in cooperation, so that the enterprise obtains experience and knowledge that it did not have before, which lays the foundation for enterprise innovation, and then promotes the enterprise's innovation investment. Along with the increase in investment, the learning ability, digestion and absorption capacity of the enterprise is further strengthened, which improves the possibility of innovation success. Therefore, compared with enterprises without R&D cooperation, enterprises with R&D cooperation are more likely to carry out product innovation, process innovation and obtain more innovation output.

Types of R&D cooperation include with suppliers, customers, universities, etc. Different cooperation partners have different characteristics and advantages. Suppliers provide intermediate products for enterprises, and cooperation between enterprises and suppliers can promote the innovation of intermediate products, or generate new intermediate products, or improve the quality and efficacy of the original products. The innovation of intermediate products further drives the enterprise's investment in product innovation, and the enterprise further increases its purchasing efforts. Continuous investment forms an atmosphere of "learning by doing" in the enterprise, the possibility of product innovation increases, and the output of innovation increases. The cooperation between enterprises and suppliers promotes the synergy of information from both sides, which forms a positive promotion effect. Therefore, the cooperation between enterprises and suppliers promotes the investment of product innovation and process innovation, and increases the innovation output.

Customers are the users of products. The two carry out R&D cooperation, the enterprise can integrate the professional and technical effectiveness of all parties, reduce the requirements of post-delivery learning, smoothly carry out after-sales, reduce the risk in product innovation, the

recognition of the product increases, the enterprise expands its market share, and the enterprise is more willing to increase its innovation input. Therefore, the cooperation between enterprises and customers prompts enterprises to invest in product innovation and the output of product innovation increases.

The basic research of universities and research institutions emphasizes the exploration of new knowledge, new principles and new methods, while the research of enterprises serves to achieve specific goals, it can be seen that universities and research institutions are the main body of knowledge innovation, and enterprises are the main body of scientific and technological innovation, and both of them carry out cooperation to realize the synergy of knowledge innovation and scientific and technological innovation, and the cooperation between industry, academia and research institutions has a positive impact on the innovation of enterprises. Therefore, the cooperation between enterprises and universities and research institutions promotes enterprise innovation input and increases innovation output.

5. Conclusion

Through the distribution of questionnaires, analysis of questionnaires and discussions, it can be found that: compared with enterprises without R&D cooperation, enterprises with R&D cooperation are more willing to make R&D investment and the level of R&D investment is increasing; enterprises with R&D cooperation are more willing to make product innovation investment, which in turn promotes the output of product innovation; the cooperation between enterprises and suppliers promotes the enterprise's product innovation and process innovation investment and increases the output of innovation output. The cooperation between enterprises and customers prompts enterprises to carry out product innovation inputs, and the output of product innovation increases. The cooperation between enterprises and universities and research institutions promotes enterprises' innovation input and increases innovation output.

The research in this paper is of great practical significance, and the government should consider how to stimulate R&D cooperation among enterprises, promote the culture of cooperation and create a favorable cooperative business atmosphere in the process of policy formulation. The government should strengthen the cooperation between enterprises and universities to promote the transformation of scientific research results in cooperation with enterprises. Enterprises should deeply recognize the benefits of R&D cooperation to the development of enterprises, seize the opportunities of cooperative R&D in a timely manner, realize technological innovation, and then realize enterprise performance innovation.

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