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Cooperative R&D and Technological Innovation Performance between Enterprises: An Empirical Analysis Based on the 2019 World Bank Survey of Kazakhstani Enterprises

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Abstract

Kazakhstani companies have a long-standing problem of low technological innovation performance. With the increasing complexity of technology research and development and the continuous increase of costs and risks, cooperative research and development between enterprises has become one of the important ways of corporate innovation. This article is based on the World Bank 2019 Survey Data of Kazakhstani companies, the propensity score matching method and the generalized propensity score matching method are used to investigate the impact of inter-firm cooperative R&D decisions and the intensity of inter-firm cooperative R&D on the technological innovation performance of enterprises. The research results show that compared with not carrying out cooperative R&D between enterprises, carrying out cooperative R&D among enterprises can significantly improve the technological innovation performance of enterprises; only when the intensity of cooperative R&D between enterprises is at a relatively low level, increasing cooperative R&D between enterprises can significantly improve the technological innovation performance of enterprises, and when the intensity of cooperative R&D is too high, it will not effectively improve the technological innovation performance of enterprises.

Keywords: cooperative R&D; technological innovation performance; knowledge spillover; R&D intensity; R&D alliance

Introduction

In an economic environment where the global division of labor continues to be refined, competition continues to intensify, and the complexity of technological innovation, risks, and costs have risen sharply, the core capabilities of enterprises are becoming more professional, and the degree of external dependence is deepening. Enterprises are gradually moving from going alone to uniting others. The Enterprises have formed a group development. During the 1960s and 1970s, the development of cooperative R&D between enterprises was slow. In the 1980s, with the increasing risks and costs of R&D projects, the continued complexity of scientific and technological development and the shortening of R&D cycles, global enterprises cooperated in R&D. It has begun to appear in large numbers (Hagedoorn, 2002). Cooperative R&D between enterprises has become an important technological innovation method for different enterprises to integrate resources and achieve complementary advantages. By carrying out cooperative R&D between enterprises, enterprises can better obtain external resources and achieve economies of scale and scope. Economy, exert the synergy effect of R&D among enterprises, reduce risks and reduce repeated R&D (Becker and Dietz, 2004).

At present, Kazakhstan's economic growth has entered the stage of "innovation-driven" development. The economic growth model that relies on increasing factor input and then expanding the scale of investment is not sustainable, and scientific and technological innovation is increasingly supporting and leading the economic and social development. Enterprise technological innovation is the foundation of Kazakhstan's economic innovation-driven development. For a long time, while Kazakhstan's scientific and technological innovation investment has increased significantly, the production technology level of Kazakhstani companies is still relatively backward, and most companies are still stuck in low-tech and low-value-added fields. The effectiveness of corporate technological innovation is not obvious. Kazakhstani companies are also facing practical problems such as a shortage of innovative talents and financial difficulties, which hinder the development of corporate technological innovation activities and the improvement of technological innovation capabilities. Overcoming the problem of insufficient corporate innovation capabilities and focusing on improving The performance of enterprise technological innovation is the focus and difficulty of Kazakhstan's economic innovation-driven development. Cooperative R&D between enterprises relieves the inherent constraints of independent innovation of a single enterprise and promotes the integration and optimal allocation of different resources between enterprises, providing new ideas for improving enterprise innovation capabilities. So, can cooperative R&D among enterprises improve the technological innovation performance of Kazakhstani enterprises? In addition, some studies have shown that for improving enterprise performance, the more investment in enterprise R&D is not better than is the investment in cooperative R&D between enterprises more beneficial to improving the technological innovation performance of Kazakhstani enterprises?

Based on the 2019 survey data of Kazakhstani companies by the World Bank, this paper uses the propensity score matching method and the generalized propensity score matching method to investigate the impact of inter-firm cooperative R&D decisions and the intensity of inter-firm cooperative R&D on the technological innovation performance of enterprises. The research results show that compared with the previous carrying out inter-enterprise cooperative research and development, and carrying out inter-enterprise cooperative research and development has significantly improved the technological innovation performance of enterprises. When the intensity of cooperative research and development between enterprises is at a low level, increasing cooperative research and development investment can significantly improve the technological innovation performance of enterprises. While cooperative research and development between enterprises is at a low level. At a higher level, the increase in cooperative R&D investment cannot effectively improve the technological innovation performance of enterprises. The research results of this article have certain reference value for the planning and development of cooperative R&D activities between enterprises.

Literature review

The literature of enterprise cooperative R&D is mainly divided into three categories, namely the influencing factors of cooperative R&D, cooperative R&D model, and cooperative R&D performance effect . The main research content of this paper is to analyze the impact of cooperative R&D between enterprises on the technological innovation performance of enterprises. In the scope of the literature on cooperative R&D performance effects, here we mainly select and comment on the relevant literature that belongs to the scope of corporate cooperative R&D performance effects. Cooperative R&D between enterprises mainly affects the technological innovation performance of enterprises in two ways, direct and indirect.

Cooperative R&D between enterprises has brought supplementary resources, risk cost sharing, and external knowledge spillover. The resource-based theory believes that enterprises can obtain the supplementary resources needed for their R&D through cooperation with other organizations, and realize the sharing of costs and risks (Srholec, 2014). Cooperative research and development can bring about knowledge spillovers outside the enterprise, and enable the enterprise to internalize external knowledge spillovers. D'Aspremont and Jacquemin (1988) constructed a three-stage game model, which believes that when the external knowledge spillover is sufficiently high enterprises' cooperative R&D investment has increased, and the company's equilibrium output has been improved. The indirect effect is mainly manifested in cooperative R&D to improve the efficiency of internal R&D. The relationship between internal R&D and cooperative R&D is complementary or alternative, which depends on the technology, what is needed for innovation is specific knowledge or general knowledge. Alternative internal and external innovation activities make external R&D cooperation bring about a drop in R&D costs and improve the efficiency of enterprise R&D. Complementary innovation activities allow companies to integrate different innovation strategies to increase its innovation output.

However, cooperative R&D by enterprises is not easy, nor is it cost-free. Cooperative R&D faces transaction cost issues, especially in the coordination, management, and control of R&D activities of different participants, such as coordinating different organizational behaviors and integrating complementarity. The assets and resources of the company, and formulate rules and regulations for joint research and development. The selection of partners is also a laborious and time-consuming event, which increases the search cost of cooperative research and development (Srholec, 2014). In addition, cooperative research and development also faces potential research and development risks and information asymmetry problems may bring threats of opportunistic behavior.

Most empirical studies have shown that cooperative R&D between companies can significantly improve the technological innovation performance of companies. Arvanitis (2012) used Swiss company data for empirical analysis, which shows that corporate cooperative R&D has increased the proportion of company's new product sales. Using German company data analysis Later, Aschhoff and Schmidt (2008) also found that cooperative research and development of enterprises increased the sales proportion of new products of enterprises, but the sales proportion of new products imitated by enterprises did not play a positive role. Becker and Dietz (2004) also used German enterprise data. The empirical findings show that corporate cooperative R&D has significantly increased the proportion of new product sales of enterprises. Miotti and Sachwald (2003) used French corporate data, and also found that corporate cooperative R&D increased the proportion of corporate new product sales. Belderbos et al. (2004) used Danish corporate data. After conducting empirical analysis, it was found that corporate cooperative research and development significantly promoted the increase in per capita sales of new products. Peeters and Potterie (2006) used Belgian corporate data and found that collaborative research not only increased the probability of companies applying for patents, but also increased the number of companies applying for patents. Other documents did not find a significant positive relationship between the two. Klomp and Leeuwen (2001) used Dutch enterprise data to conduct empirical analysis and found that cooperative research and development failed to significantly increase the proportion of new product sales. Kemp and Folkeringa (2003) used the Netherlands according to the enterprise data, the conclusion is consistent with Klomp and Van Leeuwen (2001).

Most empirical studies use the proportion of new product sales to characterize the company's technological innovation performance (Arvanitis, 2012). After reviewing relevant literature, Hagedoorn and Cloodt (2002) pointed out that the narrowly defined corporate technological innovation performance refers to the extent to which a company can introduce new inventions. Market, and the broad sense of corporate technological innovation performance covers the measurement of the performance of the firm's technological R&D and product market commercialization stage. Both narrowly and broadly defined technological innovation performance reflect the economic benefits of corporate technological innovation. New The proportion of product sales directly connects innovation activities with market success, reflects the economic benefits of enterprise technology innovation activities, and is a suitable variable reflecting the performance of enterprise technological innovation. Some studies use patents to characterize enterprise technological innovation performance, except that they fail to reflect enterprise technology in addition to the economic benefits of innovation, there are also some improprieties. Whether to apply for a patent is a strategic decision of a company. For some companies that are unwilling to apply for a patent, trade secrets or market leading time is better protection methods. Enterprises such as small enterprises are not capable of applying for patents (Kemp and Folkeringa, 2003).

The limited research by domestic scholars has focused on the impact of corporate cooperative R&D experience, partner diversification, and organizational relationships on corporate technological innovation performance. However, an intuitive question has not yet been analyzed, that is, whether Kazakhstani companies carry out inter-company collaborative R&D to enhance corporate technological innovation performance? In view of this, based on the World Bank's 2019 Kazakhstani Enterprise Survey Data, this paper uses propensity score matching to empirically examine the impact of inter-firm collaborative R&D on enterprise technological innovation performance, provides robust empirical evidence for micro-enterprises in Kazakhstan, and enriches the relevant fields. In addition, most empirical studies have examined the linear impact of corporate cooperative R&D intensity on corporate technological innovation performance. Such analysis potentially assumes that the impact of different corporate cooperative R&D intensity on corporate technological innovation performance is homogeneous and does not consider the heterogeneous influence of different enterprise cooperative R&D intensity. This paper also adopts the generalized propensity score matching method to empirically analyze the heterogeneous influence of different inter-firm cooperative R&D intensity on enterprise technological innovation performance, and rationally plan inter-firm cooperative R&D for enterprises Input to provide reference.

Methodology

Cooperative R&D between enterprises is a strategic behavior of the enterprise, and it is an action taken based on the market environment, operating conditions and business objectives faced by the enterprise. Whether the enterprise makes inter-enterprise cooperative R&D decisions or determines the strength of inter-enterprise cooperative R&D, it is selective bias. If you directly use the least squares method to analyze the impact of inter-firm cooperative R&D decisions and the intensity of inter-firm cooperative R&D on enterprise technological innovation performance, it will lead to the estimation of the correlation coefficient bias. This article will use propensity score matching and generalized propensity score matching methods respectively, to examine the impact of cooperative R&D decision-making and cooperative R&D intensity on enterprise technological innovation performance.

Data description

The sample data we use comes from the World Bank's 2019Kazakhstani Enterprise Survey Data. In 2019, the World Bank surveyed 1,600 companies located in 17 regions, including Nursultan, Almaty and Shymkent cities. The industry types include manufacturing and service companies. The survey content covers basic corporate information, infrastructure, sales and supply, production capacity utilization, innovation and technology, financing, government-enterprise relations, and labor issues. The survey content mainly involves information from 2018 and the period from 2016 to 2018. Compared with other micro-enterprise data, this data has two advantages: one is that the data has relatively comprehensive and rich enterprise technological innovation information, especially information on cooperative research and development; the other is that the data is relatively recent and publicly available micro enterprise data and information content are relatively rich.

Since this article examines the technological innovation performance of enterprises, we first delete the sample of service industry enterprises, and then delete the sample of enterprises whose answers are unclear or omitted by related variables, and get a sample of 974 manufacturing enterprises. Most of the sample enterprises are small and medium-sized enterprises, and more than 90% of them the total annual sales of the company did not reach 3 million US$. Among them, the companies that carried out cooperative research and development between enterprises accounted for 10.24% of the total sample enterprises, and the enterprises that carried out internal research and development accounted for 40.74% of the total sample enterprises. Internal R&D and collaborative R&D between companies are still the behavior of a few companies.

Propensity score matching model setting.

The propensity score matching method is based on a counterfactual inference framework, divides the research objects into treatment groups and non-treatment groups. Also, it matches two sets of samples through observable conditions, and constructs unobservable that can be compared with actual observations To determine the causal effect of the processing behavior, we set up a dual dummy variable to divide the company into a sample of the treatment group that conducts cooperative research and development between enterprises and a control sample that does not conduct cooperative research and development between enterprises, and establish Logit model is as follows:

$$P(D=1 \mid X) = Exp(\beta X)/[1+Exp(\beta X)] \tag{1}$$

In formula (1), D is whether the enterprise is to carry out inter-enterprise cooperative R&D. If it is carried out, it is assigned a value of 1, otherwise it is 0. X is a matching variable. The technological innovation performance of firms performing cooperative R & D is represented by Y1 and Y0, respectively.

According to the estimated propensity score for cooperative R&D between enterprises, the processing group companies are matched, and the conditional independence and common support conditions are established, $E(Y_0 \mid D=1, X=X_i) = E(Y_0 \mid D=0, X=X_i)$ is established, that is, to find potential "counterfactual" control samples for the treatment group samples. Therefore, the difference in technological innovation performance between enterprises and non-enterprise cooperative R&D can be estimated based on the matched samples, namely The average treatment effect (ATT) of participants is expressed by equation (2):

$$ATT = N_1^{-1} \sum_{ieI1} [Y_{1i} - E(Y_0 \mid D=0, X=X_i)] \tag{2}$$

In formula (2), $N_1$is the number of individuals in the matching treatment group, and I_1 is the sample set of the matching treatment group. In addition, if matching is performed against the control group, according to $E(Y_1 \mid D=1, X=X_i) = E(Y_0 \mid D=1, X=X_i)$ condition, the average treatment effect (ATU) of non-participants can be estimated by formula in equation:

$$ATU = N_2^{-1} \sum_{ieI2} [E(Y_1 \mid D=1, X=X_i) - Y_{0i}] \tag{3}$$

In formula (3), N_2 is the number of individuals in the matched control group, and I_2 is the sample set of the matched control group. The average treatment effect (ATE) of the sample can be further estimated, and the formula is (4)

$$ATE = N^{-1}\sum_{ie\{I1\cup I2\}}[E(Y_1 \mid D=1, X=X_i) - E(Y_0 \mid D=0, X=X_i)] \tag{4}$$

In formula (4), $N=N_1+N_2$.

Generalized propensity score matching model setting.

We establish a generalized propensity score matching model to examine the impact of the strength of cooperative R&D between enterprises on the technological innovation performance of enterprises. Similar to the propensity score matching method, the generalized propensity score matching method matches samples through observable conditions. And then infer the causal effect. The difference is that in generalized propensity score matching, the sample has countless choices in a continuous processing interval. By selecting a certain processing level, the corresponding "counterfactual" result can be constructed by matching the sample. Hirano andImbens proposed a three-stage method for estimation (Hirano and Imbens, 2004). We use this method to estimate the dose response function and treatment effect of inter-firm cooperative R&D on enterprise technological innovation performance.

The first stage is to estimate the conditional distribution of the processing variables and fit the generalized propensity score. Due to the large number of biased distributions of zero-valued cooperative R&D intensity among processing variables, we use the fractional Logit model proposed by Papke and Wooldridge (1996) to estimate. After standardizing the processing variables between [0, 1], the maximum likelihood estimation method is used to estimate the equation (5):

$$E(D_i^c \mid X_i) = F(\beta X_i) \tag{5}$$

In formula (5), D_i^c is the inter-firm cooperation R&D intensity of sample i, and Xi is the matching variable. The generalized propensity score R_i^e is fitted after estimation.

The second stage is to expand the result variable to deal with variables D_i^c and generalized propensity score R_i^e multi-order approximation to fit. Multi-order approximation can include D_i^c and R_i^e first, second or third order, you can add or without adding the interactive terms of the two, the form is flexible and diverse (Hirano & Imbens, 2004). In order to better investigate the non-linear relationship between the cooperation R&D intensity and the technological innovation performance of enterprises, we use the second-order approximation and the third-order approximation is used to fit, and cross terms are added, and multiple regressions are used for comparison and insignificant regression terms are eliminated. The regression equation is as shown in equation (6):

$$E(Y_i \mid D_i^c, R_i^e) = \sigma_0 + \sum_{j=1} (\sigma_{1j} D_i^{cj} + \sigma_{2j} R_i^{ej}) + \sigma_3 D_i^c R_i^e \quad (6)$$

The third stage is to estimate the dose-response function and its treatment effect. According to the estimated results of the second stage, the expected mean value of technological innovation performance conditions and the treatment effect for a specific treatment level d are estimated according to formula (7) and formula (8).

$$E(Y_i \mid D_i^c = d) = N^{-1} \sum_i [\sigma_0^e + \sum_{j=1} (\sigma_{1j}^e D_i^{cj} + \sigma_{2j}^e R_i^{ej}(d, \mathrm{X}_i) + \sigma_3^e D_i^c R_i^e(d, \mathrm{X}_i))] \quad (7)$$

$$TE(\Delta \mid D_i^c = d) = E(Y_i \mid D_i^c = d + \Delta) - E(Y_i \mid D_i^c = d) \quad (8)$$

Among them, N is the total number of samples and D is the increase in processing variables. We take d as 20 processing levels with an average interval of 0.05 between [0, 1), and set D to 0.01.

Variable description.

Technological innovation performance data is taken from the "proportion of sales revenue related to the introduction of new products or services by the company in the past three years". Cooperative R&D decision variable data between enterprises is taken from "whether the company has cooperated with other companies in research and development in the past three years" ", if the answer is yes, the value is 1, otherwise it is 0. The data on the enterprise cooperative R&D intensity variable is taken from "the average investment in R&D cooperation between the enterprise and other enterprises in the past three years", and the total sales of the enterprise are de-scaled.

Whether it is propensity score matching or generalized propensity score matching, the aim is to select appropriate matching variables to correct for the selection bias between the treatment group and the control group. We take into account variables that may affect both the treatment variable and the outcome variable. At the same time. On the basis of reference to relevant literature and data availability, the following matching variables are selected:

(1) Absorptive capacity. Stronger absorptive capacity enables enterprises to better internalize external knowledge spillovers, encourage enterprises to carry out cooperative research and development, and data acquisition. Since "in the past three years, did the company have internal R&D expenditure", if it is, assign a value of 1, otherwise it is 0.

(2) The size of the company. The larger the company, the more capable it is to find partners, but at the same time it is also more capable of developing Independent research and development, the data are taken from the "Total sales of enterprises in 2018", taking the natural logarithm.

(3) Export intensity. The higher the export intensity, the stronger the competitiveness and the better the ability to carry out cooperative research and development. The data is taken from "Indirect Export Sales of Enterprises" "Proportion" and "Proportion of direct export sales of enterprises" are obtained by adding the two data and dividing by 100.

(4) Financing constraints. Insufficient funds can hinder companies from developing cooperative research and development. The data is taken from "Does the company have an overdraft account", if the answer is yes, then the value is 1, otherwise it is 0.

(5) The degree of industry competition. The intense pressure brought by the fierce competitive environment can make companies seek cooperative research and development. The data is taken from "impact of informal competition on business operations".

(6) Foreign-funded enterprises. Foreign-funded enterprises are more likely to participate in cooperative research and development, especially the cooperative research and development of foreign enterprise networks. The data is taken from "The proportion of foreign-funded enterprises in enterprise shares". If the proportion exceeds 50%, the value is 1, Otherwise, it is 0.

(7) High-tech enterprise. High-tech enterprises pay more attention to the creation, learning and absorption of knowledge, and are more likely to participate in cooperative research and development. If it is a high-tech industry, the value is 1, otherwise it is 0. The descriptive statistics of variables are shown in Table 1.

Table 1. Variable descriptive statistics.

	Variable name	Average value	Standard deviation	Minimum value	Maximum value
Result variables	Technological innovation performance	11.85	16.365	0	100
Working with variables	Cooperative R&D decisions	0.98	0.299	0	1
	Cooperative R&D strength	0.003	0.021	0	0.5
	Absorption capacity	0.405	0.486	0	1
	Enterprise size	4.563	1.175	1.681	10.298
	Export intensity	0.137	0.256	0	1

Matching variables	Financing constraints	0.321	0.353	0	1
	Degree of competition	0.827	0.757	0	4
	Foreign-funded enterprises	0.039	0.100	0	1
	High-tech companies	0.253	0.328	0	1

Findings and Discussion

Propensity score matching regression results

1. Propensity scores estimation and balance test. We use the Logit model to estimate the propensity score. After matching the sample according to the estimated propensity score, the balance test before and after the comparison is performed. The results are shown in Table 2.

Table 2. Tendency score estimation and matching balance test results.

Variables	Logit estimates	Sample	Mean difference test		Standardized difference test		
			Processing group	Control group	Standard deviation	Decline	t-test
Absorption capacity	1.834*** (0.130)	Before matching After matching	0.731 0.731	0.247 0.731	102.4 0	100	11.05*** 0

Enterprise size	0.124** (0.044)	Before matching After matching	15.530 15.530	15.67 16.403	38.5 6.2	74.2	5.08*** 0.51
Export intensity	0.604** (0.210)	Before matching After matching	0.103 0.103	0.024 0.106	29.9 2.4	80.7	2.35*** 0.1
Financing constraints	0.341** (0.080)	Before matching After matching	0.382 0.382	0.024 0.382	28.1 0	100	3.74*** 0
Degree of competition	0.174*** (0.099)	Before matching After matching	1.015 1.015	0.70 1.046	23.6 -2.4	75	1.80*** -0.17
Foreign-funded enterprises	0.138 (0.246)	Before matching After matching	0.068 0.068	0.032 0.085	14.0 -6.1	41.6	2.99** -0.42
High-tech companies	0.054 (0.199)	Before matching	0.211 0.211	0.142 0.299	14.1 1.2	73.6	1.72* 0.19

<table>
<tr><td></td><td></td><td>After matching</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Propensity score model pseudo R2</td><td colspan="2">LR statistic (p-value)</td><td colspan="2">Average standard deviation</td><td>Decline</td></tr>
<tr><td>Before matching</td><td colspan="2">0.151</td><td colspan="2">147.38*** (0.000)</td><td colspan="2">32.2</td><td rowspan="2">81.1</td></tr>
<tr><td>After matching</td><td colspan="2">0.001</td><td colspan="2">0.76 (0.886)</td><td colspan="2">2.1</td></tr>
</table>

Note: the balance test results are calculated based on the 1: 5 K-nearest neighbor matching method; in the Logit estimation results, the standard error in parentheses; *, **, * * * indicate a significant degree of 10%, 5%, 1%, respectively.

Table 2 reports the 1:5 K-nearest neighbor matching balance test results. From Table 2, it can be seen that after matching, the standard deviation of each matching variable is significantly reduced compared to before matching. The results of the two-tailed t test show that after matching, there is no significant systematic difference in the mean of each matching variable. Overall, the average standard deviation has dropped significantly. Compared with the pre-matching, the estimated propensity score of the sample after the matching shows that the pseudo R2 has dropped significantly and is close to zero. The LR statistics reject the null hypothesis that the matching variables are jointly significant. These indicate that the matching variables after matching have low explanatory power to the model, and there is no systematically significant difference between the matching variables between the treatment group and the matched control group. The lower pseudo R2, greatly reduced average standard deviation, and insignificant LR statistics all indicate that the propensity score model setting aimed at balancing matching variables and eliminating selective bias is more successful.

2. Propensity score matching treatment effect estimation results. We use the 1:5 K-nearest neighbor matching method to estimate the average treatment effect of participants (ATT), the average treatment effect of non-participants (ATU) and overall average treatment effect (ATE) of the sample after matching. Three

processing effects. In order to test the robustness of the estimation results, we also use caliper matching and kernel matching methods to estimate the processing effect. The radius of caliper matching is set to 0.06, and the bandwidth setting of kernel matching uses the default 0.06. At the same time, for a simple comparison, we also list the treatment effect estimation results before matching. The above estimation results are shown in Table 3.

Table 3. Tendency score matching processing effect estimation results.

	Processing effect	Standard error	Significance level	Estimation method
Before matching	12.087	1.327	0.000	OLS
ATT	5.002	1.170	0.008	K-nearest neighbor matching
ATU	10.508	1.637	0.001	K-nearest neighbor matching
ATE	10.049	1.429	0.000	K-nearest neighbor matching
ATT	5.036	1.755	0.000	Caliper matching
ATU	10.728	1.474	0.001	Caliper matching
ATE	10.212	1.310	0.001	Caliper matching

ATT	4.860	1.779	0.000	Nuclear matching
ATU	10.541	1.434	0.000	Nuclear matching
ATE	10.037	1.271	0.001	Nuclear matching

Note: The standard errors of the treatment effects estimated by the propensity score matching methods are all calculated using the 500-bootstrap method.

The results of OLS estimation using the sample before matching show that cooperative R&D between enterprises has significantly improved the technological innovation performance of enterprises. The estimation results of the three matching methods of propensity score matching show that ATT is significantly positive, which also indicates that cooperative R&D between enterprises has significantly improved The technological innovation performance of the enterprise, but the processing effect is greatly reduced compared to the estimated result before the matching. This proves that there is a selective bias in the cooperative R&D decision-making between enterprises. Considering the strategic behaviors performed, the overall performance is that the higher the company's technological innovation performance is, the more likely it is to carry out inter-company cooperative research and development. From the estimation results of the three matching methods of propensity score matching, ATT, ATU, and ATE are all positive, and the significance level reaches 1%. This further verifies that cooperative R&D between enterprises has effectively improved the technological innovation performance of enterprises, which is similar to the results of most empirical studies. Enterprises can seek to cooperate with other enterprises in research and development to obtain what they lack It can absorb knowledge spillovers, break through the limitations of its own innovation capabilities, and achieve higher technological innovation performance.

Generalized propensity score matching regression results

1. Generalized propensity score estimation and balance test. We first use the fractional Logit model to estimate the generalized propensity score, and use the generalized propensity score to adjust and match the sample for balance test. The results are shown in Table 4.

Table 4. Generalized propensity score estimation and matching balance test results.

Variable	Fractional Logit estimates	[0,0.1]		[0.1,1]	
		Mean deviation	t statistics	Mean deviation	t statistics
Absorptive capacity	1.421*** (0.260)	0.023	0.596	-0.026	-0.65
Enterprise size	-0.133** (0.105)	-0.039	-0.122	0.063	0.144
Export intensity	-0.120 (0.497)	0.012	0.186	-0.037	-0.681
Financing constraints	0.156 (0.200)	-0.98	1.056	-0.132	-1.204
Degree of competition	0.161 (0.062)	0.076	0.392	-0.122	-0.632
Foreign-funded enterprises	1.225** (0.554)	-0.001	-0.030	0.012	0.437
High-tech companies	0.789** (0.215)	-0.023	-0.310	-0.088	-1.051

Note: The standard errors are in parentheses; *, **, *** indicate a significance level of 10%, 5%, and 1%, respectively.

We refer to the practice of Hirano and Imbens to perform a balance test, divide the processing level into two sub-intervals [0,0.1] and [0.1,1], and test that the sample after the generalized propensity score adjustment, and matching is in the two sub-intervals The conditional mean difference of each matching variable (Hirano and Imbens, 2004). The conditional mean of each matching variable is calculated based on the mean value of the processing variable in two subintervals. The balance test results show that in the two subintervals, the average deviation of each matching variable is a two-tailed t The test is not significant, indicating that the matching variables are not related to the cooperation R&D intensity between the processing variables after the matching. In other words, there is no systematic difference between the matching variables after the matching, and the generalized propensity score model is set well. The balance condition is met.

2. <u>The generalized propensity score matches the treatment effect estimation result</u>. We choose the second-order approximation of the generalized propensity score and the treatment variable to fit the enterprise's technological innovation performance. After stepwise regression testing, it is found that the cross-term of the generalized propensity score and the treatment variable is not significant, so we do not It is not included in the regression of fitting technological performance. In order to better fit and compare the technological innovation performance of enterprises, we also carried out a third-order approximation estimation. Similarly, the cross term of the generalized propensity score and the processing variable is not significant Figure 1 depicts the dose-response function. From the shape of the dose-response function, whether it is a second-order approximation estimation or a third-order approximation estimation, the dose-response function is roughly in the shape of an inverted U. This shows that with the gradual increase in the intensity of enterprise cooperative research and development, the enterprise's technological innovation performance first improves and then decreases. According to the second-order approximation estimation, the peak of the dose response function appears between [0.3,0.35].

Finally, we estimated the processing effect on the level of cooperative R&D intensity between different enterprises, and the estimated results are shown in Table 5.

Table 5. Generalized propensity score matching treatment effect estimation results.

Significance level	Processing effect a	Processing effect b	Significance level	Processing effect a	Processing effect b
0	1.293*** (0.241)	1.557*** (0.535)	0.50	-0.283 (0.542)	-0.565 (1.006)
0.05	1.023*** (0.167)	1.182*** (0.222)	0.55	-0.452 (0.630)	-0.628 (1.346)
0.10	0.854*** (0.111)	0.849*** (0.135)	0.60	-0.622 (0.729)	-0.669 (1.887)
0.15	0.684*** (0.183)	0.526* (0.244)	0.65	-0.802 (0.808)	-0.660 (1.523)
0.20	0.514*** (0.196)	0.245 (0.346)	0.70	-1.062 (1.088)	-0.639 (2.258)
0.25	0.344* (0.143)	0.105 (0.404)	0.75	-1.131 (1.077)	-0.567 (3.063)
0.30	0.174 (0.211)	-0.101 (0.402)	0.80	-1.301 (1.078)	-0.573 (4.964)
0.35	0.105 (0.288)	-0.299 (0.373)	0.85	-1.471 (1.167)	-0.359 (5.951)
0.40	-0.043 (0.370)	-0.346 (0.412)	0.90	-1.641 (1.260)	-0.204 (6.024)

0.45	-0.113 (0.455)	-0.471 (0.587)	0.95	-1.812 (1.350)	-0.007 (7.182)

Note: *a* is the second-order approximation estimation result; *b* is the third-order approximation estimation result;

parentheses are self-sampling robust standard error, calculated using 100 bootstrap method.

*, **, * * * indicate a significant degree of 10%, 5% and 1%, respectively.

It can be seen from Table 5 that the treatment effect estimated by the second-order approximation gradually decreases with the increase in the level of cooperative R&D between enterprises, which is manifested as a change from the positive treatment effect to the negative treatment effect. The treatment effect estimated by the third-order approximation is presented The trend of first decline and then rebound, but its recovery has not yet reached a positive value. The second-order approximation estimation results show that the intensity of standardized inter-firm cooperative R&D is at the level of 0 to 0.25, and increasing cooperative R&D investment will significantly improve enterprise technology Innovative performance, and the cooperative R&D intensity between standardized enterprises reaches 0.3, that is, when the cooperative R&D intensity between real enterprises reaches about 0.15, the processing effect of the cooperative R&D intensity between enterprises is no longer significant. The third-order approximation estimation results show that the standardized The R&D intensity of inter-enterprise cooperation significantly improves the technological innovation performance of enterprises at the level of 0 to 0.15, and the standardized inter-enterprise cooperative R&D intensity reaches 0.2, that is, when the actual inter-enterprise cooperative R&D intensity reaches about 0.1, The processing effect of cooperative R&D intensity is also no longer significant.

Even though there are some differences between the second-order approximation estimation and the third-order approximation estimation in the treatment effects of inter-firm cooperative R&D intensity, in general, the two are basically the same. Under the situation that the inter-firm cooperative R&D intensity is at a relatively low level, the increase in cooperative R&D investment between enterprises has significantly improved the technological innovation performance of enterprises, and when the intensity of cooperative R&D between enterprises is at a relatively high level, the increase in cooperative R&D investment between enterprises cannot significantly change the technological innovation performance of enterprises. This shows that in When the intensity of cooperative R&D between enterprises is relatively high, companies continue to increase their investment in cooperative R&D with other companies and cannot improve their technological innovation performance. Excessive cooperative R&D investment means that internal R&D is low or even complete Relying on external R&D, this can lead to insufficient internal knowledge accumulation in the enterprise. Excessive R&D investment will also have an "eroding effect" on the accumulation of human capital in the enterprise. Insufficient knowledge accumulation and human capital accumulation in the enterprise both reduce the absorptive capacity of the enterprise Even if companies continue to increase investment in cooperative R&D between companies, they cannot improve their technological innovation performance. In addition, Teece pointed out that the profitability of innovation depends on some complementary capabilities of the company, especially in the marketing and logistics links, which lack these Supplementary capabilities, innovative ideas cannot achieve commercial profitability (Teece, 1986). Most of the sample companies are small and medium-sized enterprises, and their own financial strength and financing capabilities are relatively poor, and excessively high cooperative R&D investment has squeezed the company's use of new products. The funds for other supplementary business activities such as market commercialization have offset the benefits of cooperative research and development between enterprises, thus failing to effectively improve the technological innovation performance of enterprises.

Conclusion

Based on the 2019 survey data of Kazakhstani companies by the World Bank, this paper uses the propensity score matching method and the generalized propensity score matching method to examine the impact of inter-firm cooperative R&D decisions and the intensity of inter-firm cooperative R&D on the technological innovation performance of enterprises. The technological innovation performance of companies that cooperate in research and development is higher than that of companies that do not carry out cooperative research and development between enterprises. This shows that Kazakhstani companies may achieve resource complementarity through cooperative research and development between enterprises, absorb external knowledge spillovers, and share costs and risks. Thus improving the company technological innovation performance, and only when the intensity of cooperative R&D between enterprises is at a relatively low level, increasing the investment in cooperative R&D between enterprises can significantly improve the technological innovation performance of enterprises. That shows appropriate cooperative R&D investment can effectively play the role of cooperative R&D between enterprises. The positive role of the enterprise's technological innovation performance, while excessively high cooperative R&D investment may hinder the accumulation of internal knowledge and human capital of the enterprise, and may also squeeze the capital investment of supplementary business activities such as the commercialization of new products of the enterprise, and cannot effectively improve the enterprise technological innovation performance.

There are three main enlightenments from this article. Firstly, companies should actively seek external R&D partners to carry out inter-company R&D cooperation. At present, the market competition of Kazakhstani companies is becoming increasingly fierce and the risks and importance of technological innovation are becoming more prominent, but at the same time, most companies are trapped in financing. Difficulties and the lack of innovative talents make it impossible to carry out R&D activities on their own. Through collaborative R&D between companies, companies can use external resources, absorb external knowledge, and integrate internal and external R&D activities to improve corporate technological innovation performance and achieve corporate innovation Secondly, enterprises should reasonably plan the investment in cooperative R&D between enterprises. The results of this article show that the intensity of cooperative R&D between enterprises is not as high as possible. Simply increasing the intensity of cooperative R&D between enterprises cannot effectively improve the technological innovation performance of enterprises. In the case of insufficient internal investment and lack of independent absorptive capacity, increasing investment in cooperative R&D between enterprises will cause the internal R&D investment of enterprises to be squeezed and over-reliance on external technology and knowledge, and enterprises cannot effectively internalize external knowledge spillovers. Enterprises should combine their own operations and external needs, under the principle of overall coordination, rationally plan inter-enterprise cooperative R&D investment and integrate internal and external R&D activities. Finally, this article finds that only at a relatively low level of cooperative R&D intensity, companies can enhance inter-enterprise cooperation R&D intensity can significantly improve technological innovation performance. This does not mean that it is undesirable to deepen cooperative research and development between enterprises by increasing the intensity of cooperative research and development. The transaction costs and risks brought by cooperative research and development are the reasons for enterprises to further deepen cooperative research and development between enterprises. Enterprises can reduce the transaction costs and risks brought by cooperative R&D between enterprises by strengthening the construction of cooperative governance mechanisms, and provide an institutional foundation for deepening cooperative R&D between enterprises. Insufficient human capital and knowledge accumulation and insufficient product commercialization capabilities also hinder enterprises deepen cooperative research and development between enterprises. Under the condition of ensuring normal operations, carrying out internal research and development, focusing on the accumulation of internal knowledge and human capital, and strengthening product commercialization capabilities will also help enterprises benefit from deepening collaborative research and development between enterprises.

Enterprise cooperation R&D includes inter-enterprise cooperation R&D and "industry-university-research" cooperation R&D. This paper empirically analyzes the influence of inter-enterprise cooperation R&D on the performance of enterprise technology innovation. Technological innovation requires not only strengthening cooperation between enterprises, but also intellectual support from universities and research institutions, especially in the field of basic research. Cooperative R&D is a multi-subject system engineering. The characteristics of cooperative R&D participants and the external environment may affect the performance of cooperative R&D activities and technological innovation of enterprises. The main characteristics of cooperative R&D participation and external environmental factors are included in the empirical analysis framework. In addition, there is still less empirical research on the cooperative R&D model and the influencing factors of cooperative R&D in Kazakhstan, which needs to be supplemented by more research. These issues may become the focus of further research in the future.

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