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Analysis on the Propensity Score Matching Model of the Industry–University–Research Collaboration and Enterprise Innovation: Based on Radical Innovation and Incremental Innovation Perspective

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Abstract. Based on the data from enterprise economic information database which based on the research and evaluation of the technical ability of enterprises in Liaoning Province, this paper researches the impact of industry-university-research collaboration on different types of enterprises' innovation and its influence paths by using propensity score matching method to control the endogeneity. It is found that industry-university-research collaboration has a significantly positive effect on the radical innovation performance, but does not have a significant effect on the incremental innovation. "R&D investment way" is an important path for industry-university-research collaboration to influence radical innovation, which means industry-university-research collaboration will significantly improve the marginal contribution rate of the enterprise's R&D investment.

1. Introduction

Industry-university-research collaboration (IUR) is considered as an important way to implement China's innovation-driven development strategy. However, does the IUR play its role? And what are the specific impact pathways? These questions still need to further discuss.

Existing relevant studies mainly include two aspects. One is about the relationship between IUR and internal R&D of enterprise, mainly including complementarity theory and substitution theory[1,2]. The other is about the impact of IUR on enterprise innovation performance under the interference of some factors[3,4]. Generally speaking, although many studies believe that IUR can promote enterprise innovation[5,6], there are still some objections[7].

The existing researches have great enlightening significance, but there are still two shortcomings: one is that the endogenous problem is not paid enough attention, and many researches neglect the self-selection of enterprises to participate in the IUR. Secondly, most studies only analyze the impact of IUR on the unilateral innovation performance of enterprises.

This paper tries to make the following advancements: firstly, it specifically analyses the differential impacts of IUR on enterprise radical innovation and incremental innovation. Secondly, by considering the endogenous problem in IUR, this paper makes an empirical study with the method of propensity score matching (PSM), and further explores the ways in which IUR influences enterprise innovation. Thirdly, the empirical study uses the microscopic data from Liaoning Province, which enriches the relevant researches.

2. Hypothesis

2.1 Radical innovation and incremental innovation

On the basis of Schumpeter's concept of "innovation", Henderson and Clark further divided enterprise innovation into radical innovation and incremental innovation according to the difference of innovation degree. Radical innovation is the extension of Schumpeter's "destructive innovation". It refers to the innovation that enterprises have made great breakthroughs in product process, service

and production process. The incremental innovation is the improvement and integration of existing technology, product process, services and production process on the basis of existing knowledge. Radical innovation is a high degree of innovation. But at the same time, this exploratory way of innovation is accompanied by high risk and high costs[8]. In contrast, incremental innovation has a lower degree of innovation, and also lower risks and costs[9]. This innovation is market-oriented and can accelerate the realization of economic benefits by improving products and services.

2.2 Radical innovation and IUR

Innovative resources and capabilities largely determine the success of radical innovation. And universities and scientific research institutions have abundant scientific research resources and outstanding research capabilities. Monjon and Waelbroeck believed that companies engaged in radical innovation were willing to participate in IUR, because IUR would increase the probability of breakthrough innovation[10]. From the perspective of knowledge creation, innovation is a process of learning, creating and solving problems. It requires the collision of different views, the combination of different professional knowledge and the complementarity of different knowledge. This is especially true of radical innovation. IUR has the platform and advantages of integrating heterogeneous resources, so it can improve the probability of radical innovation.

H1: IUR has a positive impact on enterprise radical innovation.

2.3 Incremental innovation and IUR

Extensive information search ability and knowledge tracking and discovery ability are keys to incremental innovation, and IUR is an important channel for enterprises to obtain valuable information. However, unlike radical innovation, incremental innovation focuses on the improvement of existing products and the development of existing markets, avoiding excessive costs and risks and pursuing fast returns. However, in the IUR, universities and research institutes prefer basic research, which is high costs and risks, and usually don't face market demand directly, which makes the transformation efficiency of innovation results low and brings negative effects on the incremental innovation of enterprises.

H2: The positive impact of IUR on enterprise incremental innovation is not significant.

3. Methodology and data

3.1 Data and variables

3.1.1 Data

The data come from the investigation and evaluation of the technological capability of enterprises in Liaoning Province from 2011 to 2013. The samples include 14 cities and 27 industries in Liaoning Province. After sorting out and eliminating invalid samples, 699 valid samples are finally obtained.

Table 1. Definition of variables and descriptive statistical analysis

Variables	Definitions	Avg.	Std.
colla	Participate in IUR, colla=1，otherwise colla=0	0.915	0.279
radinn	Sales revenue of new products	160624.3	3208180
Incinn	The total sales revenue of enterprises	298165.1	3692450
input	R&D investment by enterprises	2050.979	4614.858
human	Human capital investment by enterprises	111.129	156.391
scale	Number of employees of enterprises	130 2.944	3701.112
equipment	Original value of technology development equipment in enterprises	3075.754	12922.87
projet	Number of projects with a R&D cycle of three years or more	3.695	5.218

3.1.2 Variables

The dependent variables are radical innovation performance (*radinn*) and incremental innovation performance (*incinn*). We choose measurement index depending on previous analysis and data

availability. The independent variable is whether to participate in IUR or not (*colla*). The definitions of variables and descriptive statistical analysis are all shown in Table 1.

3.2 Methodology

Basic model. In order to compare with the empirical results after considering endogeneity, this paper first constructs the following basic models:

$$Y_{it} = \beta_0 + \beta_1 colla_{it} + BX_{it} + \varepsilon_{it} \quad (1)$$

Y_{it} includes $radinn_{it}$ and $incinn_{it}$. X_{it} is a group of control variables and ε_{it} is random disturbance.

Propensity Score Matching Model(PSM). Firstly, we constructe the determinant equation of an enterprise whether participate in IUR or not.

$$PS(z) = \Pr[colla = 1 \mid z] = E[colla \mid z] \quad (2)$$

Then we use the following formula to estimate the effect of participating in collaboration:

$$\begin{aligned} ATT &= E[\ln y_{1i} - \ln y_{0i} \mid colla = 1] = E\{E[\ln y_{1i} - \ln y_{0i} \mid colla = 1, PS(z_i)\} \\ &= E\{E[\ln y_{1i} \mid colla = 1, PS(z_i)\} - E\{E[\ln y_{0i} \mid colla = 0, PS(z_i) \mid colla = 1\} \end{aligned} \quad (3)$$

4. Results

4.1 Uncontrolled endogeneity

We first make an empirical analysis of the basic model. It shows that participation in IUR does not significantly promote enterprise's innovation performance in Table 2. This conclusion is inconsistent with the theoretical analysis, which may be caused by uncontrolled selectivity bias, so further analysis is needed.

Table 2. The regression results when uncontrolled endogeneity

Variable	Radical innovation			incremental innovation		
	(1)	(2)	(3)	(4)	(5)	(6)
colla	0.289	0.261	0.191	0.164	0.151	0.140
	(1.74)	(1.59)	(1.17)	(1.38)	(1.28)	(1.17)
Year	N	N	Y	N	N	Y
Region	N	N	Y	N	N	Y
Industry	N	Y	N	N	Y	N
R^2	0.388	0.424	0.450	0.632	0.651	0.652
F value	72.4	27.48	26.04	195.52	69.72	59.72

Note: T statistics are in parentheses; ***、** and * represent the significance level on 1%、5% and 10%.

4.2 Controlled endogeneity by PSM

In this part, PSM is used to control the endogeneity of participation in IUR. The control variables are used as matching variables for PSM, and the Probit model is used for propensity score estimation. In order to satisfy the test of common support hypothesis, 49 samples of non-overlapping regions are deleted. Table 3 shows the results of the independence test. It can be seen that the absolute value of the standard deviation of all variables after matching is less than 20%, indicating that all variables pass the independence test.

Then we evaluate the average processing effects and differences between the treatment group and the control group, Table 4 shows the results. We can see that, when the dependent variable is *radinn*, the ATT value increases to 0.577 after matching and passes the significance test at 10% statistical level. It means that IUR can significantly improve the radical innovation performance of enterprises after controlling the main characteristics of enterprises, H1 is supported. However, when the dependent variable is *incinn*, ATT value is 0.255 and doesn't pass the significance test. It means that IUR doesn't significantly improve the incremental innovation performance of enterprises, H2 is supported.

Table 3. Matching variables and independence test

Variables	Sample	Arg.		Std.(%)
		Treatment group	Control group	
input	Before matching	2.014	2.495	-7.8
	After matching	2.021	2.678	-10.7
human	Before matching	0.110	0.121	-6.7
	After matching	0.109	0.106	1.8
lscale	Before matching	6.312	6.426	-10.3
	After matching	6.290	6.225	5.9
lequipment	Before matching	7.023	6.845	13.9
	After matching	6.985	7.078	-7.3
projet	Before matching	3.926	1.414	60.8
	After matching	2.718	2.819	-2.4

Table 4. The ATT value based on nearest neighbor matching method

Dependent variable	Sample	Treatment group	Control group	ATT	Std.	T value
Radical innovation	Before matching	9.225	9.001	0.224	0.209	1.07
	After matching	9.204	8.627	0.577	0.299	1.93*
Incremental innovation	Before matching	10.270	10.234	0.036	0.192	0.19
	After matching	10.251	9.996	0.255	0.249	1.02

4.3 Discussion

This part further studies how the IUR impact on enterprise radical innovation. R&D investment and human capital investment by enterprise are considered as the important carriers for enterprises to absorb and digest external knowledge by many scholars. Therefore, the impact of IUR on enterprise radical innovation is also likely to be through R&D investment and human capital. In order to test this, we add two cross terms (*input*colla* and *human*colla*) in the basic model respectively. Table 5 shows the regression results.

Table 5. Regression results

Variables	(1)	(2)	(3)	(4)	(5)	(6)
colla	0.224	0.222	0.086	0.232	0.231	0.094
	(1.28)	(1.29)	(0.50)	(1.33)	(1.34)	(0.55)
input	0.082***	0.084***	0.084***	0.144***	0.142***	0.139***
	(3.47)	(3.47)	(3.58)	(9.04)	(8.86)	(8.86)
human	1.699*	1.273*	1.042*	-0.556	-1.170	-1.219
	(4.36)	(3.20)	(2.64)	(-0.52)	(-1.02)	(-1.09)
*input*colla*	0.070***	0.065***	0.062***			
	(2.56)	(2.38)	(2.34)			
*human*colla*				2.367	2.536	2.346
				(2.27)	(2.27)	(2.16)
Year	N	N	Y	N	N	Y
Region	N	N	Y	N	N	Y
Industry	N	Y	Y	N	Y	Y
R^2	0.261	0.313	0.378	0.257	0.312	0.377
F value	55.13	17.44	11.71	54.51	17.39	11.67

Note: T statistics are in parentheses; ***、** and * represent the significance level on 1%、5% and 10%.

In table 5, we can see that the coefficients of *input*colla* are positive and significant at 1% statistical level but *human*colla* are not significant. It shows that participation in IUR can improve the efficiency of the R&D investment of enterprises, but can't improve the efficiency of human capital investment.

5. Conclusions

To evaluate the impact of IUR on enterprise innovation needs to consider the endogenous problem first. This paper uses PSM to control the endogeneity of IUR, and analyzes the impact of IUR on different innovation performance of enterprises. It is found that IUR can significantly promote radical

innovation performance in enterprises, the impact will be underestimated if not consider the endogenous problem. IUR can't promote enterprise's incremental innovation significantly. R&D investment is an important path for IUR to influence radical innovation.

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