



# Research on Nonlinear Influencing Factors of University Innovation Based on Semi-parametric Model

YongGang Xue<sup>(✉)</sup>

Medical Business School of GuangDong Pharmaceutical University, Guangzhou, China  
xzyonggang@163.com

**Abstract.** In order to analyse the non-linear characteristics and heterogeneity of influencing factors of university innovation, this paper empirically analyses the non-linear impact of R&D investment on University Innovation by using semi-parametric model based on the University Innovation samples of Guangdong Province. The main conclusions can be gain as follows: (1) Human capital elements have nonlinear characteristics on university innovation; (2) The impact of R&D investment of different types of projects on university innovation is heterogeneous; (3) R&D funds have a positive impact on university innovation, the linear model underestimates the impact of R&D funding on university innovation. The main suggestions are as follows: (1) Funding policies and evaluation mechanism should be formulated respectively according to the characteristics of different projects and the differences of their impact on university innovation; (2) The non-linear characteristics and types of the impact of human capital elements on university innovation should to be accurately grasped, and enhance the construction of communication platform and mechanism of university scientific research and innovation personnel, and improve the synergy of human capital elements in scientific research and innovation activities; (3) Further increase the overall investment of R&D funds related to innovation activities in Colleges and universities, and formulate differentiated policies for different types of projects and innovative achievements, so as to improve the efficiency of R&D funds.

**Keywords:** University Innovation · Nonlinear effects · Heterogeneity · Semi-parametric model

## 1 Introduction

As an important subject of scientific and technological innovation, especially as an important source of original innovation achievements, universities play an important role in industrial development and regional economic development. Therefore, universities are important national strategic resources and the key to the transformation from technological innovation to growth mode innovation. Although the human resources and R&D funds invested in innovation in universities have increased significantly in recent years, there are also problems such as improper resource allocation and internal resource

efficiency to be improved. How to improve the innovation efficiency of universities with limited resource investment and maximize the efficiency of innovation resources has become an important issue in China's current research on innovation in universities. Accurately understanding the impact of R&D investment on university innovation is one of the key steps to solve this problem.

University Innovation is a production process of new scientific and technological knowledge. Production process input mainly includes capital input ( $c$ ) and labour input ( $L$ ) according to Cobb Douglas production function. This paper plans to use R D funds as capital input indicators, and scientific and technological human resources as labour input indicators. Due to the influence of factors such as diminishing marginal utility and scale effect, capital input and labour input in the production process may have a nonlinear influence process on university innovation. Therefore, it is proposed to adopt the semi-parametric model method to empirically analyse the nonlinear influence factors in the university innovation process, so as to more objectively and accurately grasp the influence process and features of R&D investment on university innovation. It provides a basis for giving better play to the utility of innovation resources in universities, reasonably allocating innovation resources and improving innovation efficiency in universities.

## 2 Literature Review

As university innovation is an important driving force and source of technological innovation, scholars from various countries have carried out research on university innovation from different perspectives. Motoyama (2014) found that universities play a central node role in R&D network in university industrial cooperation based on case study [1]; Zhang (2019) found that there is a more obvious positive interaction between research institutions and universities [2]; Elenig (2019) found that enterprises that believe that R&D institutions are more important sources of innovative knowledge than universities have a better possibility of developing service innovation [3]; Vicente-Saez (2020) suggests that an open exploration policy and a government led open platform for scientific research and innovation in universities will promote the value of social innovation [4]; Nelson (2018) found that the result of external ranking competition is that colleges and universities lose their internal academic creativity and autonomy [5]; Lyu (2019) studied universities and industrial cooperative innovation organizations and found that the innovation cooperation network has shown an upward and outward expansion trend [6]; Baron (2017) found that the open innovation ability of Polish universities is only at a potentially high level. They rarely serve open innovation although relevant support institutions have been set up [7]; Oliver (2019) studied the innovation of university industry cooperation. The results shows that only when a project has positive output, it will have an impact on the success of university industry cooperation [8].

## 3 Data and Method

### 3.1 Theoretical Basis and Assumptions

The university innovation process is a knowledge production process, which is inseparable from the knowledge creation and reuse of relevant scientific researchers in universities. Traditional production functions such as Cobb-Douglas function also emphasize

the importance of elements. Existing literature research also shows that human capital has an important impact on the innovation process, However, there is no unified conclusion on the impact of scientific research human capital input on innovation output. Hypothesis H1 is proposed based on the above analysis.

H1: The impact of human capital investment on university innovation is uncertain.

In addition to human capital investment, scientific research capital investment also has an important impact on university innovation in the process of university innovation. The more scientific research funds invested, the more sufficient resources required for scientific research activities. Sufficient scientific research funds can provide better scientific research conditions in terms of equipment, materials, etc., so that scientific research activities can obtain more support and guarantee, and will also have a certain encouraging effect on scientific researchers. Hypothesis H2 is proposed based on the above analysis.

H2: Scientific research funding has a positive impact on University Innovation.

### 3.2 Data and Empirical Methods

This paper selects the relevant data of innovation output and basic projects, applied research and experimental development of universities in Guangdong Province from 2001 to 2019 as the research samples, and uses the number of publications, patent applications and patent authorizations as the indicators of innovation output of universities. The input personnel and allocated funds are used to represent the input of scientific researchers and scientific research funds respectively. The data source is the *Compilation of Scientific and Technological Statistics of Universities* from 2002 to 2020. The empirical analysis model is implemented by R language.

Semi-parameters are introduced to achieve a more objective and accurate fitting of the nonlinear relationship between university innovation input variables and university innovation output in the empirical analysis, which can reduce the dimension of explanatory variables of the non parametric model, and improve the fitting effect of the model.

The linear model is shown in formula (1):

$$Y_i = \alpha_i + \beta_i X_i + \varepsilon_i \quad (1)$$

$Y_i$  refers to the innovation output of universities,  $X_i$  refers to the input of innovation projects of universities. The estimated values of the  $\alpha_i$  and  $\beta_i$  are estimated respectively according to the samples. In order to better fit the nonlinear relationship between variables, a nonparametric part is added to the model. The model is expanded as shown in formula (2):

$$Y_i = \alpha_i + \beta_i X_i + g(Z_i) + \varepsilon_i \quad (2)$$

The kernel estimation of the nonparametric part is as shown in Eq. (3) if the window width is  $h_n$ .

$$\hat{g}(Z_i, \beta) = \sum_{i=1}^n W_{nt}(Y_i - \alpha_i - \beta_i X_i) \quad (3)$$

If  $K(\bullet)$  represents a function, then  $W_{ni}(Z_i)$  is as Eq. (4):

$$W_{ni}(Z_i) = \frac{K\left(\frac{Z_i - z}{h_n}\right)}{\sum_{j=1}^n K\left(\frac{Z_j - z}{h_n}\right)} \tag{4}$$

A and B are as follows:

$$\hat{g}_1(Z_i) = \sum_{i=1}^n W_{ni}(Z_i) Y_i \tag{5}$$

$$\hat{g}_2(Z_i) = \sum_{i=1}^n W_{ni}(Z_i) X_i \tag{6}$$

Then model (2) is as Eq. (7)

$$Y_i - \beta_i X_i = \hat{g}_1(Z_i) - \beta_i \hat{g}_2(Z_i) + \varepsilon_i \tag{7}$$

According to formula (7):

$$Y_i - \hat{g}_1(Z_i) = \beta_i (X_i - \hat{g}_2(Z_i)) + \varepsilon_i \tag{8}$$

It can be obtained the estimated values of  $\alpha_i$  and  $\beta_i$  again according the results of model (8) and  $\hat{g}(Z_i)$  is as Eq. (9):

$$\hat{g}(Z_i) = \sum_{i=1}^n W_{ni}(Z_i) (Y_i - \hat{\alpha}_i - \hat{\beta}_i X_i) \tag{9}$$

The model is optimized by adjusting the window width  $h_n$ .

## 4 Empirical Results

In order to compare the advantages of semi-parametric model in data fitting, this paper estimates the results of general linear model and semi-parametric model respectively, and calculates the mean absolute error (MAE), mean square error (MSE) and mean absolute percentage error (MAPE) of the two models.

The empirical results are shown in Table 1.

The following conclusions can be drawn from the empirical results:

- (1) R & D investment has a significant positive impact on University Innovation: R & D investment has a positive impact on different innovation achievements of universities, which is consistent with the previous theoretical analysis hypothesis H2. This result shows that funding is an important factor in promoting university innovation. R&D funding is one of the basic resources for universities to carry out various innovative research activities, and it is an important supporting element of the entire university innovation system. R&D funding is an important guarantee for basic innovation, application technology promotion and other activities in universities.

**Table 1.** The empirical results of linear model and semi-parametric model

Type	variable	linear Model		Semi-parametric Model			
		Paper Number	Patent Applications	Patent Authorizations	Paper Number	Patent Applications	Patent Authorizations
Basic Projects	Human Capital	0.1665*	0.2481*	0.0035*	----	----	
	R&D Funding	0.2741***	0.8916***	1.0540***	0.3478***	0.7923***	1.0430***
	MAE	0.0776	0.1453	0.1165	0.0623	0.1415	0.1161
	MSE	0.0088	0.0320	0.0194	0.0065	0.0260	0.0189
	MAPE (%)	0.73%	1.37%	1.12%	0.58%	1.34%	1.11%
Applied Research	Human Capital	0.2312*	0.2412**	0.4014*	----	----	
	R&D Funding	0.5058***	1.2400***	1.4960***	0.5058***	1.3670***	1.4960***
	MAE	0.0568	0.1673	0.1863	0.0567	0.1468	0.1863
	MSE	0.0051	0.0425	0.0552	0.0051	0.0344	0.0552
	MAPE (%)	0.54%	1.58%	1.78%	0.54%	1.40%	1.78%
Experimental Development	Human Capital	0.2216**	0.7595*	0.6557*	----	----	
	R&D Funding	0.4360***	1.2990***	1.3760***	0.4541***	1.2990***	1.3760***
	MAE	0.0896	0.2006	0.1937	0.0808	0.2005	0.1937
	MSE	0.0111	0.0538	0.0508	0.0097	0.0536	0.0508
	MAPE (%)	0.86%	1.91%	1.83%	0.78%	1.90%	1.83%
Total Impact	Human Capital	0.0852*	1.325*	0.6746*	----	----	
	R&D Funding	0.3661***	0.7627***	1.0390***	0.4736***	0.8414***	1.0390***
	MAE	0.0699	0.1209	0.1176	0.0220	0.0920	0.1176
	MSE	0.0066	0.0217	0.0203	0.0009	0.0158	0.0203
	MAPE (%)	0.67%	1.15%	1.12%	0.21%	0.89%	1.12%

Note: \*\*\*, \*\*, \* respectively mean passing the significance test at the level of 1%, 5% and 10%

- (2) Human capital has a nonlinear impact on university innovation: Comparing the fitting errors of linear model and semi-parametric model, it is found that the fitting effect of semi-parametric model is significantly better than that of linear model. This shows that the fitting effect of model estimation is improved considering the nonlinear impact of human capital factors on university innovation, and the semi-parametric model is more suitable for studying university innovation.
- (3) The impact of R&D investment in different types of projects on university innovation is heterogeneous: Different types of projects have different characteristics and research purposes, which have different effects on university innovation. Applied research projects have the greatest impact on the achievements of university papers. Application research projects have the largest impact on the number of patent applications and patent authorization, and basic research projects have the smallest impact.
- (4) Considering the nonlinear impact of human capital, the impact of R&D investment on university innovation increases: Considering the non-linear impact of human capital investment, the estimated values of other relevant coefficients have increased or remained unchanged except that the basic research investment has a slight decrease in the coefficient estimates of university patent applications and patent authorizations.

## 5 Conclusion

This paper analyses the nonlinear impact of human capital elements on university innovation based on the semi parametric model estimation method. The study found that the impact of human capital elements on university innovation has nonlinear characteristics, the impact of three types of research projects' R&D investment on university innovation is heterogeneous, and R&D investment has a positive impact on university innovation.

We should formulate targeted subsidy policies and evaluation mechanisms according to the heterogeneity of the impact of different projects on university innovation. It is necessary to objectively analyse the nonlinear impact characteristics and types of human capital elements on university innovation, strengthen the communication platform and construction of University researchers, and improve the synergy of human capital elements in scientific research and innovation activities. We must increase the total amount of innovation funds, and it is necessary to increase the corresponding research funds according to the differences of project types and innovation achievements, so as to improve the efficiency of the use of R&D funds in Colleges and universities.

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