

Graduate Education, Technological Innovation and Real Economic Development

Li Zhao¹, Mingyu Wen², Yating Gao³

¹Xinjiang University of Finance and Economics, Urumqi, Xinjiang, China

²Guizhou University of Finance and Economics, Guiyang, Guizhou, China

³Xinjiang University of Finance and Economics, Urumqi, Xinjiang, China

zhaoli@xjufe.edu.cn

Abstract. From 2007, the scale of graduate education in China has been expanding year by year. So, does graduate education have an impact on China's scientific and technological innovation? Has China's graduate education promoted the development of the real economy? Based on provincial panel data from China from 2007 to 2021, this study evaluates the impact of graduate education on real economic development with mediating effect model. On this basis, a panel threshold model is established, and the differences in the impact of regional disparities in graduate education on the real economy are explored. The research results show that graduate education has a significant promoting effect on the development of the real economy. In regions with lower educational levels, graduate education has a stronger effect on promoting the development of real economy. Technological innovation plays an intermediary role in the relationship between graduate education and the development of the real economy. According to the threshold variable of technological innovation, there exists a single threshold effect in the country and regions with higher education levels, gradually increasing the positive impact on the development of the real economy. The specific policy suggestions for promoting the development of real economy in relation to graduate education mainly include further balancing the investment in graduate education, coordinating the development of graduate education with technological innovation, and strengthening the flow of resources between provinces.

Keywords: Graduate Education, Science and Technology Innovation, Development of the Real Economy

1. Introduction

The real economy is the lifeblood of China's economy. Cultivating high-tech talents for the real economy is the historical mission of higher education and also an important entry point and foothold to promote the construction of a manufacturing power and an education power. At present, the degree of modernization of China's industry is still to be strengthened, the innovation ability of enterprises is weak, and the key areas are facing the "neck" problem (Zheng, 2023). In order to achieve high-quality development, a large number of technical and skilled talents are needed, but the shortage of high-end talents is a key problem restricting the high-quality development of China's manufacturing industry. Graduate education has missions of "supplying high-end talents" and "promoting scientific and technological innovation", which is of great significance to China's social development and economic growth (Li & Wang, 2020).

Under the social background of implementing the strategy of innovation-driven development in China, it is necessary to further explore the relationship between graduate education, technological innovation and the development of the real economy.

2. Research Hypothesis

2.1 Direct Effects of Graduate Education on Real Economy Development

From the microscopic aspect, graduate education is an important pathway for the growth of individual social value. Graduate education extends undergraduate education to enhance individual

professional qualities, and at the same time can increase job opportunity and income in the transitional stage of school transition to society. In terms of the social value an individual can create, education can cultivate the comprehensive quality of individuals in distinct aspects at different stages. The more higher education an individual receives, the richer human capital with technical knowledge, professional production experience, and labor skills, the higher social value that can be created, and the more labor productivity that continuously improves and promotes economic social development(Yang et al.,2021). From the macro level, graduate education is an important method to cultivate professional human capital and optimize the allocation of labor resources. In the theory of new economic growth, Roemer deepened the impact of human capital on economic growth. He believes that the accumulation of specialized knowledge can generate incremental effects, increase the returns of other input factors, thereby increasing the total scale of returns, and thus highlighting the importance of specialized human capital in modern economic growth. Therefore, hypothesis 1 is proposed:

H1: Postgraduate education has a positive impact on the development of the real economy.

2.2 Indirect Effects of Postgraduate Education on the Development of the Real Economy

Graduate education mainly exerts an indirect impact on economic development through technological innovation, and the development of the real economy is inseparable from the innovation and development of productive technology. First of all, the development of graduate education is more suitable for promoting the combination of science and education. The development of the real economy is closely related to technological innovation, and the level of social knowledge stock will affect innovative products. Secondly, both intellectual capital and human capital have strong synergistic effects. Postgraduate education improves the social intellectual capital and fosters a group of composite intellectuals for the society(Tian & Cui,2023). Finally, graduate education utilizes the knowledge dissemination effect and knowledge spillover effect to support the flow of technology and reduce the imbalance of the level of technology innovation between regions.

Subsequently, technological innovation promotes the "agglomeration effect" of enterprises in the real economy. Because of the sharing of soft factors, such as information and knowledge, the same enterprise can transfer common factors, such as information and knowledge, between different production processes without incurring any additional cost, so the production cost of each product will decrease and the profit will increase(Wang & Zheng,2019). Accordingly, the hypothesis 2 can be proposed:

H2: Graduate education can promote the development of the real economy through technological innovation.

2.3.Threshold Effect of Postgraduate Education on the Development of the real Economy

In addition to the economic role of human capital investment, education also has an indirect impact, which is limited by the stage of regional development(Hu,2023).Graduate education promotes the development of the real economy through technology innovation, and this impact may be inconsistent due to the different levels of technological innovation. In reality, graduate education and technological innovation development have not achieved a completely synchronized integration. At a lower level of technological innovation, the continuous increase in the cultivation of graduate education may lead to the deepening of education, which means there will be an oversupply of low shallow generalized human resources(Low shallow generalized human resources refers to the creativity of low practical skills shallow knowledge of the generalized talent, everything to learn everything did not learn through the talent) in the job market, causing excessive saturation, while there will be a shortage of highly specialized human resources (The term of highly specialized human resources refers to talents with high creativity and specialized knowledge, and talents with a particular specialty even though their knowledge is not comprehensive), making it difficult to find this kind of talents. This will lead to insufficient vitality of innovation subjects, and limit the role of

postgraduate education in promoting the development of real economy through scientific and technological innovation. Accordingly, hypothesis 3 is proposed:

H3: The positive impact of graduate education on the real economy development will be affected by the regional level of technology innovation, showing a nonlinear effect, which exhibits regional heterogeneity.

3. Research Design

3.1 Variables Selection

3.1.1 Explained variables

The development level of the real economy (Real). According to Huang Qunhui's division of the real economy (Huang, 2017), this article draws on the existing processing methods to quantify it.

3.1.2 Explanatory variables

Graduate education (Edu). Referring to the previous research on the scale of higher education (Tian & Yang, 2022), the number of graduate students is used as a variable to characterize “graduate education”.

3.1.3 Mediating variables

Technological innovation (Tec). The number of patents granted annually in 31 provinces in China is used to measure the capacity of technological innovation.

3.1.4 Control variables

Based on relevant studies, the following control variables are selected: urbanization level (Ur), degree of opening up (Op), social consumption level (Soc), human capital level (Huc), and foreign direct investment (Fdi). In addition to above control variables, this article also controls the provinces and years in the model.

Based on the samples of 31 provinces, municipalities and autonomous regions in China from 2007 to 2021, this paper makes an empirical study on the role of graduate education in the real economy development. The data are derived from China Statistical Yearbook, Education Statistical Yearbook and provincial statistical yearbooks.

3.2 Model Specification

3.2.1 Mediating effect model

This article constructs a panel data econometric model for empirical analysis, applying a two-way fixed effects model to estimate one by one. The benchmark model is set as equation (1).

$$\text{Real}_{it} = \beta_0 + \beta_1 \text{Edu}_{it} + \beta \text{CON}_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (1)$$

$$\text{Tec}_{it} = \alpha_0 + \beta_1 \text{Edu}_{it} + \beta \text{CON}_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (2)$$

$$\text{Real}_{it} = \delta_0 + \delta_1 \text{Edu}_{it} + \eta_1 \text{Tec}_{it} + \beta \text{CON}_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (3)$$

Among them, Real_{it} denotes the status of real economy development in period t of region i ; the Edu_{it} represents the level of graduate education in region i during period t ; and Tec_{it} denotes technological innovation in period t of region i ; and CON_{it} denotes a set of control variables; μ_i denotes individual fixed effect; μ_t denotes time fixed effects; ε_{it} denotes a randomized disturbance term.

3.2.2 Threshold measurement model

To test hypothesis H3, that is, what are the differences in the role of graduate education in promoting the real economy development under different levels of technological innovation. A threshold regression model was used to examine the differential impact of graduate education on the development of the real economy under different levels of technological innovation, taking technological innovation as the threshold variable and graduate education as the core explanatory

variable. Combining with the research in this article, the threshold effect model is constructed as equation (5), where δ is the threshold to be estimated.

$$\text{Real}_{it} = C + \beta_1 \text{Edu}_{it} I(\text{Tec}_{it} \leq \delta) + \beta_2 \times \text{Edu}_{it} I(\text{Tec}_{it} > \delta) + \beta \text{CON}_{it} + \varepsilon_{it} \quad (4)$$

Eq. (4) is only a single-threshold model. In actual testing, there may be multiple threshold values, so the model construction is like equation (5) (taking a dual threshold model as an example).

$$\text{Real}_{it} = C + \beta_1 \text{Edu}_{it} I(\text{Tec}_{it} < \delta_1) + \beta_1 \text{Edu}_{it} I(\delta_1 < \text{Tec}_{it} < \delta_2) + \beta_3 \text{Edu}_{it} I(\text{Tec}_{it} > \delta_2) + \beta \text{CON}_{it} + \varepsilon_{it} \quad (5)$$

In these formulas, C represents the individual effect, α represents the parameter of the threshold dependent variable to be estimated, $I()$ represents the indicator function with a value of 0 or 1, and X_{it} represents the control variable, β represents the parameter to be estimated for the control variable, ε is the error term, and δ represents the threshold. The above formula is a single threshold variable model and the double threshold model can be extended.

4. Empirical Analysis

4.1 Empirical Results

The results of the mediated effects regression are shown in Table 1. Column (1) and column (2) represent the impact of graduate education on the development of the real economy and the impact of graduate education on technological innovation, respectively. It can be seen that the core explanatory variable is significantly positive at the 1% level, with a coefficient of 1.978, which implies that graduate education significantly promotes the development of the real economy, verifying hypothesis H1 that graduate education has a positive contribution to the development of the real economy.

Table 1. Intermediary effect results

	(1)	(2)	(3)
	Real	Tec	Real
Edu	1.978*** (0.551)	11.436*** (3.704)	1.053*** (0.323)
Tec			0.081*** (0.010)
Ur	12.390*** (3.263)	58.168** (22.681)	7.687*** (2.209)
Op	-1.452 (1.504)	-17.980 (15.102)	0.001 (0.523)
Soc	0.728 (0.746)	2.933 (7.021)	0.491 (0.595)
Huc	3.676 (5.274)	16.588 (50.302)	2.335 (1.857)
Fdi	-8.137 (6.914)	-77.265* (44.712)	-1.891 (4.047)
_cons	-5.833*** (1.503)	-25.413** (9.999)	-3.779*** (0.970)
N	465.000	465.000	465.000
r2	0.765	0.547	0.908
r2_a	0.755	0.526	0.904

represent significant at the 10%, 5%, and 1% levels, respectively; t-values in parentheses are robustly adjusted for heteroskedasticity via robustness to robustness by robust; same below.

4.2 Heterogeneity Analysis

The article divides regions into areas with higher education levels and areas with lower education levels (You et al., 2023), and regresses the 31 provinces into two groups. The results are

shown in Table 2. The study found that graduate education has a significant role in promoting real economy development, regardless of whether it is in provinces with higher or lower levels of education. Specifically, according to the results in Table 3, the coefficients of the core explanatory variables of graduate education on the provinces with higher education level and provinces with lower education level are 1.473 (at the 5% level) and 4.294 (at the 1% level), respectively. The results show that graduate education can significantly promote the development of the real economy in both regions with higher education level and regions with lower education level, and the promotion effect of graduate education on real economy development is stronger in regions with lower education level.

Table 2 .Heterogeneity analysis

	(1)	(2)
	Areas with higher levels of education	Areas with lower levels of education
Edu	1.473**	4.294***
	(0.568)	(0.248)
Ur	16.915***	-3.355
	(3.555)	(2.646)
Op	-3.108	-1.766**
	(1.914)	(0.820)
Soc	2.345	-0.026
	(1.493)	(0.633)
Huc	8.649	2.998
	(7.538)	(2.231)
Fdi	-10.995	3.519
	(7.618)	(7.087)
_cons	-9.638***	1.027
	(2.496)	(1.215)
N	225.000	240.000
r2	0.774	0.931
r2_a	0.752	0.925

4.3 Threshold Mod

A threshold panel model including technological innovation was established to determine the threshold of the impact of graduate education on the development of the real economy. The number of thresholds is determined by the threshold effect test, as shown in Table 3. The single threshold value of technological innovation in 31 provinces of China is 19.8778, and the single threshold value of technological innovation in regions with higher education level is 19.8778, while the threshold effect of technological innovation in regions with lower education level is not significant.

Table 3 .Panel self-sampling test results Table

	Number of thresholds	F-statistic	P-value	threshold value
31 provinces	single threshold	385.42	0.0000	19.8778
	double threshold	17.92	0.3575	0.0910
Areas with higher levels of education	single threshold	398.72	0.0000	19.8778
	double threshold	19.07	0.4225	31.4395

Areas with lower levels of education	single threshold	18.49	0.4075	4.5688
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Table 4. further empirical estimation

	(1)	(2)
	31 provinces	Areas with higher levels of education
Ur	3.937** (1.874)	4.321** (1.960)
Op	-0.197 (0.641)	-0.517 (0.595)
Soc	1.285* (0.649)	1.489* (0.820)
Huc	3.649 (2.981)	3.413 (3.655)
Fdi	1.174 (4.078)	2.934 (2.764)
Edu ($Tec_{it} \leq \delta$)	1.185*** (0.256)	0.861*** (0.165)
Edu ($Tec_{it} > \delta$)	2.657*** (0.268)	2.528*** (0.264)
_cons	-2.408*** (0.627)	-2.944** (1.001)
N	465.000	225.000
r ²	0.859	0.901
r ² _a	0.857	0.897

Based on the results of the threshold effect test shown in Table 4, the impact coefficient of graduate education in 31 provinces and provinces with higher education levels has gradually increased.

5. Conclusions and Implications

The main conclusions of this study are as follows: 1) Graduate education positively promotes the development of the real economy. 2) Technology innovation shows a significant positive mediating effect between graduate education and the development of the real economy. 3) Graduate education in underdeveloped areas has a stronger effect on promoting the development of the real economy. 4) Graduate education has a threshold effect of technological innovation on the development of the real economy, and this threshold effect mainly occurs in areas with higher educational levels. In addition, the marginal effect of post-graduate education is showing an upward trend.

From these research results, policy implications can be drawn. The first point to consider here is that government education, as the primary mean of human capital education and training, can make up for the insufficient investment in education by individuals and enterprises. Specifically, provinces that develop education should invest more in education development measures, such as improving education infrastructure and setting up special funds to attract high-quality labor. Moreover, every industry is inseparable from the support of technological innovation. The development of the real economy requires the continuous optimization of the environment of technology innovation and the continuous input and output of technology innovation.

6. Data Availability

The data that support the findings of this study are available upon request.

7. Conflicts of Interest

The authors declare that they have no competing interests.

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