Review of Economic Assessment

Homepage: https://anser.press/index.php/REA

Can University Scientific Research Activities Promote High-Quality Economic Development? Empirical evidence from provincial panel data

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ABSTRACT

Scientific and technological innovation and human capital savings are important ways to promote the high-quality development of China's economy. On this basis, using the panel data of 30 provinces in China from 2009 to 2017, this paper empathically tests the impact of university research activities on high-quality growth of China's economy, and explores the influence mechanism from two dimensions of talent cultivation and achievement transformation. Based on the spatial perspective, the regional heterogeneity of these influences is analyzed. This paper finds that: First, research and development activities in universities effectively boost the high-quality development of China's economy. Secend, the stimulating effect of university research and development on economic growth. On the one hand, through the talent training function of scientific research activities, it enriches the accumulation of human capital and drives the economic development; On the other hand, constrained by the predicament of scientific research achievement transformation, the stimulating effect of university scientific research activities on economic growth will be limited to a certain extent. Third, there are significant regional differences in the promoting effect of university research activities on high-quality economic development, and this difference may come from the spatial spillover effect of university research activities. This study has important enlightening significance to understand the relationship between university scientific research activities and high- quality economic development.

KEYWORDS

University scientific research activities; High-quality economic development; Spatial spillover effect

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ISSN 2972-3515
doi: 10.58567/rea01010003

Received 1 November 2022; Accepted 27 December 2022; Available online 30 December 2022

The world is undergoing profound changes unseen in a century. The international situation has undergone profound changes, China's economy and society have entered a new normal, and a new development pattern is on the horizon. How to solve the problem of high-quality economic development has become a core issue that China must answer in its journey to become a great modern socialist country. The core economic mechanism of high-quality economic development lies in technological innovation and factor quality upgrading (Gao et al., 2020). Higher education is an important hub for scientific and technological innovation and improving the quality and efficiency of labor resources.

In this context, in order to promote the convolutions and high-quality development of higher education and promote the modernization of the governance system and governance capacity of institutions of higher learning, the National Development and Reform Commission of the Ministry of Education and the Ministry of Finance issued the notice of "Evaluation Measures for the Effectiveness of "Double First-class "Construction (Trial)" (hereinafter referred to as the Evaluation Measures) in March 2021.The evaluation method requires colleges and universities to actively face the main battlefield of national economy, and actively integrate into regional and industrial development based on superior disciplines. To accelerate the technology transfer and achievement transformation of colleges and universities, improve the ability of colleges and universities to serve the national major strategy, industrial development and regional development, strengthen the construction of colleges and universities in key fields and the training of talents in urgent need, so as to significantly improve the ability of colleges and universities to serve the social and economic development. Under this tone, the development of higher education must firmly grasp the two main lines of scientific and technological innovation and talent training, adhere to the fundamental task of establishing morality and cultivating people, integrate scientific research and talent training, promote the conrotatory development of higher education, and contribute first-class talents and achievements on the educational front to the high-quality development of China's economy. To lay a solid foundation of science and technology and talents for the great rejuvenation of the Chinese nation.

To promote high-quality economic development, we must adhere to the principle of integrating efficiency with quality and adhere to the strategy of innovation-driven development. Fundamentally, to build a new development pattern, we cannot do without the support of science and technology and talents, and more importantly, we cannot do without the continuous and in-depth promotion of higher education. Institutions of higher learning are at the important intersection of science and technology, talents and innovation, and play an irreplaceable key role in the process of building a new development pattern and promoting high-quality economic development (Liu, 2021). Therefore, higher education must provide the necessary talent support for high-quality economic development, give full play to the core role of talent training base, expand the team of highly skilled talents for high-quality economic development of China, and comprehensively improve the quality of human capital. At the same time, to build a new development pattern, colleges and universities are required to rise to the challenge, seize the opportunity, take the initiative to shoulder the great responsibility of overcoming the "bottleneck" problem, focus on the core and key technologies, and better play the important role of the main force of scientific research. Therefore, the significance of promoting the conrotatory development of higher education is not only education itself, but also closely related to the high-quality development of China's economy and the effective response to the great changes not seen in a century.

Scientific research activities are an important means for colleges and universities to effectively integrate scientific and technological innovation and talent training. In the process of performing the core function of scientific research and development, colleges and universities not only create new knowledge and new technology, but also cultivate a large number of excellent talents for economic and social development. Further promoting scientific research activities is the concrete embodiment of colleges and universities integrating their own development into the national strategy. Therefore, this paper will focus on the possible impact of university research

activities on high- quality economic development. In the following, this paper will draw on Chen et al. (2018). In this paper, labor productivity (GDP per capita) is used as the proxy indicator of high-quality economic development, and the inter-provincial panel data of 30 provinces, municipalities and autonomous regions in China from 2009 to 2017 are used to try to analyze the relationship between university research activities and high-quality economic development in China. This paper tries to answer the following questions: Can the scientific research activities of universities promote the high-quality development of China's economy? If so, what is the economic transmission mechanism behind it? Further, is there spatial heterogeneity in this economic relationship, and if so, does this difference have spatial spillover effects? By answering the above questions, we hope to provide corresponding policy suggestions for the relationship between higher education and high-quality economic development in the new era.

The remaining part of this paper is arranged as follows: the first part is theoretical analysis and research hypothesis; The second part introduces the data and empirical strategy of this paper; The third part presents the benchmark regression results and the corresponding robustness tests. In the fourth part, the mechanism is analyzed. The fifth part analyzes the heterogeneity of the above studies and gives the possible sources of regional heterogeneity from the perspective of space. The last part is the conclusion and enlightenment.

1. Theoretical analysis and research hypothesis

Since the reform and opening up more than 40 years ago, China's education cause has developed vigorously, and the education front has made important contributions to the high-quality development of China's economy. In 2018, China's GDP was about 9,030.95 billion yuan, and the country's total investment in education was about 4,614.300-billion-yuan, accounting for 5.13% of China's GDP. Among them, the research and development expenditure of institutions of higher learning is about 96.756-billion-yuan, accounting for 2.10% of the total investment in education. The research and development expenditure of institutions of higher learning has become an important part of China's total education expenditure. At the present time of building a new development pattern, scientific and technological innovation and personnel training have already become an important force in promoting high-quality economic development. Therefore, this paper will use the R&D expenditure of colleges and universities as a proxy variable to reflect the scientific research activities of colleges and universities, and analyze the key issue of whether the scientific research activities of colleges and universities can contribute to the high-quality economic growth of China through scientific and technological innovation and talent training.

1.1. Research hypothesis: The impact of university scientific research activities on high-quality economic development

Further promoting the scientific research activities in universities cannot be separated from the continuous investment of R&D funds. Easterly and Rebello (1993), Barro and Sala (1999), and Blumenau et al. (2006). His work on the theoretical analysis and empirical research on the impact of public education expenditure on economic growth is of great significance. They analyzed the effect of public education expenditure on economic growth in developed and developing countries respectively, and came up with two different views. One view is that education expenditure will have an inhibitory effect on economic growth. One view is that education expenditure steadily promotes economic growth, and the other view is that education expenditure steadily promotes economic growth. As for the difference in the conclusions of these studies, this paper argues that we can think about the difference from two aspects: on the one hand, the region where the study is conducted, and on the other hand, the structure of education expenditure analyzed by the study. Affected by the economic development stage and industrial structure of the region, if the economic development of the region is relatively backward and the industrial

development is in the primary stage, increasing investment in secondary education and higher education will lead to the weakness of primary education, and then the quality of basic education will decline, which will have a negative impact on economic growth (Lloyd, 2000). At the same time, the excessive investment in secondary education and higher education makes the talent structure not match the industrial structure, leading to brain drain and improper investment, thus restricting economic growth (Ye et al., 2003). Therefore, when analyzing the impact of education input on economic growth, it is necessary to base on the economic development stage of the study region and the structural difference of education input, otherwise the general analysis of the contribution of education input to economic growth is likely to produce errors (Guo and Jia, 2009).

At present, China's economic development has entered a new stage, and the structure of domestic demand, industrial structure, technological system and economic growth drivers are undergoing profound changes. We must take the initiative to make adjustments and come up with new ideas and patterns to guide development in light of new situations and tasks. To achieve the new development pattern, we must rely on scientific and technological innovation and high-quality labor input, and the scientific research activities of colleges and universities themselves are an important means of talent training and scientific and technological research and development. Under the new development pattern, increasing the support for scientific research activities of colleges and universities, on the one hand, provides knowledge reserve for China's economy to stride to a higher level (Hong, 2018; Li and Fan, 2019) On the other hand, it also cultivates a large number of high-quality labor force for the high-quality development of China's economy (Huang et al., 2021). Therefore, we should focus on analyzing the impact of university R&D expenditure on high-quality economic growth under the new development pattern.

Based on the above analysis, this paper puts forward the following hypothesis:

Hypothesis 1: The growth of university R&D investment has effectively boosted the high-quality development of China's economy.

1.2. Mechanism analysis: talent cultivation and achievement transformation

When analyzing the relationship between education and economic development, talent cultivation and scientific and technological innovation are the key factors that must be considered. Schultz (1961) Schultz (1961) pointed out that school education is an important means to improve the quality of labor force, and investment in education can accelerate the accumulation of human capital and improve the ability of human capital as a producer and consumer. Lucas (1988) This paper constructs the economic mechanism of formal education saving human capital, introduces human capital into the economic growth model, and analyzes the driving effect of increasing marginal return of human capital on economic growth. He believes that the faster the growth of human capital and technological progress is, the more able it is to drive the continuous growth of economy. In the practice of higher education, scientific research and development has always been regarded as the core mission of colleges and universities. Li et al. (2020) According to Li et al. (2020), higher education itself is gradually independent from the process of material production, and has become the supply-side driving force for technological progress and structural change. Besides, Lin Yifu (2010) The source of economic growth is endogenous to the factor endowment structure of an economy. When the factor endowment structure represented by human capital and scientific and technological innovation changes, the high-quality economic development will be natural. Therefore, the development of higher education is conducive to improving the quality of human capital, thus promoting high-quality economic growth (Jiang and Xu, 2021).

As mentioned above, under the modern economic development model, higher education itself is increasingly regarded as an independent economic subject, becoming the supply-side driving force of technological progress and economic structural change (Wang et al., 2017; Li et al., 2020). Therefore, when analyzing the mechanism of higher education on economic growth, the spillover effect of higher education on economic and social development must

be included in the analysis framework. For a long time, the transformation of scientific research achievements in Chinese universities has attracted widespread attention from all walks of life (Fan, 2007). The effective transformation of scientific research achievements plays an extremely important role in promoting economic and social development. With the deepening of the construction of "double first-class" colleges and universities, the efficiency of technology transfer and achievement transformation of construction colleges and universities has become the inspection content of the construction effect of "double first- class" colleges and universities. However, a large number of studies have shown that the transformation of scientific and technological achievements in colleges and universities is faced with many difficulties, and the phenomenon of "high output and low transformation" is serious, which negatively hinders the service of colleges and universities for local economic development (Fan, 2007; Meng et al., 2020; Song, 2020). Therefore, the achievement transformation level of institutions of higher learning may hinder the role of scientific research activities in promoting high-quality economic development. However, most of the existing literature analyzes the constraint effect of university achievement transformation on economic development from a qualitative perspective, and few papers give the answer to this question from a quantitative perspective. Therefore, this paper enriches the research on the impact of university achievement transformation on economic development from a quantitative perspective.

Based on the above analysis, this paper puts forward the following hypotheses:

Hypothesis 2: The driving effect of university R&D investment on economic growth, on the one hand, enriches the accumulation of human capital and drives economic growth through the knowledge increase and talent training brought by scientific research activities themselves; On the other hand, due to the constraints of the transformation of scientific research achievements, the driving effect of university research activities on economic growth will be limited to a certain extent.

2. Research design

2.1. Baseline model and data description

Reference from Chen Shiyi & Chen Dengke (2018). The research design of this paper is as follows: First, based on the relevant data of 30 provinces in China from 2009 to 2017, this paper empirically analyzes the impact of university research activities on the quality of China's economic development.

$$lnpgdp_{it}(lngdp_{it}) = \beta_0 + \beta_1 lnrd_{it}(lnl.rd_{it}) + \beta_2 open_{it} + \beta_3 lnpopdensity_{it} + \beta_4 urban_{it} + \beta_5 popgrow_{it} + \beta_6 lninfrus_{it} + \beta_7 lnnet_{it} + \beta_8 lnfinde_{it} + \gamma_i + \epsilon_t + \varepsilon_{it} \quad (1)$$

Where, $lngdp_{it}$ represents the logarithm of per capita GDP of province i in year t, which is used to measure the quality of economic development of the province; in order to ensure the reliability of the results, we also use the GDP level of the province ($lnpgdp_{it}$) to replace the level of GDP per capita to conduct the robustness test. This paper measures the impact of university R&D investment on the quality of economic development, which is the core parameter concerned in this paper. If the coefficient of university R&D investment is significantly positive after controlling a series of provincial characteristic variables, it indicates that university research activities effectively promote the high quality of economic development, otherwise it is not. Similarly, considering the lag of university R&D and ensuring the robustness of the test results, this paper also incorporates the one-period-lagged value ($lnl.rd_{it}$) of university R&D investment into the measurement model. In addition, this paper also controls the individual and time effects (γ_i and ϵ_t) to alleviate the error of missing variables. Finally, there is the error term.

It should be noted that this paper is based on relevant research (Hu and Zhang, 2013; Chen and Chen, 2018; Chu et al., 2020) The controlled provincial characteristic variables are as follows: the degree of openness to the outside world ($open_{it}$), which is expressed by the proportion of foreign direct investment in GDP; Urban population density ($lnpopdensity_{it}$) is represented by the logarithm of population per unit area. The level of economic

urbanization ($urban_{it}$) is represented by the proportion of secondary and tertiary industries in GDP; Infrastructure construction ($lninfrus_{it}$) is expressed by the logarithm of the length of grade highway per capita; Internet popularity ($lnnet_{it}$), the number of Internet users; Financial depth ($lnfinde_{it}$), measured by the logarithm of the loan balance of financial institutions per capita; in addition, the population growth rate ($popgrow_{it}$) is controlled.

2.2. Mechanism analysis: mediating effect model

Drawing on the existing research and analysis (Wen, 2004; Guo et al., 2020). The mechanism testing model of this paper is set as follows:

$$MED_{it} = \alpha_0 + \alpha_1 lnrd_{it} + \alpha_2 X_{it} + \gamma_i + \epsilon_t + \varepsilon_{it} \quad (2)$$

$$lnpgdp_{it}(lngdp_{it}) = \beta_0' + \beta_1' lnrd_{it} + \beta_2' MED_{it} + \beta_0' X_{it} + \gamma_i + \epsilon_t + \varepsilon_{it} \quad (3)$$

Where, $MED_{it}$is the mediating variable, namely, the level of scientific research transformation in colleges and universities and the indicators of talent training. Combined with Model (1), Equations (2) - (3) are the basic procedures of mediating effect to the testing procedure of mediating effect (Qian, 2015) Firstly, the coefficient $\beta_1$in Model (1) is tested. If β_1 is not significant, the mediating effect test is stopped, indicating that there is no mediating effect and the mechanism is invalid. If α_1 and β_2' both coefficients are significant, further test will β_1' be conducted. If the coefficient β_1' is significant, the mediating effect is significant and the mechanism is established; if the coefficients are not significant, the mediating effect is complete; If at least one of α_1 and β_2' is not significant, Sobel test is needed. If the test passes, the mediating effect exists. Otherwise, the mediating effect is not significant. Specifically, MED_{it} is includes $edustru_{it}$ and $lntechtransfer_{it}$ two variables, $edustru_{it}$ represents the indicators of talent training in colleges and universities, which are expressed by the proportion of the number of labor force with junior college degree or above in the number of employed persons; $lntechtransfer_{it}$ represents the scientific research transfer rate of colleges and universities, which is expressed by the logarithm of the number of technology transfer contracts of colleges and universities. Table 1 shows the statistical description of the above explained variables, core explanatory variables and control variables.

Table 1. Descriptive statistics of main variables.

Variable names	Number of observations	Average	Standard deviation	Minimum	Maximum
lngdp	270	9.609	0.874	6.986	11.404
lnpgdp	270	10.633	0.484	9.241	11.768
lnrd	270	13.866	1.327	9.804	16.50
lntransfer	252	4.989	1.743	0	8.144
edustru	270	0.074	0.063	0.01	0.375
open	270	0.024	0.021	0	0.108
lnpopdensity	270	7.852	0.43	6.639	8.669
urban	270	0.553	0.13	0.299	0.896
popgro	270	0.053	0.027	-0.006	0.115
lninfrus	270	3.428	0.602	1.639	4.907
lnnet	270	6.799	1.009	3.49	8.784
lnfinde	270	-3.273	0.666	-4.737	-1.293

2.3. Data source and description

The main data of 30 provinces in China from 2009 to 2017 are from the China Statistical Yearbook, the National Bureau of Statistics, the China Labor Statistical Yearbook, the China Education Statistical Yearbook, the China Education Funds Statistical Yearbook, and the Compilation of Science and Technology Statistics of Higher Education Institutions by the Ministry of Education. The linear interpolation method was used to supplement the missing data.

3. Analysis of empirical results

3.1. Benchmark regression results

According to the analysis idea of the third part, Table 2 reports the regression results of the benchmark model. Columns (1) to (2) show the regression results with per capita GDP as the proxy variable for high-quality economic growth. Since the data type used in this paper is panel data, Hausman test is needed to determine the specific estimation method used in the model. According to the test results, the fixed effect model (FE) should be used for estimation, and the fixed effect model is used for analysis in subsequent studies. It can be found from the regression results that after controlling the relevant variables, the R&D expenditure of colleges and universities has a positive impact on the per capita GDP. However, after considering the lagged effect of scientific research activities of colleges and universities on economic development, the R&D expenditure of colleges and universities still has a positive effect on the high-quality economic growth, and the degree is enhanced and the significance level is improved. This preliminarily confirms hypothesis 1 put forward in this paper, that is, the growth of university R&D investment effectively boosts the high-quality economic development of China.

Table 2. Research and development expenditure of universities and high-quality economic growth: benchmark regression.

Explained variable	(1)	(2)	(3)	(4)	(5)	(6)
	GDP per capita				Real GDP	
lnrd	0.0489*		0.0949***		0.0969***	
	(1.75)		(2.80)		(4.75)	
lnlrd		0.0506**		0.0835***		0.0872***
		(2.49)		(3.19)		(4.44)
open	-3.267***	-3.075***	-3.045***	-2.983***	-3.036***	-2.941***
	(-4.19)	(-4.44)	(-4.74)	(-4.24)	(-5.29)	(-5.06)
lnpopdensity	-0.0114	-0.0342	0.00330	-0.0291	-0.00290	-0.0278
	(-0.31)	(-1.00)	(0.10)	(-0.87)	(-0.10)	(-1.03)
urban	1.658***	1.471**	1.219*	1.302**	0.641*	0.883**
	(3.10)	(2.67)	(1.87)	(2.09)	(1.88)	(2.53)
popgro	-0.350	0.574	-0.178	0.765	0.0679	0.834
	(-0.52)	(0.83)	(-0.26)	(1.02)	(0.12)	(1.57)
lninfrus	-0.305*	-0.363**	-0.641***	-0.553**	-0.546***	-0.515***
	(-1.78)	(-2.73)	(-2.82)	(-2.67)	(-6.57)	(-5.85)
lnnet	0.226***	0.128***	0.257***	0.145***	0.297***	0.185***
	(7.20)	(4.32)	(8.63)	(4.89)	(10.89)	(6.28)
lnfinde	0.237***	0.309***	0.279***	0.335***	0.260***	0.317***
	(6.27)	(7.35)	(6.15)	(7.20)	(8.10)	(9.56)
-cons	10.32***	11.48***	9.848***	10.66***	9.543***	10.41***
	(11.94)	(15.49)	(10.79)	(12.84)	(17.04)	(18.28)
hausman	chi2(10) =83.97	chi2(10) =99.22	chi2(10) =50.84	chi2(10) =33.62		
test	Prob>chi2 =0.0000	Prob>chi2 =0.0000	Prob>chi2 = 0.0000	Prob>chi2 = 0.0002		
sigma_u _cons					0.417***	0.511***
					(6.90)	(7.06)
sigma_e _cons					0.0610***	0.0521***
					(21.57)	(20.21)
N	270	240	270	240	270	240
Model setting	FE	FE	FE	FE	MLE	MLE

*Notes: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively. In order to avoid possible*

heteroscedasticity problems, all measurement results in this paper use White heteroscedasticity-consistent standard error, which is omitted below.

In order to ensure the reliability of the research results, this paper will conduct a robustness test in two aspects: variable replacement and estimation method change. Columns (3) to (4) of Table 2 replace the proxy variable of high-quality economic development with real GDP, and find that the results are still credible, and university research activities still have a positive impact on high-quality economic growth. Columns (5) to (6) replace the OLS estimation with the maximum likelihood estimation (MLE) on the basis of columns (3) to (4), and find that the results are still reliable, which further verifies hypothesis 1 that the increase of university R&D expenditure effectively promotes the high-quality economic development.

In terms of control variables, the impact of opening up degree, economic urbanization level, Internet popularization degree and financial depth on high-quality economic growth is consistent with the results of existing literature (Wang et al., 2002; Shao et al., 2013; Fu Yuan Hai and Lin Jiawei, 2021) In other words, the level of economic urbanization, Internet popularization and financial deepening have effectively promoted high-quality economic growth. However, contrary to intuition, infrastructure construction has a negative impact on economic growth, which may be due to the network property of transport infrastructure, which makes the panel data model from a non-spatial perspective ignore the spatial spillover effect generated by transport infrastructure, and then misestimate the impact of transport infrastructure on regional economic growth (Zhang, 2012).

3.2. Robustness test: endogeneity and instrumental variable method

In theory, the externalities generated by university research activities will improve the level of local economic development. But at the same time, the reality is that when the level of economic development in a certain region is higher, the local government is more able to invest resources into the scientific research activities of colleges and universities, which is more conducive to the scientific research and development activities of colleges and universities to serve the practice of local economic development and improve the quality of regional economic development. This shows that there may be a bidirectional causal relationship between the explained variable economic development and the core explanatory variable of university R&D expenditure, which may lead to the endogeneity problem that may make the estimated results inconsistent. Therefore, in this part, we will use the instrumental variable method to estimate, so as to reduce the estimation bias caused by endogeneity.

Instrumental variables are required to meet both strict exogeneity and high correlation with endogenous explanatory variables. In terms of correlation, the R&D expenditure of higher institutions may be affected by the number of students enrolled in the current year, the number of college students, the number of teachers, and the R&D expenditure of the previous year. To be specific, China's higher education basically implements the allocation mode of "comprehensive quota + special subsidy", that is, in the case of considering the average education cost of students, the base is determined according to the school's teaching staff, school level and other aspects, and other specific conditions of the school in the current year (such as infrastructure) to formulate the financial allocation form of special subsidy (Lin and Chen; Ben;2011). Therefore, the above variables can be regarded as alternative variables of instrumental variables in terms of correlation.

In terms of exogeneity, instrumental variables are required to be uncorrelated with disturbance terms. Under the setting of linear model in this paper, the instrumental variable is required to be uncorrelated with the explained variable. Considering that the lagged value of research funding has been included in the analysis in the benchmark regression, it is excluded first. Secondly, considering the number of teachers in a school, studies have shown that college teachers have strong socioeconomic attributes (Zhao and Luo, 2000; Wei Hongwei, 2015). Social part-time jobs, achievement transfer and self- employment are closely related to economic growth, so the number of teachers does not meet the requirements of exogeneity.

Considering the number of college students and the number of students enrolled in the current year, generally speaking, the number of college students is not included in the statistical category of labor force. According to the C-D production function, it is difficult for the number of college students not included in the scope of labor force to have a positive impact on economic growth. At the same time, when analyzing the economic performance of the number of students in colleges and universities, the lagged multi-period data of the number of students in colleges and universities are mostly used to analyze the economic impact of human capital on labor inflow (Xia and Lu, 2020). Therefore, the number of students in the current period is difficult to have a correlation with economic growth. In addition, the determination of instrumental variables is generally based on variables with strong exogeneity such as history or geography (Sheng et al., 2011) and the quota allocation of college enrollment is largely affected by historical conditions (Wang and Ma, 2016).

At the same time, in order to balance the development gap between regions, the state tends to tilt the enrollment quota of colleges and universities to the western ethnic areas. Moreover, with the reform of "enrollment plan allocation method" clearly implemented in 2014, the planned index of college enrollment is increasingly deviating from the "territorial" characteristics. Due to the influence of various factors, the enrollment number of colleges and universities in the current period can be considered to have a low level of correlation with the degree of economic development in the current period. Therefore, on this basis, the enrollment number of colleges and universities and the number of college students can be used as instrumental variables to be included in the analysis framework to overcome the possible endogenous problems.

Table 3. Research and development expenditure of universities and high-quality economic growth: IV-GMM estimation.

Explained variable	(1)	(2)	(3)	(4)
	GDP per capita		Real GDP	
lnrd	0.147**		0.250***	
	(2.07)		(3.14)	
lnlrd		0.137**		0.226***
		(2.53)		(3.66)
open	-2.795***	-2.824***	-2.299***	-2.568***
	(-4.24)	(-4.84)	(-3.11)	(-3.85)
lnpopdensity	-0.0161	-0.0281	-0.00417	-0.0191
	(-0.57)	(-1.05)	(-0.13)	(-0.63)
urban	1.821***	1.785***	1.476***	1.820***
	(4.84)	(4.45)	(3.50)	(3.97)
popgro	-0.826	0.329	-0.932	0.361
	(-1.22)	(0.60)	(-1.23)	(0.58)
lninfrus	-0.327***	-0.432***	-0.677***	-0.667***
	(-3.00)	(-3.76)	(-5.54)	(-5.08)
lnnet	0.190***	0.108***	0.200***	0.112***
	(5.21)	(3.56)	(4.89)	(3.24)
lnfinde	0.216***	0.268***	0.246***	0.267***
	(6.27)	(6.72)	(6.37)	(5.87)
Anderson canon. corr. LM statistic	20.745***	28.347***	20.745***	28.347***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Cragg-Donald Wald F statistic	10.881	15.605	10.881	15.605
Hansen test p-value	0.0970	0.4026	0.4312	0.7262
N	270	240	270	240

*Notes: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively.*

Since the data used in this paper are inter-provincial panel data, there are large differences in economic development among provinces, which may lead to heteroscedasticity problems. Meanwhile, the number of

instrumental variables used in this paper is 2, referring to Fu and Lin (2021). Based on the advantages of the GMM estimation method, this paper uses the two-stage GMM instrumental variable method to carry out the econometric lined 3 reports the estimation results of IV-GMM. In terms of the reliability test of instrumental variables, the P values of Anderson canon. corr. LM statistics are all greater than 1% significance level, rejecting the null hypothesis that instrumental variables cannot be identified. In terms of the weak instrumental variable test, the Cragg-Donald Wald F statistics are higher than the critical value of stock-yogo test at the corresponding level, indicating that the enrollment number of the above universities is highly correlated with the number of students and the scientific research investment of the universities. In the over-identifiability test, the P values of Hansen's test are all greater than 0.05, which cannot reject the null hypothesis of over-identifiability of instrumental variables. Therefore, the selection of the above instrumental variables can be considered as effective.

In the same way as the benchmark regression test method, columns (1) - (2) of Table 3 respectively report the IV-GMM estimation results with per capita GDP as the explained variable and the R&D expenditure of universities and its one-period lag value as the core explanatory variable. It can be seen that after using the instrumental variable method, the estimated results of the core explanatory variables are still significantly positive. At the same time, after replacing the explained variable (columns (3) - (4) of Table 3), the conclusion is still valid, which further confirms Hypothesis 1 in this paper. It shows that the growth of university R&D investment has steadily boosted the high-quality development of China's economy.

4. Analysis of impact mechanism

The above analysis confirms the role of university R&D expenditure in promoting high-quality economic development. On this basis, we hope to further analyze the economic mechanism behind this phenomenon. According to Hypothesis 2, the driving effect of university R&D investment on economic growth is, on the one hand, through the knowledge increase and talent training brought by scientific research activities themselves, it enriches the accumulation of human capital and drives economic growth; On the other hand, as an independent economic entity, the transformation level of scientific research results will affect the driving effect of scientific research activities on economic growth. In order to test whether the above hypothesis is correct, we first examine the influence of the transformation of scientific research achievements on relevant economic variables, and then consider the possible mediating effect of talent training. The details are as follows:

Table 4. Research and development expenditure of universities and high-quality economic growth: analysis of the influencing mechanism.

Explained variable	Transformation of scientific research achievements				Personnel training			
	(1) lntransfer	(2) lnpgdp	(3) lntransfer	(4) lngdp	(5) edustru	(6) lnpgdp	(7) edustru	(8) lngdp
lnrd	-0.237	0.0813***	-0.237	0.134***	0.0121	0.0366	0.0121	0.0742***
	(-0.74)	(3.83)	(-0.74)	(5.16)	(1.53)	(1.50)	(1.53)	(2.88)
lntransfer		0.000841		-0.00103				
		(0.15)		(-0.17)				
edustru						1.020*		1.719***
						(2.02)		(3.43)
Control variables	yes	yes	yes	yes	yes	yes	yes	yes
_cons	6.473	9.485***	6.473	9.216***	0.320	9.991***	0.320	9.297***
	(0.64)	(10.70)	(0.64)	(10.12)	(1.65)	(11.16)	(1.65)	(11.07)
Sobel	Z = -3.121 < 0. 97		Z = -1.019 < 0. 97		Z = 3.218 > 0. 97		Z = 0.9932 > 0. 97	
Mediating effect	(-)		(-)		(0.0183)		(0.00865)	

N	252	252	252	252	270	270	270	270

*Notes: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively.*

4.1. Mechanism analysis: Transformation of scientific research achievements

We use the logarithm of the number of technology transfer contracts of universities as the mediating variable to test whether scientific research activities of universities can boost economic growth through the transformation of scientific and technological achievements. In columns (1) to (2) and (3) to (4) of Table 4, per capita GDP and GDP are respectively used as the explained variables of Model (3) for regression. It can be seen that the coefficients α_1 and β_2' in Model (2) and Model (3) and at least one of them are not significant, so Sobel test is needed to test the results. The results show that the Z statistics of columns (1) and (2) are less than 0.97, and the Z statistics of columns (3) and (4) are also less than 0.97, indicating that the mediating effect is not significant (Fang and Na, 2020). It can be seen that the increase of R&D activities in universities can hardly affect economic growth through the transformation of scientific research achievements, and bring new growth momentum for the high-quality development of regional economy.

However, it is observed that the sign of Z statistic is negative, which may lead to a masking effect (Wen, 2014), so we refer to Duan and Zhuang (2021), the results show that the transformation mechanism of university scientific research achievements shows a masking effect between university scientific research activities and economic growth. The P value of Sobel test with per capita GDP as the explained variable is 0.0018, so the masking effect is significantly established. This proves the correctness of Hypothesis 2 to a certain extent; that is, the driving effect of university research activities on economic growth will be limited due to the constraints of scientific research achievements transformation dilemma.

4.2. Mechanism analysis: Talent cultivation

Considering the possible mediating effect of talent training mechanism, this paper uses the ratio of the number of junior college workers or above to the number of employed workers to represent the labor force with higher education training, so as to analyze the mediating mechanism between talent training and university scientific research activities and economic growth. Consistent with the research idea of the transformation of scientific research achievements, columns (5) to (6) and (7) to (8) of Table 4 take per capita GDP and GDP as the explained variables of Model (3) to test the mediating effect. It can be found that the Z-statistics of columns (5) to (8) are all greater than 0.97, indicating that the mediating effect is established. At the same time, the coefficients of the mediating effect are 0.0183 and 0.00865 respectively, which are lower than those in Table 2, indicating that the mediating effect is partial. In other words, the knowledge growth and talent training brought by scientific research activities have obvious externalities, and the investment in scientific research enriches the accumulation of human capital, thus promoting the high- quality economic growth.

Combined with the above two mechanisms, the driving effect of university R&D investment on economic growth is that, on the one hand, through the talent training characteristics of scientific research activities, the accumulation of human capital is enhanced, and the quality of economic growth is improved; On the other hand, due to the constraints of the transformation of scientific research achievements at the present stage, the driving effect of scientific research activities in universities on economic growth is limited to a certain extent, which hinders the improvement of high-quality economic development of scientific research activities in universities. Hypothesis 2 is confirmed.

5. Heterogeneity analysis

5.1. Regional heterogeneity analysis

The spatial layout of higher education in China has always been significantly affected by macro-control. Since the founding of the People's Republic of China, through a series of policies and measures, a distribution pattern of higher education based on central cities such as Beijing, Shanghai, Nanjing, Wuhan, Chengdu, and Xi'an and with key universities as the core has been formed (Liu, 2019). Compared with the level of economic development, there is no serious imbalance between the eastern and western regions in the geographical spatial distribution of higher education in China (Hou and Xue,2008). This is not consistent with the spatial distribution pattern of China's economic development, and the spatial difference of higher education resources among regions is not prominent, which is in sharp contrast with the regional economic development level. On this basis, the remaining part of this paper will firstly conduct an empirical study on the regional differences of the influence of university scientific research activities on high-quality economic growth; Based on the spatial perspective, the possible spatial spillover effect is tested.

Table 5. Research and development expenditure of universities and high-quality economic growth: regional heterogeneity analysis.

	(1) Eastern Region1	(2) Central Region	(3) Western Region	(4) Northeast Region
lnrd	0.172***	0.118***	-0.0132	0.0656
	(8.43)	(4.57)	(-0.59)	(1.78)
open	-4.243***	-1.680	-0.280	-5.338*
	(-13.41)	(-1.66)	(-0.13)	(-2.95)
lnpopdensity	-0.207***	0.0454	0.00305	0.0730
	(-4.02)	(0.63)	(0.07)	(1.13)
urban	0.625	4.301***	3.136**	-0.585
	(1.64)	(5.80)	(2.80)	(-0.32)
popgro	0.120	-1.652	0.360	-4.885**
	(0.21)	(-1.64)	(0.16)	(-9.76)
lninfrus	-0.491**	0.320*	-0.502	-0.202
	(-2.48)	(2.25)	(-1.54)	(-0.57)
lnnet	0.172***	0.145***	0.196***	0.356**
	(5.02)	(4.78)	(3.67)	(6.33)
lnfinde	0.157***	0.0626	0.277***	0.00631
	(6.29)	(0.87)	(4.51)	(0.08)
_cons	10.73***	5.185***	11.64***	8.537**
	(14.74)	(6.30)	(9.41)	(6.23)
N	90	54	99	27

*Notes: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively.*

Table 5 shows the measurement results of heterogeneity analysis, and columns (1) to (4) correspond to the eastern, central, western and northeastern regions, respectively. From columns (1) and (2) of Table 5, it can be seen that the driving effect of university R&D expenditure on high-quality economic growth is significantly positive in the eastern and central regions, indicating that in the eastern and central regions, university research activities have strongly promoted economic development. At the same time, the coefficient in the eastern region is higher than that in the central region, indicating that compared with the central region, the universities in the eastern region have a

[1] According to the Statistical Bulletin of the People's Republic of China on National Economic and Social Development 2017, the eastern region includes: Beijing, Tianjin, Hebei and Shanghai Hainan, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; The central region includes: Shanxi, Anhui, Jiangxi, Henan and Hubei and Hunan 6 provinces; The western region includes: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang 11 provinces (autonomous regions and municipalities); Northeast China consists of Liaoning, Jilin and Heilongjiang provinces.

stronger ability to serve the local economic and social development. However, for the western and northeastern regions, the R&D expenditure of local colleges and universities does not have a positive impact on the economic and social development of the regions. However, as mentioned above, the western region has Chengdu, xi 'an and other important educational towns, while the northeast region has many powerful key universities. Are the scientific research activities of these universities ineffective? We guess that this is an error caused by ignoring the spatial perspective. Therefore, in the next part, this paper will analyze the spatial effect of university scientific research activities on economic development based on the spatial perspective.

5.2. The source of regional heterogeneity: spatial perspective

In order to analyze the possible spatial effect of university scientific research activities, this paper adopts the estimation strategy of Lesage et al. (2008), and uses the square of the inverse of geographical distance to construct the spatial weight matrix. Based on the spatial error model (SEM), the spatial Durbin model (SDM) is used to analyze the possible spatial spillover effect. The purpose of setting SEM is to identify the spatial errors that may be missed by the non-spatial model, and preliminarily verify the existence of spatial effects. The reason for using SDM is that SDM is a standard framework for analyzing various spatial effects, which can be reduced to spatial autocorrelation model (SAM) and spatial error model (SEM) under different coefficient values (Wu et al., 2019). The SEM and SDM Settings used in this article are as follows:

$$lnpgdp_{it} = \beta_0 + \beta_1 lnrd_{it} + \delta x_{it} + \gamma_i + \tau \sum_{j=1}^{n} w_{it}\, \varepsilon_{it} + \mu_{it} \tag{4}$$

$$lnpgdp_{it} = \beta_0 + \beta_1 W lnpgdp_{it} + \beta_2 W lnrd_{it} + \delta w x_{it} + \gamma_i + \tau \sum_{j=1}^{n} w_{it}\, \varepsilon_{it} + \mu_{it} \tag{5}$$

Among them, Model (4) is the spatial error model (SEM), and Model (5) is the spatial Durbin model (SDM), W is the inverse geographic distance spatial weight matrix. Table 6 shows the specific results of the spatial econometric model.

Table 6. Research and development expenditure of universities and high-quality economic growth: spatial perspective.

Explained variable	(1)	(2)	(3)	(4)
	GDP per capita		Real GDP	
lnrd	0.00411	0.00989	0.0410**	0.0495***
	(0.26)	(0.59)	(2.50)	(2.83)
W lnrd		0.210**		0.227**
		(2.45)		(2.49)
Control variables	yes	yes	yes	yes
Spatial	0.849***	0.523***	0.877***	0.406***
rho	(18.44)	(5.36)	(25.16)	(3.91)
Direct effect		0.0231		0.0596***
		(1.17)		(3.06)
Spatial spillover effect		0.443**		0.405***
		(2.32)		(2.67)
Total effect		0.466**		0.465***
		(2.30)		(2.87)

N	270	270	270	270
R2	0.775	0.149	0.647	0.211
Model setting	SEM	SDM	SEM	SDM

*Notes: ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively. The figures in parentheses are the t values of the corresponding variables.*

In Table 6, columns (1) and (3) show the SEM estimation results of the explanatory variables are GDP per capita and GDP. By examining the spatial Durbin model, it can be found that the coefficients of the spatial lag term $Wlnrd_{it}$ in columns (2) and (4) are all significant, which further confirms the spatial spillover effect of university research activities on high-quality economic growth. It should be noted that the estimation results of SDM model do not directly reflect the spatial effect, which needs to be solved by partial differential method (Wu et al., 2016). The decomposition process is simplified. Table 6 shows the specific decomposition results. The results show that the direct effect of university scientific research activities on high-quality economic growth is not significant when GDP per capita is the explained variable, but is significantly positive when GDP is the explained variable, which indicates that the direct effect of university scientific research activities on local economic growth is not robust at the national level. The spatial spillover effect is significantly positive under the conditions of GDP per capita and GDP, which indicates that there is a positive spatial spillover effect of university scientific research activities on economic growth. In other words, the scientific research activities of universities in this region positively promote the high-quality growth of other regions. This shows that the scientific research activities of colleges and universities in the western and northeastern regions are not invalid. From the spatial perspective, the scientific research activities of colleges and universities in the above two regions promote the economic growth of other regions.

6. Conclusions and policy implications

Using the panel data of 30 provinces in China from 2009 to 2017, this paper empirically examines the impact of scientific and technological R&D activities of universities on the high-quality economic development of China, and discusses the mechanism of the impact from two aspects of talent cultivation and the transformation of scientific research achievements. In addition, this paper also uses relevant instrumental variables to deal with the possible endogeneity between university research expenditure and high-quality economic development.

Furthermore, this paper analyzes the regional heterogeneity of university research activities on economic growth from a spatial perspective, and constructs a spatial econometric model based on this. From the perspective of spatial spillover effect, this paper explains the source of regional heterogeneity.

The results show that: First, the increase of university R&D investment has effectively boosted the high-quality development of China's economy. Second, The driving effect of university R&D investment on economic growth is that on the one hand, through the knowledge growth and talent training brought by scientific research activities, it enriches the accumulation of human capital and drives economic development; On the other hand, due to the constraints of the transformation of scientific research achievements, the driving effect of university research activities on economic growth will be limited to a certain extent. Third, There are significant regional differences in the promoting effect of university scientific research activities on the high-quality economic development, and the reason for this difference may be the spatial spillover effect of university scientific research activities, that is, the scientific research activities of universities in this region positively promote the high- quality growth of other regions.

The conclusions of this paper provide the following policy implications for the scientific research activities of universities and high-quality economic development.

Talent training is the core mission of institutions of higher learning, and institutions of higher learning should firmly grasp the key of talent training. Adhere to the general tone of "cultivating morality and cultivating people",

promote the integrated development of science and education, and closely combine student training with scientific research tasks. While laying a solid professional foundation for students, we also focus on cultivating their scientific research and innovation capabilities. We will focus on the quality of graduates to provide a solid talent foundation for high-quality economic development in China.

Moreover, promote the reform of scientific research evaluation of university teachers, and emphasize the innovation of scientific research achievements and their contribution to economic and social development. Efforts should be made to build a scientific research system and innovation system that ADAPTS to the national economic and social development, to solve the possible "bottleneck" problem of core and key technologies in the process of national development, to emphasize the application of scientific research achievements in colleges and universities, to break through the "blocking points" and "stuck points" in the transformation of scientific research achievements in colleges and universities, to innovate the scientific research evaluation system, and to emphasize the contribution ability of scientific research achievements to social services. Highlight the important role of university technology transfer and achievement transformation in the evaluation of teachers' scientific research, strengthen the construction of key disciplines and talents training according to the trend of social development, and improve the ability of colleges and universities to serve local economic development.

Finally, to reasonably coordinate the distribution difference between the spatial layout of higher education resources and the economic and social development in China, on the one hand, it is necessary to strengthen the ability of local colleges and universities to serve the local economic and social development, so that the local industrial development and the construction of scientific research disciplines in colleges and universities can be promoted in a coordinated manner; On the other hand, it is necessary to face up to the spatial spillover effect of scientific research activities in colleges and universities. It is necessary to establish a reasonable way for the transformation of achievements among regions, overcome local protectionism, build a nationwide market for the transformation of scientific research achievements, increase the economic compensation for the outflow of achievements, and jointly promote the high-quality development of China's economy.

Funding Statement

This research received no external funding.

Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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