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The Relationship between R&D Funding and Research Output in Regular Higher Education Institutions

-- An analysis based on panel data from 111 domestic "211 Project" and provincial-ministry co-established universities

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Abstract: This study uses panel data from 111 Chinese "211 Project" and provincial-ministry co-established universities from 2008 to 2016. R&D funding is the explanatory variable, while the number of publications in international and national journals and the total number of projects are the dependent variables. A multiple linear regression model is employed to investigate the relationship between R&D funding and research output across different regions in China. The results indicate a significant positive correlation between R&D funding and both the number of publications in international and national journals and the total number of projects. However, the extent to which increased funding promotes research output varies by region.

Keywords: Regular Higher Education Institutions; R&D Funding; Research Input-Output.

1. Introduction

Higher education institutions are a significant source of scientific output in China. President Xi Jinping emphasized the importance of higher education in building a strong education system during the fifth collective study session of the Central Political Bureau. The number of published papers has long been a major metric for assessing the achievements of higher education. In recent years, China's higher education sector has rapidly developed, and funding for research has steadily increased. From 2000 to 2020, national higher education research expenditures grew significantly from 12,030.589 million yuan to 237,509.173 million yuan. This trend is closely linked to the national emphasis on research and supportive policies. Concurrently, the number of academic publications rose from 284,235 in 2000 to 1,129,917 in 2020, indicating increased research activity and improved research quality. National policies directly impact research output, with documents such as the "National Medium- and Long-term Science and Technology Development Plan (2006-2020)" advocating for increased research investment and support for universities in fundamental and cutting-edge research. The "14th Five-Year Plan for Scientific and Technological Innovation" aims to enhance the efficiency of research funding usage and encourage high-level research outcomes. Policies like the "Several Measures to Further Strengthen the Cultivation and Utilization of Young Scientific and Technological Talent" stress the importance of supporting young researchers through various funding channels. Additionally, regulations like the "Interim Measures for the Management of the National Key R&D Program" aim to optimize resource allocation and improve transparency and efficiency in research funding, thereby fostering continuous research output from universities. Despite significant differences in research funding and output among universities, it is essential to explore the underlying reasons and their impacts.

2. Literature Review

2.1. Domestic and International Research Status

Extensive research has been conducted on the impact of R&D funding on research outcomes. Existing studies on the scale of funding and research project output fall into two main categories: those comparing the impact of funding on research output and those analyzing the dynamic relationship between R&D funding and research outcomes. Research indicates a positive influence of R&D funding on the quantity and impact of publications. For example, Yu Zhenglu and others conducted statistical analysis on the output and impact of papers from four types of programs or fund projects from the perspectives of institutions, regions, disciplines, high-end papers, and zero-citation rates. They also studied the time relationship between scientific and technological investment and paper output[1]. Jiri Vanecek found that R&D funding supports nearly all types of research outputs[2]. However, there is debate over the impact of funding on research quality. Studies like that of José Miguel Benavente show a positive significant impact of research funding on the quantity and quality of publications[3], while Rachel Heyard found that increased funding boosts research publication and dissemination, with significant improvements in research quality[4]. Geographic and disciplinary differences also affect the impact of R&D funding on research outcomes. For example, Wang Feifei found that funding enhances paper quality, with varying effects across regions and disciplines[5]. The quality of researchers also influences the impact of R&D funding, as noted by Fadderke et al.[6], who found that the performance of researchers receiving substantial funding improved, with variations across disciplines. Research has also explored the influence of R&D funding on young researchers in universities. For instance, Huang Yifan's study using a multi-period difference-in-differences method showed varied effects of R&D funding on different performance indicators of young university researchers

across disciplines and age groups[7].

Another type of research has analyzed the dynamic relationship between funding for science and technology and research outcomes. For example, Duan Peixin used the difference-in-differences method to examine the impact of increased funding on research output and further eliminated irrelevant project outputs to verify the "net effect" of funding changes. The study found that an increase in scientific funding significantly enhanced both the quantity and quality of research output. When considering the "net effect" by excluding irrelevant outputs, the increase in funding was even more significant for improving project output quality[8]. Wang Feifei and colleagues found that an increase in the number of funded projects could generally enhance scholars' performance, and an increase in funding amounts could more dynamically boost output capacity and influence[9]. Ma Jianxia and others showed that when papers were funded by projects of a certain scale, their impact was relatively high; however, an increase in the number of funded projects did not necessarily lead to an increase in citations[10]. Some scholars have explored the connection between citation and funding types based on organizational divisions. For example, Gök et al.'s research found a positive correlation between citation impact and funding types, but a negative correlation with funding intensity[11]. Wu Fei's study indicated a significant positive correlation between per capita research funding in higher education institutions across various regions and the number of published scientific papers and patent applications. The increase in per capita research funding had a greater effect on promoting the number of patent applications than on published research papers, with regional differences in its impact[12]. Zhang Huili and colleagues used a VAR model for empirical analysis and found a long-term equilibrium relationship between university research input, the structure of funding sources, and university research output. They concluded that the impact of university research input on research output has a lag effect and a significant promoting effect[13].

2.2. Literature Evaluation

Existing research has provided a solid theoretical and empirical foundation for understanding the relationship between R&D funding and research outcomes. However, there is room for improvement. Domestic studies rarely analyze the specific context of Chinese universities, while the circumstances of foreign universities differ significantly from those in China. This study uses panel data from 111 "211 Project" and provincial-ministry co-established universities from 2008 to 2016 to explore the relationship between R&D funding and research output, particularly focusing on the number of publications in international and national journals and the total number of projects.

3. Research Design

3.1. Variable Selection

This study uses R&D funding in regular higher education institutions as the explanatory variable and research output as the dependent variable to examine the relationship between research input and output. Following relevant literature, R&D funding is chosen as the explanatory variable. The number of publications in international and national journals and the total number of projects are selected as the dependent variables. To account for the impact of regional economic development on scientific output, GDP and total retail sales of consumer goods in different regions are included as control variables. Additionally, the number of researchers involved in scientific projects is included as a control variable. Table 1 provides specific variable definitions and symbols.

Table 1. Definition and symbol of variable

Type of Variable	Name of Variable	Symbol of Variable	Definition of Variable
dependent variable	publications in international and national journals	publications	The number of publications in international and national journals
	total number of projects	projects	Total number of projects in each school
explanatory variable	R&D funding	funds	Actual R&D funding invested by each school(thousand CNY)
control variables	GDP	GDP	Gross domestic product of each provincial administrative region in a given period (in real terms)
	total retail sales of consumer goods	sales	Total consumer goods sold directly by industry to urban and rural residents and social groups (in real terms)
	researchers involved in scientific projects	SS	The number of researchers involved in scientific projects in each school that year

3.2. Research Sample and Data

Panel data from 111 "211 Project" and provincial-ministry co-established universities from 2008 to 2016 were used, obtained from the EPS database. To ensure data stability and reliability, extreme or abnormal values were trimmed.

3.3. Model Construction

Based on the above hypotheses and analysis, a multiple linear regression model was constructed to study the relationship between R&D funding and research output using panel data from 111 "211 Project" and provincial-ministry co-established universities from 2008 to 2016:

$$publications_{i,t}=a0+\alpha1 funds_{i,t}+\alpha2 GDP_{i,t}+\alpha3 sales_{i,t}+\alpha4 SS_{i,t}+\Sigma college+\Sigma year+\varepsilon_{i,t} \quad (1)$$

$$number_{i,t}=a0+\beta1 funds_{i,t}+\beta2 GDP_{i,t}+\beta3 sales_{i,t}+\beta4 SS_{i,t}+\Sigma college+\Sigma year+\varepsilon_{i,t} \quad (2)$$

where $\alpha0$ and $\beta0$ are constants, αi and βi ($i=1,2,3,4$) are

regression coefficients of explanatory and control variables, and εi (i=1,2) are random error terms.

4. Empirical Analysis

4.1. Descriptive Statistical Analysis

Stata 17.0 was used for descriptive statistical analysis of the sample data to understand the overall characteristics. Table 2 shows that the sample size is 887, with an average R&D funding of 623,468.1 yuan, a minimum of 1,203 yuan, and a maximum of 4,233,080 yuan, indicating a significant disparity in R&D funding among schools. The average number of publications in international and national journals and total projects are 1,378 and 1,946, respectively, with standard deviations of 1,662.442 and 1,781.018, indicating large disparities in research output among schools.

Table 2. Descriptive analysis

Variable	Obs	Mean	SD	Min	Median	Max
publications	887	1377.572	1662.442	3.000	730.000	10418.000
projects	887	1946.130	1781.018	10.000	1397.000	11130.000
funds	887	623468.100	701852.400	1203.000	373976.000	4233080.000
GDP	887	20137.065	14736.297	398.000	15758.000	73546.000
sales	887	7999.029	5834.478	130.000	6313.000	31095.000
SS	887	1066.622	1091.686	10.000	727.000	7793.000

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

4.2. Correlation Analysis

Tables 3 and 4 show the correlation analysis results, demonstrating the reliability of the sample. A significant positive correlation exists between R&D funding and the number of publications in international and national journals at the 1% level, with a correlation coefficient of 0.833. Similarly, a significant positive correlation exists between R&D funding and the total number of projects at the 1% level, with a correlation coefficient of 0.850. The correlation coefficients confirm the reliability of the sample, warranting further regression analysis.

Table 3. Correlation analysis1

	publications	funds	GDP	sales	SS
publications	1	0.828***	0.395***	0.405***	0.739***
funds	0.833***	1	0.361***	0.363***	0.807***
GDP	0.232***	0.194***	1	0.967***	0.236***
sales	0.263***	0.218***	0.971***	1	0.238***
SS	0.769***	0.745***	0.130***	0.149***	1

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Table 4. Correlation analysis 2

	projects	funds	GDP	sales	SS
projects	1	0.883***	0.300***	0.292***	0.828***
funds	0.850***	1	0.361***	0.363***	0.807***
GDP	0.227***	0.194***	1	0.967***	0.236***
sales	0.249***	0.218***	0.971***	1	0.238***
SS	0.782***	0.745***	0.130***	0.149***	1

*, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

4.3. Benchmark Regression Analysis

Stata 17.0 was used for regression model testing, with fixed effects for schools and years. Table 5 shows that the number of publications in international and national journals and the total number of projects are significantly positively correlated with R&D funding at the 1% level, validating the research hypothesis.

Table 5. Regression Analysis

	(1)	(2)
	publications	projects
funds	0.001***	0.001***
	(9.699)	(7.230)
GDP	0.029	0.040**
	(1.397)	(2.553)
sales	-0.025	-0.086**
	(-0.506)	(-2.160)
SS	0.619***	0.607***
	(3.456)	(4.788)
_cons	-489.915**	638.036***
	(-2.226)	(3.408)
school	YES	YES
year	YES	YES
N	887	887
R^2	0.929	0.959
Adj. R^2	0.92	0.95

The values in parentheses are t-values adjusted for clustering. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

4.4. Heterogeneity Analysis

To study the impact of regional differences on the relationship between research input and output, the sample data were grouped by region (east, central, and west) based on the 2003 National Bureau of Statistics standards. Regression model testing using Stata 17.0 revealed that the number of publications in international and national journals and total projects significantly correlated with R&D funding in the eastern and central regions at the 1% level but not in the western region. This indicates that the impact of R&D funding on research output varies with regional development levels.

Table 6. Heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	publications	publications	publications	projects	projects	projects
funds	0.003***	0.000***	0.241	0.000***	0.018**	0.000***
	(3.88)	(8.08)	(1.24)	(9.12)	(3.08)	(11.52)
GDP	-0.001	-0.026	-0.033	-0.012	0.053	0.058*
	(-0.10)	(-0.78)	(-0.47)	(-0.45)	(1.33)	(1.95)
sales	0.033	0.091	0.164	0.054	-0.035	-0.132**
	(1.23)	(0.90)	(1.30)	(0.90)	(-0.51)	(-2.71)
SS	0.642***	0.103	0.714*	0.620***	0.410	0.892***
	(3.86)	(0.70)	(2.01)	(3.59)	(1.82)	(6.78)
_cons	-335.222**	-181.860	-279.447	125.253	27.087	80.114
	(-2.48)	(-1.01)	(-1.08)	(0.59)	(0.09)	(0.64)
school	YES	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES	YES
N	479	208	200	479	208	200
R^2	0.795	0.798	0.691	0.805	0.714	0.829

The values in parentheses are t-values adjusted for clustering. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

4.5. Robustness Test

We conducted robustness tests using a one-period lag and the inclusion of omitted variables. The regression results are presented in Tables 7 and 8. After lagging the dependent variable by one period, the hypothesis tests were performed using the same method. The results show that funding for science and technology is significantly and positively correlated with the number of publications in international and national journals, as well as the total number of projects, at the 1% significance level. When the omitted variable "province" is included, while controlling for school, time, and province, the significant positive correlation between funding for science and technology and the number of publications in international and national journals, as well as the total number of projects, remains at the 1% significance level. Thus, the model in this paper passes the robustness test, and the conclusions remain valid.

Table 7. Lagged one period test

	(1)	(2)
	publications	projects
funds (one-period lag)	0.001***	0.001***
	(6.05)	(5.32)
GDP(one-period lag)	0.019	0.046***
	(0.66)	(2.78)
sales(one-period lag)	0.002	-0.094**
	(0.03)	(-2.29)
SS(one-period lag)	0.640***	0.419***
	(2.91)	(2.97)
_cons	-444.091	926.374***
	(-1.45)	(4.29)
school	YES	YES
year	YES	YES
N	665	665
R^2	0.927	0.959

The values in parentheses are t-values adjusted for clustering. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

Table 8. The inclusion of omitted variables

	(1)	(2)
	publications	projects
funds	0.001***	0.001***
	(9.53)	(7.10)
GDP	0.029	0.040**
	(1.37)	(2.51)
sales	-0.025	-0.086**
	(-0.50)	(-2.12)
SS	0.619***	0.607***
	(3.40)	(4.71)
_cons	-489.915**	638.036***
	(-2.19)	(3.35)
school	YES	YES
year	YES	YES
province	YES	YES
N	887	887
R^2	0.929	0.959

The values in parentheses are t-values adjusted for clustering. *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively.

5. Conclusion

In summary, the following conclusions can be drawn: First, an increase in the funding for science and technology can enhance the number of publications in international and national journals as well as the total number of research projects. This indicates that increased funding for science and technology promotes research output. Second, the effect of science and technology funding on research output exhibits regional differences.

Based on these conclusions, the following recommendations are proposed: First, to increase the research output of higher education institutions, the government should increase funding for research across different regions, motivating researchers in higher education institutions and promoting research output. Second, the government should allocate research funding according to the research resources of different regions. The eastern and central regions have relatively abundant research resources compared to the western region, which has higher potential for research output. Therefore, the government should increase research funding for the western region to boost the research output of ordinary higher education institutions in that area.

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