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THE MEDIATING ROLE OF HUMAN CAPITAL IN THE RELATIONSHIP BETWEEN EDUCATION EXPENDITURE AND SCIENCE AND TECHNOLOGY INNOVATION: EVIDENCE FROM CHINA

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Abstract: *In recent years, China's rapid economic development has been accompanied by an increase in education spending, resulting in the accumulation of human capital. However, there is ongoing debate regarding whether and how education expenditures have fostered innovation in science and technology (S&T). This study uses panel data from 31 Chinese provinces, cities, and autonomous regions from 2006 to 2015 to look at the relationship between education spending, human capital development, and S&T innovation. It seeks to shed light on this problem. Our results reveal that education expenditure has a significant positive impact on S&T innovation, and human capital accumulation plays a mediating role in this relationship. Specifically, an increase in education expenditure can not only enhance the innovation ability of the educated but also strengthen their ability to accept and apply new technologies, leading to the transformation and transmission of knowledge. Furthermore, our study shows that education expenditure has a greater impact on S&T innovation than capital formation. The findings of this study have important policy implications. Given that education expenditure is an effective means of promoting S&T innovation, it is recommended that the Chinese government continue to boost investment in education, enhance the convenience of education consumption, and advance education supply-side reform. Additionally, policymakers should consider the structure of education expenditures and how it affects innovation, as well as the different impacts of household and public expenditures, education consumption, and education investment on the economy. In conclusion, this study provides evidence supporting the important role of education expenditure in fostering S&T innovation in China. By investing in education, China can continue to build its human capital, promote economic development, and advance social progress.*

Keywords: science and technology innovation; human capital accumulation; mediating effect.

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1. Introduction

Most people agree that there is a strong link between spending on education, building up human capital, and innovations in science and technology (S&T). Education expenditures not only contribute to socioeconomic development but also to the accumulation of human capital and the advancement of S&T innovation. The accumulation of human capital can accelerate the growth of S&T innovation and stimulate economic growth, provided that education expenditures are increased and education quality is enhanced.

In China, the rise of industrialization has been driven by societal development, technological advancements, and increasing economic status. However, this process requires a significant amount of human capital, which can be achieved through effective education that promotes technological advancements and enhances societal output. Education plays a crucial role in improving the quality of the economy, providing human capital for economic development, and stimulating innovation in the industry. At the micro-level, education also leads to increased family income and provides individuals with the opportunity to attain higher education, improve their skills, and enhance their personal and family status in society.

As family income in China continues to rise, both per capita household income and household education expenditures have increased. Education can increase human capital and make the social production system more efficient, resulting in significant positive externalities for society. This study aims to analyze the current situation of education in China from the perspective of human resource development and S&T innovation. It focuses on the effectiveness of education for human capital accumulation and proposes policy recommendations for guiding education consumption and using education to drive S&T innovation and promote economic transformation.

2. Literature Review

Education expenditure is divided into two main types: education consumption and education investment. Education consumption is defined as government or family spending on education services and products. In the 21st century, education consumption is increasingly seen as including more than just conventional school education; it is now seen as a more comprehensive form of consumption. Tao Meichung (2007) defines it as investment spending, where educators can develop human capital through investment expenditure on education, which will generate future income. "Education Investment" is money spent on educational infrastructure. Liu Hu (2011) further divides education consumption into two types: application-based and research-based. The former belongs to horizontal education, and while the total amount of social knowledge may not increase, it can improve the human capital of educated people by participating in social production activities and thus creating and increasing social wealth. Research-based education consumption explores and innovates knowledge-based consumption through research-based learning and plays a decisive role in accumulating S&T. National education has evolved from classroom-based learning to social and lifetime education. In the 21st century, education consumption now includes continuing education and lifetime education, as well as school and extracurricular tutoring.

Most of the writing about the link between education and S&T innovation has focused on how important it is in general.Nelssciencal.and tecnology on et al. (1966). argued that the role of education is twofold: first, it enhances the innovation ability of the educated, and second, it strengthens the ability to accept new technologies and apply them to all aspects of economic life. Ye Maolin (2005) pointed out that education enables individuals to accumulate human capital and is an important component of S&T. Liping Fu (2012) attributed the fundamental role of educational development in scientific and technological progress to the fact that educational development accelerates the transmission and transformation of knowledge and that the most important measure of educational development is investment in education funding. Yao Xuesong (2016) used provincial panel data to empirically study the role of capital and educational development on S&T innovation and found that educational development, as measured by educational expenditure investment, has a greater impact on S&T innovation than capital formation. However, this literature does not analyze the issue of the relationship between the structure of education expenditures and innovation.

Spending on education comes in two parts that go together. Household and public spending, education consumption, and education investment all have different effects on the economy.For instance, Zhang Wenyao

(2012) found a long-term cointegration relationship between higher education input and the western Chinese economy, but no short-term relationship.Qiao Lin (2013) used Fidel's model to prove that education consumption raises total factor productivity, has large spillover effects, and affects economic growth in BRICS nations. This also shows the difference between education consumption and education investment. Hu, Q. X., et al. (2013) discovered hierarchical spillover effects of education investment in China, split education's contribution to the economy into three levels, and described the impact paths at different levels, stressing the positive benefits of education consumption. Zhong Wu Ya (2014) examined long- and short-term education investments in Beijing, Shanghai, and Guangdong, China, and showed that moving education resources, notably from agglomerated to non-agglomerated locations, can boost total factor productivity and economic growth. Liu Hu et al. (2015) used the Granger test and the ECM model to find a greater economic impact from productive education consumption in China. Zhao Li et al. (2018) verified the association between college expansion and income gaps using DID analysis. Yu Wei et al. (2018) employed a threshold regression model to evaluate China's nonlinear education input-economic growth efficiency relationship. Wang Ying (2007) contends that although education and economic growth in China influence each other, the Cobb-Douglas function regression shows that educational inputs remain neutral to economic output growth. In addition, Song Jiale et al. (2010) use empirical analysis to find that the spillover effect of human capital on economic growth in China in recent years is significant; Mao Shengyong et al. (2010) find that higher education consumption in China is fast but uneven, and there are regional differences in the pulling effect. The preceding research contrasts the economic impact of education consumption and education investment and indirectly confirms its mode of action and differentiated influence on regional innovation from the standpoint of total factor productivity and human capital.

Throughout the previous literature, two aspects stand out: First, there are more studies on education in general, whereas there are nearly no studies on the influence of household education consumption on innovation. In contrast, examining home education consumption can help reveal structural changes in social involvement in education inputs and assess whether household education consumption is consistent with the economic objectives of innovation under the influence of market mechanisms. Second, when it comes to the association between education and STI (science and technology innovation), the majority of studies are limited to direct correlation studies, and there have been fewer investigations on the mediation effects of human capital. According to Romer's (1990) new growth model, education's input is a scaled input of knowledge input and capital input. Logically, there may be growing, decreasing, or constant returns to scale, and empirical analysis from the standpoint of the mediating influence of human capital would disclose this point more clearly. Based on the aforementioned considerations, this paper employs panel data collected from statistical yearbooks, etc., and, after processing, analyzes the mechanism of the role of education expenditures on regional innovation, in addition to conducting regression analysis and confirming the mediating effect. This research verifies the mediating role of human capital between education expenditure and S&T innovation by analyzing the effect of education expenditure on fostering S&T innovation from the standpoint of education expenditure.

This study's hypothesis is based on the preceding discussion:

H1. There is a positive relationship between education spending and STI, and human capital acts as a mediating variable in this relationship.

H2 STI is affected in various ways depending on the composition of a country's spending on education.

This research aims to investigate the connection between monetary investments in education and scientific and technological innovation (STI), confirm the mediating function of human capital in this connection, and assess the impact of education spending structure on STI.

3. Research Methodology

3.1 Mechanisms of the explanatory variables

The impact of education spending on STI is multifaceted and complex, and more research is needed to understand how education advances science and technology. Most academics, on the other hand, believe that spending on education promotes the growth of human capital and technological progress, and that the growth of human capital and technological progress help to promote technological innovation.

From the perspective of knowledge acquisition, educational resources are sourced internally and externally in two ways: internally, it is mainly the human capital formation caused by educational expenditures that stimulates STI; externally, it should be the technology spillover from the foreign investment process that promotes STI through learning and competition; the latter is not a direct consequence of educational expenditures and should be considered here as a control variable.

Modern growth theory also looks at whether spending on education can help make the best use of human capital and the best use of capital between the sectors that make goods and those that make knowledge when resources are limited. Based on this line of thought, this essay looks at how spending on education affects the growth of science and technology, as well as how human capital acts as a bridge between the two.

3.2 Selection of indicators

3.2.1 Explained variables

The number of patent applications (P). Patents and new products are the results of scientific and technological innovations. Because of this, the number of grants, applications, and valid patents has been used in the literature as a measure of innovation. Tang et al. (2011) say that the number of patent applications is a better measure of how much scientific progress has been made.In this paper, the number of applications is used as a measure of how new the technology is.

3.2.2 Explanatory Variables

Household consumption expenditure on education per capita(HEE). Not many empirical studies have been conducted in the previous literature using this indicator of education consumption, and data are difficult to obtain. Considering the availability of data, the household education consumption indicator here is the education consumption data from urban residents' consumption in the statistical yearbooks of each province to examine the residents' education consumption input.

Government financial expenditure on education (GEE). Fiscal funds play a pivotal role in the implementation of compulsory education and the promotion of higher education. At this stage, China's education funding mainly relies on state fiscal investment on the one hand, and government fiscal education expenditure is welfare expenditure, which replaces household consumption expenditure and facilitates the education consumption of poor households. On the other hand, it is public expenditure that mainly establishes public facilities, supplies educational resources, and improves the quality of education. For the sake of comprehensiveness of indicators, local financial education expenditures in the 2006–2015 provincial statistical yearbooks are summed up here with national financial education expenditures to represent government financial education expenditures and highlight the contribution of public resources to innovation.

3.2.3 Control variables

Human capital stock (HC) is measured using the average number of years of education in each province. According to human capital theory, education expenditure contributes to the creation of social wealth by increasing the productivity of educated workers. Therefore, human capital stock is considered an important control variable in the model.

Foreign direct investment (FDI) is another control variable included in the model. There has been a debate among scholars about the relationship between FDI and technological innovation, with some suggesting that FDI has a positive impact while others suggest that it has a negative impact. The authors include FDI as a control variable to account for this uncertainty and to test its impact on technological innovation in different provinces in China.

The data used for these indicators are obtained from various sources, including the China Statistical Yearbook, China Demographic Yearbook, and Wind database.

3.3 Construction of panel model

On the basis of an analysis of the factors that affect science and technology innovation, an econometric model is developed with patent applications as the explanatory variables and actual utilization of foreign capital, per capita education consumption expenditure of urban residents, government financial education expenditure, and human capital stock as the explanatory variables. From 2006 to 2015, statistical data from 31 provinces were used to develop a panel data model.

The panel data model was established using the data of 31 provinces from 2006 to 2015. The models are as follows.

$$P_{it}=\beta_0+\beta_1 GEE_{it}+\beta_2 HC_{it}+\beta_3 HEE_{it}+\beta_4 FDI_{it}+\mu_{it} \quad (1)$$

where *i* denotes 31 provinces, *t* denotes time, β_0 is the intercept term, β_1, β_2, β_3, β_4 are the coefficients, and μ is the random error term.

3.4 Intermediary effect analysis model construction

Given that there are two independent variables in this paper, the two independent variables are tested separately for mediating effects. First, using government financial education expenditure per capita as the independent variable and variables such as education consumption expenditure per household as the control variables, equation (2)(3)(4)(6) is used to establish the regression model of mediating effect A; then using education consumption expenditure per household as the independent variable and variables such as foreign direct investment and government financial education expenditure as the control variables of the model, equation (2)(3)(5)(6) is used to establish the regression model of mediating effects of structural model B.

$$P_{it}=\beta_0+\beta_1 GEE_{it}+\beta_2 HEE_{it}+\beta_3 FDI+\mu_{it} \quad (2)$$

$$HC_{it}=\beta_0+\beta_1 GEE_{it}+\beta_2 HEE_{it}+\beta_3 FDI_{it}+\mu_{it} \quad (3)$$

$$P_{it}=\beta_0+\beta_1 HC_{it}+\beta_2 HEE_{it}+\beta_3 FDI_{it}+\mu_{it} \quad (4)$$

$$P_{it}=\beta_0+\beta_1 HC_{it}+\beta_2 GEE_{it}+\beta_3 FDI_{it}+\mu_{it} \quad (5)$$

$$P_{it}=\beta_0+\beta_1 GEE_{it}+\beta_2 HC_{it}+\beta_3 HEE_{it}+\beta_4 FDI_{it}+\mu_{it} \quad (6)$$

In models A and B, equations (2), (3), and (6) are the three regression models involved in the test of the mediating effect. Equation (2) is a requirement for testing the mediating effect, and the significance of the mediating effect of human capital can only be tested further if the regression coefficient of government spending on education for science and technology innovation passes the given significant level test. Equation (3) looks at how spending on education by the government affects human capital. Spending on education by the government is the independent variable, and human capital is the dependent variable. Then equation (6) is constructed with government financial education expenditure and human capital stock as independent variables and science and technology innovation as dependent variables to test whether the mediating transmission mechanism with human capital as the mediating variable holds.

Using the test of model A as an illustration, if the coefficient an of the government financial expenditure on education (the antecedent variable) in equation (3) and the regression coefficient b of human capital (the mediating variable) in equation (6) are both significant, then the mediating effect holds; furthermore, if the antecedent variable of equation (6) is government financial expenditure on education, for which the regression coefficient C' is not significant, then the mediating effect does not hold. Assuming that the regression coefficients an of the antecedent variable in equation (3), government financial expenditure on education, and b of the mediating variable, human capital, in equation (6) are at least one nonsignificant, it is necessary to construct the Sobel statistic and conduct the Sobel test to determine whether the mediating variable in the hypothesis, the existence of a mediating effect, is significant.

4. Data Analysis and Findings

4.1 Results of Empirical analysis

Using Stata 14.0 statistical analysis software, we used equation (1) as the basic model to establish panel data and used generalized least squares (OLS), a fixed effect model, and a random effect model to obtain the estimation results of the impact of education expenditure on science and technology innovation, respectively. (See Table 1)

Table 1. Estimation results of the panel model

Variables	OLS Models	Fixed effects models	Random effects models
InHEE	0.774** (0.138)	0.394** (0.117)	0.368** (0.121)
InFDI	0.375** (0.0290)	0.00413 (0.0388)	0.132** (0.0359)
InGEE	0.924** (0.0628)	0.764** (0.0696)	0.750** (0.0650)
InHC	0.460 (0.353)	2.813** (0.490)	2.620** (0.444)
C	-9.894*** (1.389)	-7.792** (1.261)	-9.039** (1.301)
OBS	310	310	310
R^2	0.890	0.885	
wald			2008.18**
F	614.85**	530.52**	
Hausman		113.82***	

*Note: Standard deviations are in parentheses; ***, **, and * indicate passing the 1%, 5%, and 10% significance tests, respectively; OBS indicates the number of observations.*

Source: compiled by the authors.

The coefficients of the explanatory variables in both the fixed-effects model and the random-effects model are positive and pass the 1% significance test. The Wald test shows that the overall regression coefficient is significant. Meanwhile, the p-value of the Hausman test shows that $p<0.05$, so the original hypothesis is rejected and the estimation of the fixed-effects model is accepted. The estimation results were analyzed on the basis of the fixed-effects model as follows:

The coefficients of per capita household consumption expenditure on education and government financial expenditure on education are both positive and both pass the 1% significance test. The positive coefficient of household education consumption indicates that China's residents' education consumption is purposeful and plays a positive and active role in innovation.

The coefficient of government financial expenditure on education is significantly larger than the per capita household expenditure on education, indicating that the effect of government financial expenditure is more obvious. This is because, first, public spending still accounts for a large proportion of China's education spending, with economies of scale, and most of the public spending belongs to basic education spending. Since the government generally undertakes public investment in education, public investment in education trains teachers for residents' education consumption and facilitates residents' access to better education resources. Public investment in education also establishes public facilities, which provide more convenience for residents' education consumption and ensure that they can choose more education products.

Foreign investment does not pass the 10% significance test, but the coefficients are all positive, showing the complexity of the relationship between foreign investment and regional levels of science and technology innovation. Whether foreign investment is internalized as a substitute for regional education expenditure is closely related to the level of foreign technology, the current situation of regional human capital, the system of technology transfer, etc. A simple analysis can hardly reveal the relationship between foreign investment and regional innovation.

The coefficient of human capital is positive and passes the 1% significance test, which is also in line with the expectation that for every 1% increase in the stock of human capital, the number of patents granted will increase by 2.813%, with a significant effect.

4.2. Results of intermediary effect analysis

Given that the value of the Hausman statistic for equation (1) is 118.82 and that it passes the 1% significance test, it indicates that the test results are within the 99% confidence interval; therefore, the original hypothesis of the random-effects framework is rejected and the fixed-effects model is only reasonable. Consequently, the subsequent equations are estimated using fixed effects, and the estimation outcomes are presented in Table 2.

Table 2. Fixed effects regression results for each equation

Variables	Equation(2)	Equation(3)	Equation(4)	Equation(5)	Equation(6)
InGEE	0.940***	0.0625	—	0.917**	0.764**
	(0.0660)	(0.00768)	—	(0.0537)	(0.0696)
InHEE	0.517**	0.0439 **	1.231**	—	0.394**
	(0.121)	(0.0141)	(0.106)	—	(0.117)
InHC	—	—	5.179**	3.117**	2.813***
	—	—	(0.526)	(0.490)	(0.490)
InFDI	0.00477	0.000228	0.161**	-0.00224	0.00413
	(0.0410)	(0.00477)	(0.0432)	(0.0395)	(0.0388)
C	-4.330***	1.231***	-1.444	-11.52***	-7.792***
	(1.170)	(0.136)	(1.341)	(0.617)	(1.261)
Hausman	59.9***	23.13***	27.6***	36.04**	113.82**
R^2	0.872	0.712	0.835	0.881	0.885
F	624.05	227.42	465.61	678.04	530.52

Source: compiled by the authors.

Models A and B are essentially identical, so the test of mediating effects is described using Model A's (2)(3)(4)(6) equations. These are the stages of the examination: First, the effect of government education expenditures on innovation in science and technology is examined. According to the results of equation (2), the coefficient of government expenditure on education passes the 1% significance test with a coefficient of 0.94, indicating that the next stage of testing the mediating effect can be conducted. Second, the impact of government spending on education on human capital stock is investigated. The coefficient of public expenditures on education, as determined by Equation 3, is 0.063, which is significantly positive. This indicates that increasing government spending on public finance for education has a significant impact on human capital in a region, thereby increasing its stock. Third, the effect of government spending on education and human capital on technological innovation is examined. The coefficient of government expenditure on education is 0.764% and the coefficient of human capital is 2.813%, both of which are significantly positive, indicating that both government expenditure on education and human capital have a positive impact on the level of technological innovation in a region.

The mediating effect of human capital Table 3 shows that some of the effect of government spending on education on STI is mediated by the amount of human capital already in place. The total effect coefficient C in the model is 0.940, and it is significant at the 1% level. This means that government spending on education raises the level of science and technology innovation by a large amount. In addition, the coefficients of a and b are 0.063 and 2.813, respectively, both of which are significant at the 1% level, proving that the mediating variable human capital stock does have a significant mediating effect, with a mediating effect value of 0.177, which accounts for 18.8% of the total effect; that is, 18.8% of the effect of government spending on education to promote science and technology innovation is achieved through human capital stock. The mediating effect accounted for 18.8% of the total effect, i.e., 18.8% of the effect of government education expenditure on promoting science and technology innovation was achieved through human capital stock.

Table 3. Mediating effects of human capital with government financial education expenditure as the independent variable

Intermediate variables	Original factor	Intermediary Effect		Sobel test
InHC	*C*	*a*	*b*	*Zab*
	0.940	0.063	2.813	—
Test results	Direct effect	C’	0.764	Significant
	Intermediary effect	ab	0.177	Significant
	Intermediary effect / total effect	ab/c	0.188	18.8%

Source: compiled by the authors.

Table 4 shows that the effect of per capita spending on education by urban residents on science and technology innovation is partly mediated by the stock of human capital. In the first phase of the model, the total effect coefficient C is 0.517 and is significant at the 1% level. In the first step of the model, the total effect coefficient C is 0.517, which is statistically significant at the 1% level. This means that per capita spending on education by urban residents has a positive effect on the growth of science and technology innovation.The regression coefficients a and b are both significant at the 1% level, indicating that the mediating variable of human capital stock has a distinct mediating effect, and the value of the mediating effect is 0.124, accounting for 24.0% of the total effect, i.e., 24.0% of the effect of per capita education consumption expenditure of urban residents on the promotion of science and technology innovation is achieved through the mediating variable of human capital stock. Human capital stock mediates 24% of the total effect, or 24% of the effect of per capita education consumption expenditures on science and technology innovation.

Table 4. Mediated effects of human capital with urban residents' per capita consumption expenditure on education as the independent variable

Intermediate variables	Original factor	Intermediary Effect		Sobel test
InHC	*C* 0.517	*a* 0.044	*b* 2.813	*Zab* —
Test results	Direct effect	*C'*	0.394	Significant
	Intermediary effect	*ab*	0.124	Significant
	Intermediary effect / total effect	*ab/c*	0.240	24.0%

Source: compiled by the authors.

When you look at Tables 3 and 4, you can see that the amount of human capital has a bigger effect on innovation than the amount of education a household gets. This suggests that household education consumption is more focused and internalized into specialized human capital compared to public education expenditure. On the other hand, public education spending prioritizes the fundamental role of innovation output and emphasizes the joint role of capital and knowledge in generating innovation through inputs. However, both of these approaches demonstrate Romer's idea of a new economic growth model in that both education spending and human capital play a role in promoting science, technology, and innovation (STI). Education spending has a direct positive effect on STI, but its indirect effect through human capital stock becomes weaker in comparison to the total effect. This diminishing return to scale of education expenditure suggests that as knowledge stock increases, household education consumption and public education investment have complementary effects. However, in cases where public investment lags, the marginal payoff of education consumption decreases, leading to diminishing returns on the scale of education expenditure.

5 Conclusions

5.1 Study Conclusions. This paper shows that spending on education has a big positive effect on China's progress in science and technology, and that spending on education should be taken into account when promoting science and technology progress. Human capital stock is an important intermediary effect, with 18.8% and 24.0% of the effects of government financial expenditure on education and the per capita education consumption expenditure of urban residents respectively realized through human capital stock. Human resources are the key, and it is a feasible path to increase the stock of human capital by stimulating education expenditure and then to improve the level of technological innovation. Therefore, the following points are suggested.

5.2 Policy Recommendations.

Investment in Education Resources: The state should pay attention to investment in education resources, guide families to spend on education, improve human capital, and ensure the balance of public resources for education. Basic education is the cornerstone of the whole education system, and investment in education resources is an important guarantee for the long-term development of education in a country.

Diversified Education Investment System: China should gradually build a diversified education investment system by encouraging social capital outside the government to invest in school running, actively guiding the private sector to support education, and forming a diversified school running innovation system with the government, scientific research institutes, and real enterprises as one system. Businesses, private organizations, and individuals should also start and set up education public welfare funds to solve the problem of a lack of funds for education and boost the vitality of education.

Higher Education: The government should facilitate the transformation of individuals into human capital and encourage more people to attend college. The government should unify the management, planning, and coordination of higher education, improve the consumption structure, encourage the integration of social capital into the investment system, guide the reasonable expenditure of families on higher education consumption, highlight the nature of human capital investment, increase the profitability of higher education through the market mechanism, and actively promote the human capital of education. In addition, the government should increase its investment in higher education and encourage families to spend more on higher education by providing incentive payments to children who enroll in postgraduate and doctoral study programs.

Productive Education: Productive education is the reproduction base for scientific and technological progress, divided into research-oriented education and application-oriented education. The government should pay attention to the investment in productive education, realize the positive interaction between higher education and industry-university research projects, and provide a good platform and channel for the industrialization of science. Research-based education should provide support for basic research, such as financial support, human resources support, and hardware support.

In conclusion, investment in education is crucial for innovation and the long-term development of a country. The government should take steps to improve the efficiency of transforming human capital, encourage investing in different kinds of education, and put more money into higher education and education that makes people more productive. These recommendations aim to stimulate innovation and create a sustainable educational system that benefits both individuals and society.

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