An Empirical Analysis of the Impact of Innovative Human Capital on Economic Growth

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Abstract. In today's rapid development of knowledge economy and network, innovative human capital is an important element for the development of a region and the core of regional economy. As a special economic zone and innovation center in China, it is important for Shenzhen to assess the potential impact of its innovative human capital on economic growth. Therefore, this paper takes Shenzhen as an example to explore the impact of innovative human capital on economic growth based on the Cobb-Douglas production function model and economic statistics methods, and deeply analyze its intrinsic connection. The empirical analysis shows that: the level of science and technology innovation and the rest of the influencing factors in Shenzhen have a significant role in promoting economic growth; the impact of innovative human capital stock on economic growth is positive and strong; Shenzhen is in the leading position in science and technology innovation. In future economic development, other provinces and cities can learn from Shenzhen's experience to promote sustained high-quality economic development with innovative human capital.

Keywords: Innovative human capital, Economic growth, The Cobb-Douglas production function, Empirical analysis

1 Introduction

In the process of comprehensively constructing the national image of the new era of socialism, we regard high-quality development as the primary task of the charge, with the goal of building a modernized industrial system, and the core of which is to realize the transformation and upgrading of the real economy. Against this backdrop, innovative human capital is particularly critical as an enabler and potential tapper for driving economic growth. Exploring how to find new economic growth through human capital is an important theme that needs to be studied in depth now.

In early research, labor and capital were often regarded as the determinants of economic growth, until the "father of human capital" Schultz [1] first systematically put forward the theory of human capital in 1960, the impact of economic growth perspective has undergone a fundamental shift. In 1988, Lucas [2] broadened the use of human capital theory by introducing it into economic growth models and proposed a capital-driven endogenous growth theory. Since then, empirical studies on the impact of human capital on economic growth have gradually emerged.

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Human capital is recognized as one of the main determinants of economic growth and plays an important role in the technological progress of countries [3]. The EU 2020 strategy focuses on three areas of growth: smart, sustainable and inclusive, which cannot be achieved without a significant contribution of people's skills, knowledge or values, often referred to as human capital, whose slow investment is affecting the sustainable development of countries [4]. Lin et al [5] focused on the quantity and quality of human capital and its direct and indirect impact on economic growth based on the consideration of spatial spillover effects, empirically examined the role of human capital on China's regional economic growth, and constructed a system of indicators for evaluating economic growth by adopting the spatial Durbin model. Xu et al [6] used panel data models and spatial econometric methods based on Lucas's endogenous growth theory to explore the relationship between innovative human capital and provincial economies (regional economies with different degrees of openness). Dai et al [7] empirically analyzed through a dynamic panel threshold model with endogeneity and found that the accumulation of human capital in the country has a prominent driving influence on economic growth. They also observed that the relationship between financial development and economic growth in the country has a double threshold effect based on human capital accumulation. Cai et al [8] studied through the spatial Durbin model, found that China's higher education aggregation and economic development presents a gradually decreasing distribution characteristics from east to west, human capital and science and technology research and development on the aggregation of higher education and economic growth of the joint regulation between the significant, spatial spillover effect is significant. In recent years, with the rapid progress of science and technology, more new directions of development have appeared in the research on the impact of human capital and innovation level on economic growth [9-12].

Innovative human capital can contribute to national economic growth, and major economies have become more attuned to sustainable development. In this context, it is important to assess the potential impact of innovative human capital on economic growth. As a special economic zone and innovation center in China, Shenzhen's innovative human capital has a positive effect impact on economic growth. Therefore, this paper will take Shenzhen as an example to deeply analyze the intrinsic connection between economy and human capital, aiming to find strategies to promote the sustainable development of both sides.

2 Data and methodological aspects

2.1 Data selection

2.1.1 Total social output indicator Y_t, dependent variable.

Data are from the Guangdong Provincial Statistical Yearbook and are in billions of yuan. Gross regional product (GDP) can directly reflect the economic development of a country or region, and in this paper, the GDP of Shenzhen is directly selected to characterize it from 2000 to 2021.

2.1.2 Physical capital factor stock K_t, independent variable.

Data are from the Shenzhen Statistical Yearbook and are in billions of yuan. This paper selects the investment in fixed assets as the independent variable to examine the impact of the stock of material capital factors on the economy.

2.1.3 Stock of human capital factors H_t, independent variable.

Data are from the China Population and Employment Statistical Yearbook, and the unit of human capital factor stock is 10,000 person-years. In this paper, the method of years of education is chosen to calculate the stock of human capital factors.

2.1.4 Level of science, technology and innovation G_t, independent variable.

Data source Shenzhen Statistical Yearbook, data in billions of yuan. In scientific research and technological development, R&D funding largely affects the ability of an organization or a country to carry out activities such as new technology development, new product development, new method research, etc. Therefore, this paper adopts the internal R&D expenditure as an important indicator to measure the level of science and technology innovation.

2.1.5 Size of local government F_t, independent variable.

The data are from the Shenzhen Statistical Yearbook, and the data unit is billion yuan. Local general public budget expenditures cover the supply of government services and products in various fields, such as education, science and technology, infrastructure construction, etc. Therefore, this paper adopts local general public budget expenditures as an important indicator of the size of local governments.

2.1.6 Size of foreign direct investment W_t, independent variable.

The data are from the Shenzhen Statistical Yearbook, and the data are in billions of yuan. The actual foreign investment absorbed directly affects the economic development of the receiving country, including the introduction of new technologies and the promotion of economic growth, etc. Therefore, this paper adopts the local general public budget expenditures as an important indicator of the size of the local government.

Considering the effect of heteroskedasticity, and for the convenience of subsequent research, this paper pre-processes the data by taking the logarithm of each variable before analyzing the data, and this treatment does not affect the analysis results.

2.2 Descriptive statistical analysis

We performed descriptive statistics on each of the statistical characteristics of the variables mentioned in section 2.1 above to obtain an overall picture of the individual data, and the results are shown in Table 1.

Table 1. Results of descriptive statistics in Shenzhen.

variant	unit (of measure)	sample size	maximum values	minimu m values	upper quartile	average values	(statistics) standard deviation
Y	billions	22	30664.85	2219.20	10995.93	13213.19	9214.53
K	billions	22	2518.57	537.86	1068.07	1240.08	672.28
H	period of 10,000 man-years	22	14982.40	4659.86	8798.44	9440.20	3637.99
G	billions	22	1682.15	48.12	351.34	490.04	436.09
F	billions	22	4593.8	225.04	1417.54	1977.06	1694.36
W	billions	22	767.528	137.302	311.38	361.12	361.12

2.3 Model building

The Cobb-Douglas production function is widely used to describe the production function in microeconomics. The function is expressed as shown in Equation (1).

$$Y = AK^{\alpha}L^{\beta} \quad (1)$$

Where Y denotes output, K denotes capital, L denotes labor, A is a technology-related constant, and α and β denote the output elasticities of capital and labor, respectively. Due to the different quality of labor force generated by the stock of human capital has a different degree of influence on economic growth, so this paper is based on the assumption of the premise of the different quality of labor force, the labor force's influencing factors are amended to the input of human capital factors, and the variables mentioned above are brought into the model to arrive at Equation (2).

$$Y_t = A_t {K_t}^{\beta_1} {H_t}^{\beta_2} {G_t}^{\beta_3} {F_t}^{\beta_4} {W_t}^{\beta_5} \varepsilon \quad (2)$$

Where A is a constant and Ɛ is a random disturbance term. Continue to construct the regression model by logarithmically transforming both sides of Equation (2). Taking logarithms can transform this model into a linear model without changing the relative relationship of the data, thus making the model more concise and reducing the absolute value of the data, while attenuating the covariance and heteroskedasticity of the model, etc., and facilitating the subsequent calculations. The resulting regression model is shown in Equation (3).

$$\ln Y_t = a + \beta_1 \ln K_t + \beta_2 \ln H_t + \beta_3 \ln G_t + \beta_4 \ln F_t + \beta_5 \ln W_t + \varepsilon \quad (3)$$

3 Regression analysis and results discussion

Before regression analysis, we first verify the smoothness of the data using the ADF (Augmented Dickey-Fuller) test. Based on the integrated data and Equation (3), the ADF test is performed on the data LnY, LnK, LnH, LnG,LnF and LnW to obtain Table 2.

Table 2. Stability test results for each variable.

variant	LnY	LnK	LnH	LnG	LnF	LnW
ADF statistic	-2.042	-0.279	-2.823	-1.165	-4.178	-0.592

Critical value 5%	-3.054	-3.068	-3.155	-3.013	-3.022	-3.155
stability	unsteady	unsteady	unsteady	unsteady	unsteady	unsteady

Table 2 reveals that all six variables show no smoothness on the ADF smoothness test, indicating that there is a serious non-stationarity in this time series data.

The prerequisite assumption for establishing a multiple linear regression model is that the independent variables are independent of each other and there is no covariance; however, in reality, there is likely to be a correlated covariance between the independent variables about economic growth, so we next analyze the autocorrelation analysis and multiple covariance test for the logarithmically logarithmized data.

From the results of the correlation test, it can be concluded that the correlation coefficients between the variables are greater than 0.5, indicating that there is still a strong correlation between the variables. In general, the value of VIF (Variance Inflation Factor) is greater than 10, which indicates that there is a serious multicollinearity problem between the independent variables. Through the results, we can learn that although the VIF value of LnK is 5.069 less than 10, the VIF value of LnH is 140.495, the VIF value of LnG is 65.488, the VIF value of LnF is 95.260, and the VIF value of LnW is 17.718, which are all greater than 10, indicating that there is a serious multicollinearity relationship in the data in general. Therefore, this paper adopts "ridge regression" to solve this problem. When serious multicollinearity exists between the explanatory variables, the stability and predictive ability of the model will be reduced, while ridge regression introduces a regularization parameter, sacrificing a certain degree of unbiasedness, in exchange for the stability of the model's overall parameter estimation and the enhancement of the prediction accuracy. The results of ridge regression are shown in Figure 1 and Table 3.

Figure 1. Variable Ridge Trace Diagram I.

Table 3. Results of ridge regression coefficients .

model	K=0.158	Non-standardized		Standardized	t	Sig.
		B	standard error	Beta		
1	(constant)	-0.294	0.316	-	-0.532	0.026***
	LnK	0.147	0.047	0.095	3.123	0.007***
	LnH	0.474	0.031	0.228	15.487	0.000***

LnG	0.208	0.013	0.262	15.541	0.000^{***}
LnF	0.194	0.015	0.244	12.654	0.000^{***}
LnW	0.273	0.048	0.151	5.684	0.000^{***}

We can get the above results by performing ridge regression analysis through SPSSPRO software, and it can be seen from Figure 1 that LnK, LnH, LnG, LnF and LnW are gradually stabilized before the value of K is 0.2. According to the results of ridge regression, we can get that the correlation coefficient R^2=0.988, Adjusted R^2=0.985, which indicates a goodness model fit. The significance of LnK, LnH, LnG, LnF and LnW , which are mainly studied in this paper, in the model is also less than 0.05, which indicates that the effects of these five independent variables on economic growth are all very significant. From Table 3, we can get: the elasticity coefficient of the amount of investment in fixed assets β_1=0.147, the elasticity coefficient of the human capital investment β_2=0.474; the elasticity coefficient of internal expenditure on R&D funding β_3=0.208, the size of local government β_4 = 0.194, the size of foreign direct investment β_5 = 0.273, and thus the regression function is obtained as shown in Equation (4):

$$lnY = -0.294 + 0.147lnK + 0.474lnH + 0.208lnG + 0.194lnF + 0.273lnW \quad (4)$$

In order to further study the impact of innovative human capital on the economic growth of Shenzhen city, this paper adds the human capital stock and the level of scientific and technological innovation and denotes it as LnX. Firstly, we carry out the autocorrelation test and the VIF test on LnY and LnX, and get the following results:

Table 4. Autocorrelation test results between variables.

	LnY	LnX
LnY	1	0.993**
LnX	0.993**	1

From the result of the correlation test in Table 4, it can be concluded that the correlation coefficient between LnY and LnX is higher than 0.9, indicating that there is a strong correlation between them. Although the results of the VIF test showed the VIF of LnK is only 4.664, the VIF of the remaining three independent variables exceeds 10, indicating a serious multicollinearity problem among the independent variables. Then, we can find that LnY and LnX are linearly related by drawing a scatter plot.

However, the VIF test results all still have a serious multicollinearity problem. In order to solve this problem and optimize our model, we continue to use ridge regression analysis to fit all the independent variables, which can allow us to explore the effects of these independent variables on the dependent variable more comprehensively, and shrink the regression coefficients by adjusting the ridge parameters to prevent overfitting and improve the predictive performance of the model. The results of the ridge regression are shown in Figure 2 and Table 5.

Figure 2. Variable Ridge Trace Diagram II.

Table 5. Results of ridge regression analysis between variables.

model	K=0.151	Non-standardized coefficient		Standardized coefficient		
		B	standard error	Beta	t	Sig.
2	(constant)	-1.754	0.397	-	-4.416	0.000***
	LnK	0.204	0.058	0.131	3.494	0.003***
	LnX	0.596	0.038	0.303	15.719	0.000***
	LnF	0.26	0.021	0.327	12.361	0.000***
	LnW	0.387	0.06	0.213	6.433	0.000***

As can be seen in Figure 2, the ridge regression curve tends to be stable until the value of K reaches 0.2. Through the ridge regression of LnY,LnK, LnX,$LnF$and LnW, it can be concluded that the elasticity coefficient of fixed asset investment amount β_1 =0.204, the elasticity coefficient of innovative human capital investment β_2=0.596, the elasticity coefficient of local government size β_3=0.26, the size of foreign direct investment β_4= 0.387. Therefore, the obtained regression function is shown in Equation (5).

$$\ln Y = -1.754 + 0.204\ln K + 0.596\ln X + 0.26\ln F + 0.387\ln W \quad (5)$$

In order to further illustrate the applicability of the study, the data of Guangdong Province and Zhuhai City are analyzed in a simultaneous comparison. the VIF test shows that the relevant data of Guangdong Province and Zhuhai City have serious multicollinearity, and the same ridge regression model is used for the analysis to calculate the elasticity coefficients of the factors and the GDP growth rate, as shown in Table 6 and Fig. 3. We can easily see that the elasticity coefficients of the three factor outputs of Shenzhen in terms of scientific and technological innovation, government size and FDI size are higher than those of Guangdong Province, and the GDP growth rate is also higher than that of Guangdong Province, which indicates that Shenzhen has a very good experience in leading the way in enhancing economic growth through innovative human capital. For Zhuhai, the elasticity coefficient of the overall factor output is slightly lower than that of Guangdong Province. Overall, Zhuhai still has room for improvement in science and technology innovation, which can be improved from the aspect of science and technology innovation, and then increase the attractiveness of foreign direct investment, so as to expand the scale of development of the city and increase the GDP growth rate. Shenzhen can continue to optimize innovative human capital based on the city's past experience and share its excellent experience with the rest of the cities in Guangdong Province, thus driving the overall economic development of Guangdong Province.

Table 6. Coefficient of Elasticity of Factor Output, GDP Growth Rate, Shenzhen, Zhuhai, Guangdong (2000-2021).

Region	$\boldsymbol{\alpha}$(K)	$\boldsymbol{\beta}$(H)	$\boldsymbol{\gamma}$(G)	$\boldsymbol{\delta}$(F)	$\boldsymbol{\theta}$(W)	$\boldsymbol{\alpha}+\boldsymbol{\beta}+\boldsymbol{\gamma}+\boldsymbol{\delta}+\boldsymbol{\theta}$	GDP growth rate
Shenzhen	0.147	0.474	0.208	0.194	0.273	1.296	13.68%
Zhuhai	0.219	0.780	0.107	0.163	0.079	1.348	11.09%
Guangdong Province	0.203	0.678	0.147	0.174	0.224	1.426	12.52%

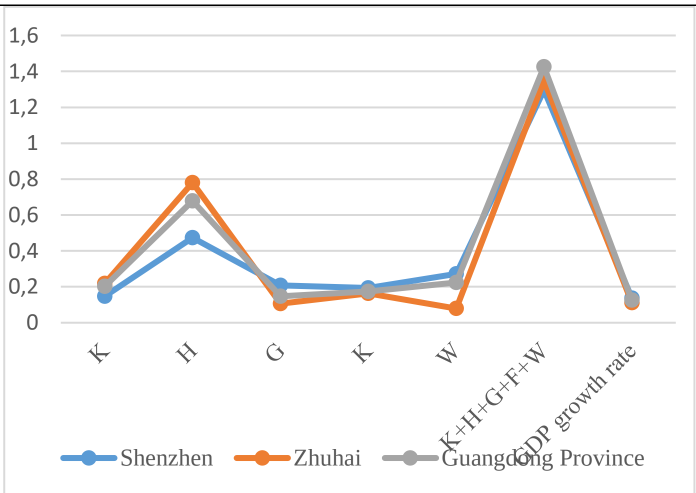

Figure 3. Coefficient of Elasticity of Factor Output, GDP Growth Rate, Shenzhen, Zhuhai, Guangdong (2000-2021).

4 Conclusions and recommendations

First, the stock of human capital, the level of scientific and technological innovation, the size of the government and the size of foreign direct investment in Shenzhen all have a significant contribution to economic growth. The output elasticity coefficients of each independent variable show that they have a positive impact on economic growth. Second, when human capital stock and the level of science and technology innovation are combined into innovative human capital for in-depth consideration, the output elasticity coefficient of innovative human capital stock is 0.596, indicating that innovative human capital stock has a positive and strong impact on economic growth. Finally, the economic growth of Shenzhen is mainly based on the pulling effect of the level of scientific and technological development, the size of local government, and the size of foreign direct investment on the economy. Shenzhen has a clear advantage over Zhuhai in all three aspects and is in the leading position in Guangdong Province. Driven by innovative human capital, Shenzhen's GDP growth rate has exceeded the GDP growth rate of Guangdong Province, which suggests that Guangdong Province can learn from Shenzhen's experience of driving economic growth with innovative human capital in its future economic development and generalize it to cities in need of a pull.

Therefore, we suggest that Shenzhen increase the policy investment in innovative human capital, build an innovative human capital training system, improve the incentive mechanism for innovative human capital, and continue to drive economic growth with innovation. At the same time, it should continue to increase investment in R&D, activate the power of innovation and development, and commit itself to promoting sustained and high-quality economic development through innovative human capital, as well as playing a leading role in Guangdong Province to help other cities enhance their economic growth, thereby promoting the overall economic development of the country.

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