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Article

Role of innovation and human capital in regional economic growth and progress

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Abstract: Since 1999, China's higher education has experienced significant growth, with the government dramatically increasing college enrollment rates, thereby enhancing the overall quality of education. However, most existing studies have primarily focused on the quantity of education, with little attention having been given to the impact of higher education quality (HEQ) on economic growth. This study aims to explore how higher education quality (HEQ) contributes to regional economic growth through scientific and technological innovation (STI) and human capital accumulation. Using panel data from 31 Chinese provinces from the period 1999 to 2022, panel regression models and instrumental variable methods were employed to analyze both the direct and indirect impacts of higher education quality (HEQ) on economic growth. The results confirm that improving higher education quality (HEQ) is crucial for sustaining China's economic growth. More specifically, higher education promotes regional economic expansion both directly, by enhancing labor productivity, and indirectly, by facilitating scientific and technological innovation. Furthermore, the study suggests that the balanced distribution of educational resources across regions should be prioritized to support coordinated regional development. This research provides insights for policymakers on how balanced regional economic development can be achieved through educational and technological policies. This work also lays a foundation for future studies.

Keywords: quality of higher education; regional economic growth; science and technology innovation; human capital accumulation

1. Introduction

Since 1999, higher education in China has experienced significant growth, with the government dramatically increasing university enrollment rates, thereby enhancing the overall quality of education. However, most existing studies have primarily focused on the quantity of education, with little attention having been paid to the specific impact of higher education quality (HEQ) on economic growth. Unlike previous studies, this research not only focuses on the improvement of higher education quality (HEQ) but also conducts an in-depth analysis of its direct and indirect impacts on regional economic growth through the dual pathways of, firstly, scientific and technological innovation and, secondly, human capital accumulation.

Based on panel data from 31 provinces in China covering the period 1999 to 2022, this study employs quantitative methods to verify the importance of enhancing higher education quality (HEQ) in order to sustain China's economic growth. The existing literature largely emphasizes the contribution of educational expenditure to economic growth, but the critical role of education quality tends to have been overlooked. By conducting quantitative analysis, this study bridges the research gap regarding the relationship between higher education quality (HEQ) and economic growth, exploring how quality enhancement can drive economic development through improved innovation capacity and technological progress.

This research focuses on the differential impact of higher education quality (HEQ) on regional economic development, not only verifying its significant contribution to China's overall economic growth but also revealing the imbalanced allocation of educational resources across regions. The findings provide policymakers with a theoretical foundation to promote the coordinated allocation of educational resources across regions and support the sustainable development of China's economy.

The contribution of higher education to China's economic growth has been in the spotlight since the 1950s. Schultz's research shows that from 1929 to 1959, education contributed 33% to the U.S. economy (Schultz, 1961). Influenced by the U.S. education system, China has dramatically increased its college enrollment since 1999, with freshman enrollment growing at an average annual rate of 26.6% between 1999 and 2003. Nevertheless, the Chinese government's expenditure on education as a percentage of GDP was only 2.79% in 2004, far below the 5.1% average of developed countries. Data indicate that every 1% increase in higher education enrollment results in approximately 71.2 billion yuan of GDP growth (Li and Sun, 2023).

While previous research has explored the effects of educational expenditure on economic development and emphasized the role of higher education quality (HEQ), the current scholarship still primarily focuses on the quantity of education rather than its quality. Additionally, there is a noticeable lack of quantitative evaluation of the relationship between higher education quality (HEQ) and economic growth. This study aims to explore the pathways between and dynamics of enhancing higher education quality (HEQ) and economic progress through quantitative methods. Grounded in human capital theory and the theory of scientific and technological innovation, this study examines the role of higher education quality (HEQ) in driving economic growth through human capital accumulation and improved innovation capacity. More specifically, enhancing the quality of higher education directly impacts workforce efficiency and indirectly fosters economic advancement by boosting innovative potential and advancing technological development.

This study uses a multi-provincial panel data framework to examine the interplay between higher education quality (HEQ) and technological innovation, focusing on regional per capita GDP as the key variable. The research aims to uncover both the direct and indirect impacts of enhancing higher education quality (HEQ) on economic development, laying a theoretical foundation with which policymakers can promote the shared development of educational resources across regions and sustainably boost China's economy. Empirical results have confirmed the direct and indirect impacts of enhancing higher education quality (HEQ) on economic expansion, based on an examination of its diverse effects across different regions of China (Gu, 2021).

The graphical abstract of this study (**Figure 1**) illustrates the relationship between higher education quality (HEQ), technological innovation (measured by patent counts), and economic growth (measured by per capita GDP) in China from 1999 to 2022. The data emphasize that regions with superior education quality experience significant growth in both innovation and economic development, highlighting the crucial role of education in fostering regional progress.

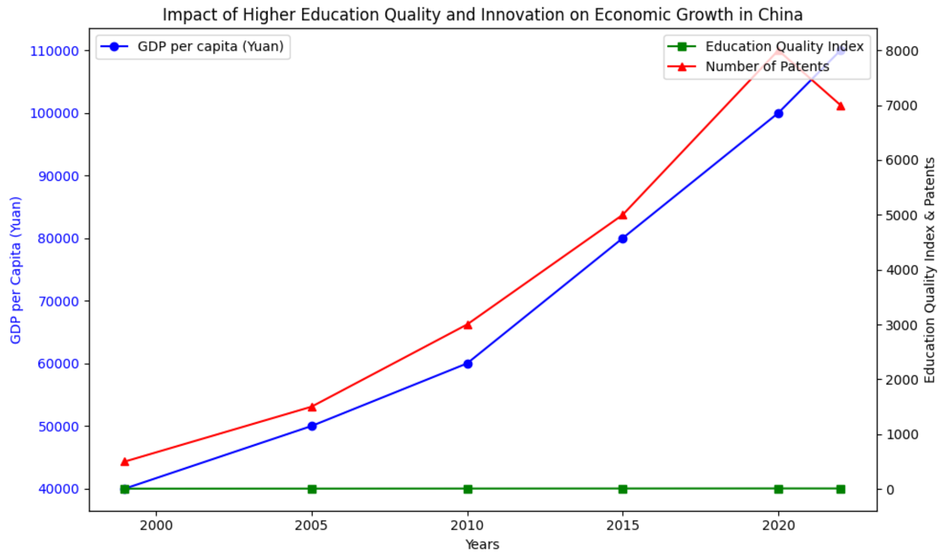

Figure 1. The impact of Higher Education Quality (HEQ) and innovation on economic growth in China (1999–2022).

2. Literature review and hypotheses

In recent years, academic attention has gradually shifted from the quantity of education to its quality, especially regarding the impact of higher education quality (HEQ) on regional economic expansion (Nguyen et al., 2024). Although a large body of research has explored the impact of educational scale on economic development, increasing evidence shows that the quality of higher education can promote sustainable economic progress by fostering innovation and accumulating human capital (Xu et al., 2020). Bouhajeb et al. (2018) pointed out that improving the quality of higher education contributes to local economic growth by promoting technological progress and human capital accumulation. These studies establish an important connection between education quality and economic development.

However, most existing research has focused primarily on the impact of education quantity on economic growth, ignoring the core role of education quality. Li and Liu (2021) emphasized that improving the quality of higher education is crucial for promoting long-term economic growth. The significance of enhancing higher education quality (HEQ) lies in fostering regional economic growth through science, technology, innovation, and human capital development. This conclusion is supported by worldwide empirical studies (Xu et al., 2020). Higher education serves as an important human asset for innovation, significantly increasing the number of patents and technological advancements, especially by educating leading researchers and technicians to drive innovation.

Recent studies further emphasize that improving educational standards can directly and simultaneously enhance workforce productivity, promote technological progress, and stimulate regional economic growth through technological gains (Yang, 2024). For example, China’s eastern coastal regions, such as Beijing and Jiangsu, are well-known for their advanced educational facilities, superior research and innovation capabilities, and significantly faster economic growth rates (Lin et al. 2021). Suggested that achieving synchronized economic advancement across regions depends on narrowing the gaps in higher education, particularly by improving the quality of education in central and western regions.

Moreover, recent studies have pointed out that policymakers must focus on improving higher education standards to promote sustainable and consistent economic development across regions, which requires a balanced allocation of educational resources nationwide (Li and Liu, 2021). Existing research suggests that the dual impacts of innovation and the quality of higher education are more crucial for economic growth than previously assumed, highlighting the urgent need to support these factors in future policy decisions.

The uniqueness of this study lies in not only its focus on the quantity of higher education but also its in-depth analysis of how improving education quality drives regional economic growth directly and indirectly through two pathways: scientific and technological innovation and human capital accumulation. By analyzing panel data from Chinese provinces covering the period 1999 to 2022, this study explores the role of higher education in driving regional economic development and provides policymakers with the theoretical support required to achieve shared educational resources and balanced regional economic growth. **Figure 2** shows the theoretical framework of this study.

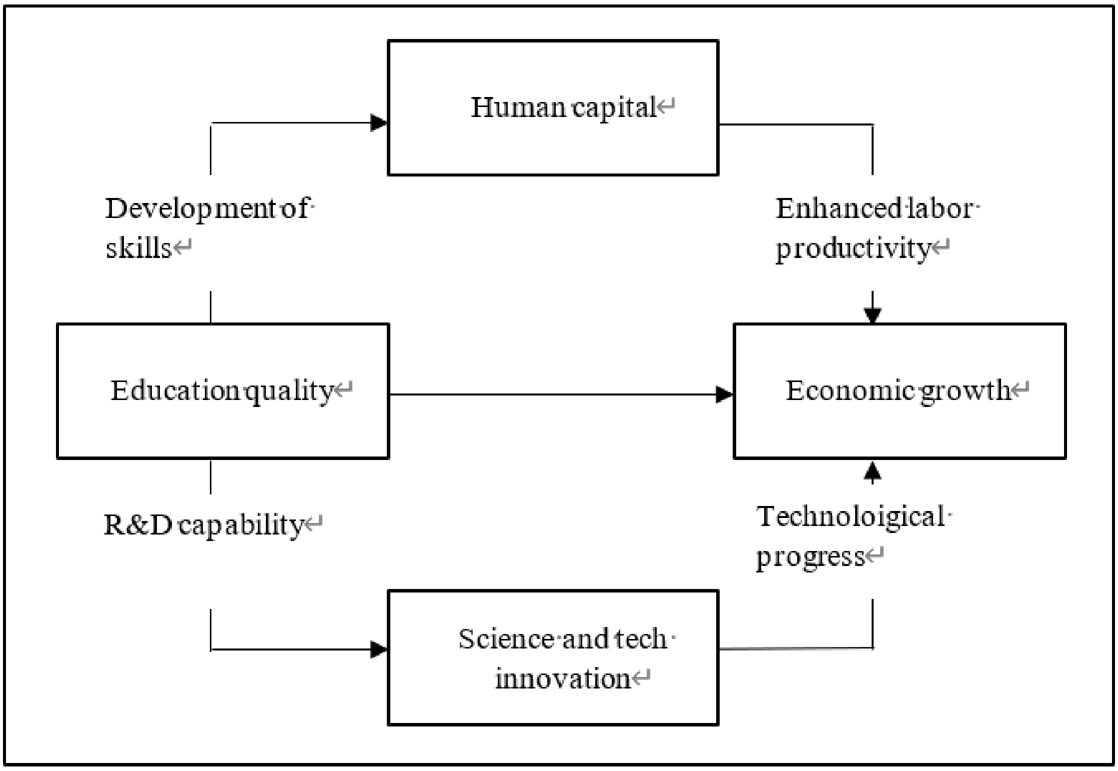

Figure 2. Mechanisms linking quality improvement in higher education to economic growth.

Based on the literature review and research content, the following research hypotheses are proposed:

1) Hypothesis 1 (Direct Effect): The quality of higher education has a significant and positive direct impact on regional economic growth. Improving the quality of higher education can directly enhance regional economic output (measured by per capita GDP) because high-quality higher education provides society with more advanced talent and knowledge accumulation.
2) Hypothesis 2 (Indirect Effect via Technological Innovation): The quality of higher education has an indirect positive effect on regional economic growth through scientific and technological innovation (STI). The quality of higher education can indirectly promote economic growth by fostering scientific and technological innovation (e.g., patent counts, R&D investments), thereby creating a continuous innovation-driven economic development path.
3) Hypothesis 3 (Regional Differences): The impact of higher education quality (HEQ) on regional economic growth varies significantly across different regions. Due to their superior educational and innovation resources, the eastern regions will see a more significant impact of higher education quality (HEQ) on economic growth, while the impact on central and western regions is relatively weaker. Therefore, balanced economic growth may be affected by the imbalance in educational resources across regions.
4) Hypothesis 4 (Moderating Effects of Control Variables): Workforce, capital investment, market openness, urbanization, and other control variables will moderate the relationship between higher education quality (HEQ) and economic growth. These factors may enhance or weaken the impact of higher education on economic growth to some extent. For example, regions with higher market openness are more likely to gain economic benefits from higher education, and increased urbanization will amplify the positive impact of education on the economy.

To verify the above hypotheses, the study used a cross-provincial panel data model, with data from the National Bureau of Statistics of China and university rankings utilized to construct a higher education quality (HEQ) index, including key indicators such as per capita GDP, total R&D personnel, and the number of patents. The dependent variable in the model is regional per capita GDP, while the independent variables are the quality of higher education and its interaction with scientific and technological innovation (STI). Control variables include factors such as workforce, capital investment, market openness, and urbanization, which help develop the understanding of the independent effect of higher education on economic growth.

3. Research methods

3.1. Variable selection

This study aims to validate the transmission mechanisms proposed in Chapter 3 through empirical research by constructing a model based on inter-provincial panel data to evaluate the impact of higher education quality (HEQ) on national and provincial economic growth. The model takes regional per capita GDP as the dependent variable, with higher education quality (HEQ) and its interaction with science, technology, and innovation (STI) as the independent variables. Control variables include workforce, financial resources, market openness, urbanization, and infrastructure factors. The foundational model primarily assesses the direct positive effect of higher education quality (HEQ) on per capita GDP, while the interaction between higher education and STI is used to evaluate its indirect impact. To avoid multicollinearity, STI was chosen as the intermediary variable instead of human capital because STI is often used as a proxy for human capital. Therefore, the model focuses on reflecting the indirect effects of higher education through STI.

The control variables in this study encompass several critical factors. First, the capital factor is measured by logarithmically transforming gross fixed capital formation, which serves as an indicator of provincial capital investment. The degree of market openness is assessed by calculating the ratio of total imports and exports to GDP, indicating the level of integration with the global market. Urbanization is evaluated by determining the proportion of the urban population to the total population, reflecting the level of urban development. These control factors play a vital role in understanding the broader economic context and isolating the independent impact of higher education quality (HEQ) on economic growth. The calculation of this index is based on data from the National Bureau of Statistics of China (Su et al., 2013) and the top 500 universities in Shanghai Softech's China University Ranking (Yao, 2003). In computing the higher education quality (HEQ) index, university data were used as the sample for analysis before subsequently being transformed into a regional higher education quality (HEQ) index (Saxenian, 2003).

In this study, the higher education quality (HEQ) index is computed using the following methodology:

1) Higher education quality (HEQ) Score of a University: Let I (where i = 1, 2, …, n) represent the institutions that publish university rankings, with n being the total number of ranking institutions, and m representing the sample size of ranked universities. The higher education quality (HEQ) score C_j of the j-th ranked university is calculated as follows:

$$C_j = m + 1 - j \tag{1}$$

2) Provincial Higher education quality (HEQ) Calculation: Assume k represents the province label, and x (x = 1, 2, …, y) is the list of universities located in a particular province. The provincial higher education quality (HEQ) B_k is calculated as follows:

$$B_k = \sum_{x=1}^{y} C_{k,j,x} \tag{2}$$

3) Provincial Higher education quality (HEQ) index: To combine the ranking data of various institutions, we use θi as the weight assigned to each institution's regional macro-score. The provincial higher education quality (HEQ) index A_k is calculated as follows:

$$A_k = \sum_{i=1}^{n} \theta_i B_{k,i} \tag{3}$$

The weight θi is calculated using the following formula:

$$\theta_i = \frac{1}{n} \tag{4}$$

Therefore, the provincial higher education quality (HEQ) index A_k can be represented as follows:

$$A_k = \sum_{i=1}^{n} \left(\frac{1}{n}\right) B_{k,i} \tag{5}$$

In this study, k refers to mainland China, excluding Hong Kong, Macau, and Taiwan, with the k values ranging from 1 to 31. The higher education quality (HEQ) index, as calculated using the above formulae, effectively reflects changes in the higher education quality (HEQ) for each province in China. This approach captures ranking fluctuations, allowing an analysis of their impacts on economic growth. However, universities with relatively stable rankings may not show significant changes in their individual quality due to healthy competition. As such, their impact may be less pronounced in the aggregate provincial scores.

To address this limitation, we also use average years of schooling as an alternative measure of higher education quality (HEQ) for robustness testing. The formula for this is as follows:

$$\text{Average years of schooling} = (P_0 \times 0) + (P_1 \times 6) + (P_2 \times 9) + (P_3 \times 12) + (P_4 \times 16)$$

where:

P_0: Proportion of population with no schooling

P_1: Proportion of population with primary education

P_2: Proportion of population with lower secondary education

P_3: Proportion of population with upper secondary education

P_4: Proportion of population with tertiary education or above

Innovation outputs include published scientific papers, scientific monographs, registered technological achievements, and patents granted. Patents are particularly emphasized due to their credibility. While these indicators may not capture all aspects of innovation quality, they provide reliable data for measuring inventive knowledge. R&D funding and personnel investment are considered innovation inputs. In our analysis, we use the total number of domestic patents granted as an indirect independent variable, without distinguishing between invention, utility model, and design patents because these aspects collectively reflect the level of technological innovation (Nagaoka et al., 2010).

The quality of higher education alone is insufficient to comprehensively explain economic expansion. Consequently, we include multiple control variables grounded in neoclassical economic theory and features of Chinese socialism (Czarnitzki and Hottenrott, 2011). These control variables are as follows:

- Capital Factor: Measured using the logarithm of gross fixed capital formation, which indicates the level of capital investment across provinces.
- Market Openness: Determined by the ratio of total imports and exports to GDP, indicating the integration level with global markets.
- Urbanization: Measured by the proportion of the urban population to the total population, reflecting urban development.

These variables assist in understanding the broader economic context and isolating the impact of higher education quality (HEQ) on economic growth. Data for these control variables and the higher education quality (HEQ) indices were sourced from the China Statistical Yearbook from 2015 to 2022.

3.2. Research design

The central examination in this study relies on tallying domestically issued patents as an indirect independent variable. Within China's statistical framework, patents fall into three varieties: patents for inventions, utility models, and design patents. The quantity of patents approved in these three categories can aptly signify the extent of technological advancement. Hence, this study does not differentiate their distinct effects on economic expansion but utilizes instead the aggregate of patents for evaluation. The robustness assessment of this research emphasizes the human aspect in technological advancements, considering the number of full-time equivalent R&D staff as a secondary variable in tandem with the independent variable. The standard of higher learning alone does not suffice to fully account for economic expansion. Therefore, this study incorporates into its evaluation various control variables grounded in both neoclassical economic theory and specific aspects of Chinese socialism. In particular, this paper focuses on controlling variables such as the workforce, capital, market openness, urbanization, and infrastructure levels. **Tabel 1** provides specific variable definitions. Aside from the higher education quality (HEQ) index figures supplied by the top three ranking bodies, the remainder of the data comes from the China Statistical Yearbook spanning the period 2015 to 2022. To assess how enhancing the quality of higher education directly and indirectly affects economic development, we employ a specific provincial panel data regression model:

$$PGDP_{i,t} = \alpha + \beta_1 HEQ_{i,t} + \beta_2 PAT_{i,t} + \beta_3 \left(HEQ_{i,t} \times PAT_{i,t}\right) + \sum_k \gamma_k \, Controls_{k,i,t} + \delta_t + \epsilon_{i,t} \tag{6}$$

Parameter Definition:

$$\begin{aligned} \alpha &= \frac{\alpha_1 + \alpha_2 + \alpha_3}{3} \\ \beta_1 &= \frac{\beta_1 + \theta_1 + \phi_1}{3} \\ \beta_2 &= \frac{\beta_2 + \theta_2 + \phi_2}{3} \\ \beta_3 &= \frac{\beta_3 + \theta_3 + \phi_3}{3} \\ \gamma_k &= \frac{\gamma_k + \lambda_k + \psi_k}{3} \\ \delta_t &= \frac{\delta_t + \tau_t + \rho_t}{3} \end{aligned} \tag{7}$$

Gross domestic product per capita (PGDP) is the dependent variable of the model and represents the economic output per capita of a province at a given point in time. Higher education quality (HEQ) is one of the independent variables, representing the overall level of higher education in that province. Domestic patent authorization (PAT) is also an independent variable; it serves as a proxy for technological innovation and reflects the results of scientific and technological innovation. The interaction term (HEQ × PAT), on the other hand, is used to measure the impact of the synergy between higher education quality (HEQ) and STI on economic growth. Control variables ($Controls$) include labor, capital, market openness, urbanization level, and infrastructure level; these are used to control for other factors that may affect economic growth. Time fixed effects (δ_t) and error terms ($\epsilon\_\{i, t\}$) are then used to control for time-invariant factors and unobservable random disturbances.

a) Direct impact: Higher education quality (HEQ) and technological innovation (PAT) have a direct positive impact on economic growth. Improvements in the quality of higher education can directly increase the productivity of the labor force, thus boosting economic growth.
b) Indirect impact: Higher education quality (HEQ) further enhances its contribution to economic growth by promoting scientific and technological innovation (PAT) . The model quantifies this indirect effect through the interaction term (HEQ × PAT).
c) Regional analysis: The model also considers how inter-regional economic differences might impact the results by analyzing the eastern, central, and western regions of China separately. The model reveals the key roles of higher education quality (HEQ) and science and technology innovation in promoting regional economic growth, and it provides a theoretical basis for policymakers with regard to resource allocation and development strategy formulation.

3.3. Sample and descriptive statistics

Table 1 presents the descriptive statistics for each variable used in this study. The dataset includes 248 samples for ten variables: pgdp, asy, heq, pat, rdp, lab, kap, open, urb, and inf. The following summary is based on **Table 2**. It shows the observed values of each variable.

Table 1. Variables description and measurement.

Variables	Description and measurement
PGDP	Dependent variable. Regional gross domestic product (GDP) per capita, calculated as the logarithm of regional GDP per capita. GDP per capita at current prices.
HEQ	Direct independent variable. Quality of higher education calculated using the (logarithm_zed) Higher education quality (HEQ) Index, which is based on university ranking agencies.
ASY	Indirect independent variable. Average years of schooling; see text for formula.
PAT	Indirect independent variable Proxy variable for STI, calculated as the logarithm_ zed of the number of patents granted in the country.
RDP	Indirect independent variable Proxy variable for STI, calculated as the logarithm of the number of full-time equivalent R&D personnel.
LAB	Control variables. Labor coefficient, calculated as the logarithm of total employment.
KAP	Control variables. Capital element, calculated as the logarithm of gross fixed capital formation.
OPE	Control variables. Market openness, calculated as total exports and imports as a share of GDP.
URB	Control variables. Urbanization, calculated as the urban population as a percentage of the total population.
INF	Control variables. Level of infrastructure, in terms of road mileage in each province.

Table 2. Descriptive statistics.

Stats	Sample size	Average value	Maximum value	Minimum value	Upper quartile	Standard deviation	Skewness	Kurtosis	J-B statistic
PGDP	248	11.008	12.155	10.164	10.940	0.413	0.621	2.971	15.959
HEQ	248	7.552	9.828	0.000	8.038	1.868	−2.183	8.850	550.614
ASY	248	9.362	12.682	5.085	9.374	1.093	−0.187	6.562	132.533
PAT	248	10.513	13.679	5.288	10.636	1.489	−0.622	3.698	21.013
RDP	248	11.218	13.788	7.027	11.510	1.402	−0.751	3.522	26.113
LAB	248	7.558	8.875	5.257	7.629	0.857	−0.802	3.188	26.950
KAP	248	9.674	11.116	7.167	9.803	0.907	−0.526	2.484	14.176
OPE	248	0.239	1.041	0.008	0.135	0.235	1.581	4.672	132.201
URB	248	0.617	0.893	0.288	0.608	0.117	0.372	3.601	9.462
INF	248	11.741	12.910	9.470	11.990	0.841	−1.388	4.010	90.150

The data reveals significant differences in per capita GDP and higher education quality (HEQ) across China's provinces. The highest and lowest per capita GDP vary by approximately two units, indicating significant economic growth disparities among the provinces. The eastern coastal areas tend to exhibit higher economic levels, whereas the central and western provinces lag behind. The data for higher education quality (HEQ) also show significant variations, with the lowest score being zero, suggesting some Chinese regions have substandard higher education quality (HEQ), while others have superior educational standards.

This unequal distribution of economic and educational resources indicates that policy should focus more on synchronized regional development, particularly by promoting the fair distribution of educational resources and effective economic growth strategies to achieve balanced development nationwide.

The evolving correlation between China's provincial higher education quality (HEQ) index (HEQ) and economic growth indicates significant regional differences. From both temporal and spatial perspectives, Beijing, Jiangsu, Hubei, Liaoning, and Shanghai are the leading five provinces in terms of the higher education quality (HEQ) index, whereas Xinjiang, Hainan, Ningxia, Qinghai, and Tibet rank at the bottom. Over time, the higher education quality (HEQ) and economic growth in most regions have shown significant improvements.

In **Figures 3** and **4**, the vertical coordinates represent the logarithmic values of the higher education quality (HEQ) index and the average years of schooling, respectively. In **Figures 5** and **6**, the horizontal coordinates represent the interaction terms between the logarithms of the higher education quality (HEQ) index, the average years of schooling, and the logarithmic value of domestic patent numbers. The dynamic trend lines and scatter plots indicate significant positive linear relationships between PGDP and HEQ, as well as between HEQ and patent numbers (PAT).

Figure 3. Direct effect.

Figure 4. Indirect effect.

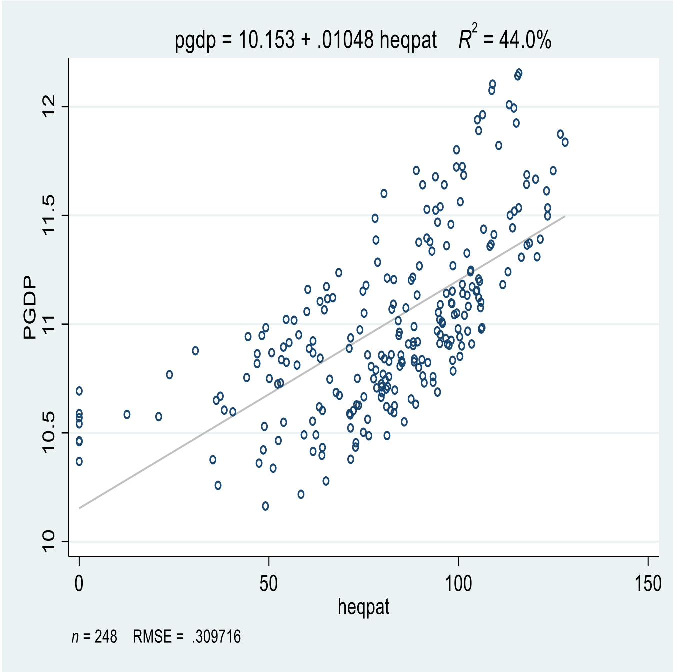

Figure 5. Direct effect.

Figure 6. Indirect effect.

3.4. Empirical test and economic interpretation

As outlined in **Table 3**, the statistical method of the Levin-Lin-Chu unit root test is applied to the panel data to ascertain if the time series data possesses a unit root; that is, it assesses the non-stationarity of the data. Presented next is an overview of the information in **Table 3**: h_0 denotes that the panel data possesses a unit root, while the null hypothesis indicating the unit root of the data suggests its irregularity. h_a represents the uniformity of the panel data, with the secondary hypothesis suggesting its smoothness. There are 31 panels with eight time periods each, with the test conducted using data that include 31 panels, each with eight time periods. The AR variables, both public and asymptotic, with N divided by T nearing zero, as well as the autoregressive variables, are also public, based on the hypothesis of asymptotic N divided by T nearing zero. This examination relies on the asymptotic N divided by T theory nearing zero. This examination is grounded in the principles of asymptotic behavior. The model incorporates panel averages, temporal patterns.

In statistical terms, the raw *t*-value stands at −15.9571, representing the unadjusted t-statistic. With an adjusted *t*-value of −6.4061 and a *p*-value of 0.0000, the adjusted *t*-value also stands at −6.4061, aligning with a *p*-value of 0.0000, suggesting the dismissal of the initial hypothesis and the smoothness of the panel data.

Table 3. Levin-Lin-Chu unit root test results (GDP per capital yuan).

Null hypothesis (H0)	**Panel data contains unit roots**
Alternative hypothesis (Ha)	**Smooth panel data**
Number of Panels	31
Number of time periods	8
AR parameter	Public
Asymptotic	N/T- > 0
Panel mean	Included
Time trend	Included
ADF regression	1 Lag
LR variance	Bartlett core, mean 6.00 lag (selected by LLC)
Unadjusted *t*-value	−15.9571
Adjusted *t* value	−6.4061

Table 4 shows the GDP per capita (yuan), the years of schooling, and the higher education quality (HEQ) for different records.

a) GDP per capita (yuan): Indicates the GDP per capita of each province in dollars. The figures in the table range from $39,692 to $113,692, showing the level of economic development in each record.
b) Years of schooling: Indicates the average number of years of schooling, reflecting the level of education among the population. The values in the table range from 8.57 to 12.08 years, indicating that the average number of years of schooling varies across provinces and time.
c) Quality index of higher education: Indicates the quality index of higher education, with values ranging from 656 to 6375, reflecting differences in the quality of higher education by province.

Table 4. Levin-Lin-Chu unit root test results (GDP per capital yuan).

GDP_per_capita_yuan	**Years_of_schooling**	**Quality_index_of_higher_education**
39692	8.7959947	656
43686	8.5655937	1402
49092	8.6050317	3485
56063	8.8710635	5228

Table 4. (*Continued*).

GDP_per_capita_yuan	Years_of_schooling	Quality_index_of_higher_education
60561	8.8385245	4664
62411	9.0055006	5919
69676	9.2467752	6375
72888	9.316108	6811
113692	12.080651	2714
39692	8.7959947	656
43686	8.5655937	1402

Table 5. Summary of variables.

Variable	Obs = .	Obs > .	Obs < .
Quality_Index_oo	1	248	-
Number_of_Granta	1	248	-
HEQ_PAT	1	248	-

According to **Figure 7** and **Table 4**, per capita GDP consistently exhibited an upward trajectory during the period studied. Beginning at an estimated 40,000 yuan, there was a steady rise in per capita GDP to above 70,000 yuan in the eighth period; it subsequently escalated considerably to above 110,000 yuan in the ninth period. Such evidence points to a vigorous economic expansion over a span of time, particularly in the later phase of the observation timeline. Initially, the mean length of education stayed largely constant, with minor variations spanning 8.5 to 9 years. A significant rise is observed in the ninth cycle, marked by a rise in the average duration of education to more than 12 years. According to **Table 5.** There was a greater fluctuation in the higher education quality (HEQ) Index relative to other measures. There was a significant increase from 656 in the initial period to approximately 6800 by the eighth period. Nevertheless, during the ninth period, the index plummeted dramatically to approximately 2700, signaling a major deterioration in the quality of higher education in recent times. The variability might suggest that despite the substantial enhancements in higher education quality (HEQ) over time, difficulties or interruptions were encountered by the end of the period.

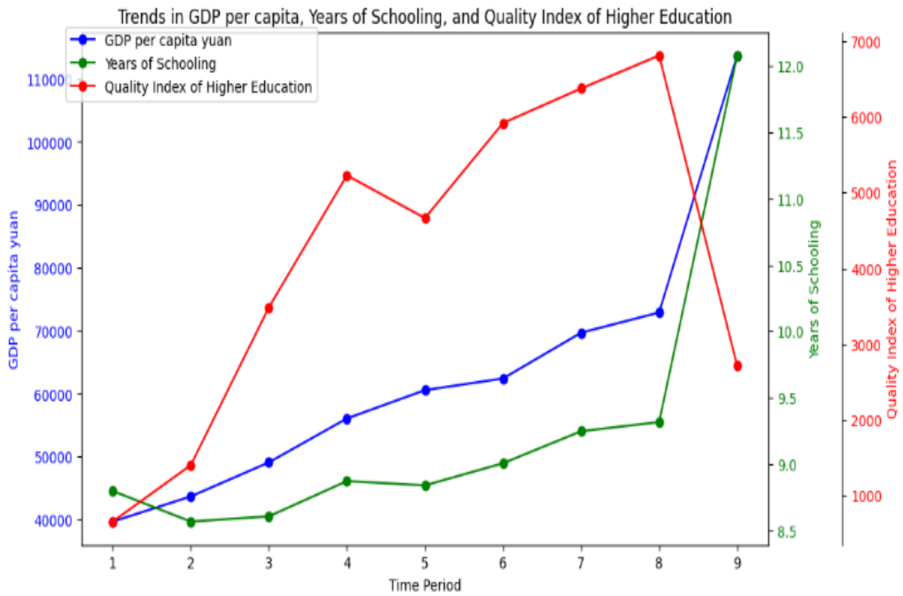

Figure 7. Economic development, education, and quality of higher education in Yuan.

As outlined in **Table 3**, the Quality_Index_oo metric exhibits one absent element and 248 legitimate observations, comprising 242 distinct values between 0 and 18,554, thus signifying notable regional variances in educational standards. The Number_of_Granta metric also exhibits a single absent value and 248 credible observations, all of which are distinct, with a span from 5.29 to 13.68. This indicates extensive variations across regions or over time, possibly indicating a modified metric that is similar to the patent tallies. Likewise, the HEQ_PAT variable exhibits a single absent value, 248 credible observations, and 243 distinct values ranging from 0 to 217,526.4, indicating regional disparities in the quality of higher education and the outcomes related to patents. The absent values and considerable fluctuations in these variables demonstrate the distinct geographical disparities, rendering the data apt for comparative analyses.

Figure 8 provides a summary of three key variables:

a) Quality_Index_oo, Number_of_Granta, and HEQ_PAT. The chart presents both the total number of observations for each variable and the range of unique values (from the minimum to the maximum) within those observations.

b) Blue Bars (Total Observations): Each blue bar represents the total number of observations available for each variable. All three variables have 248 observations.

c) Red Lines and Dots (Unique Value Ranges): The red lines indicate the range of unique values for each variable. These highlight that while the number of observations is consistent across the variables, the range of values they represent varies significantly, particularly for HEQ_PAT, which exhibits the broadest range.

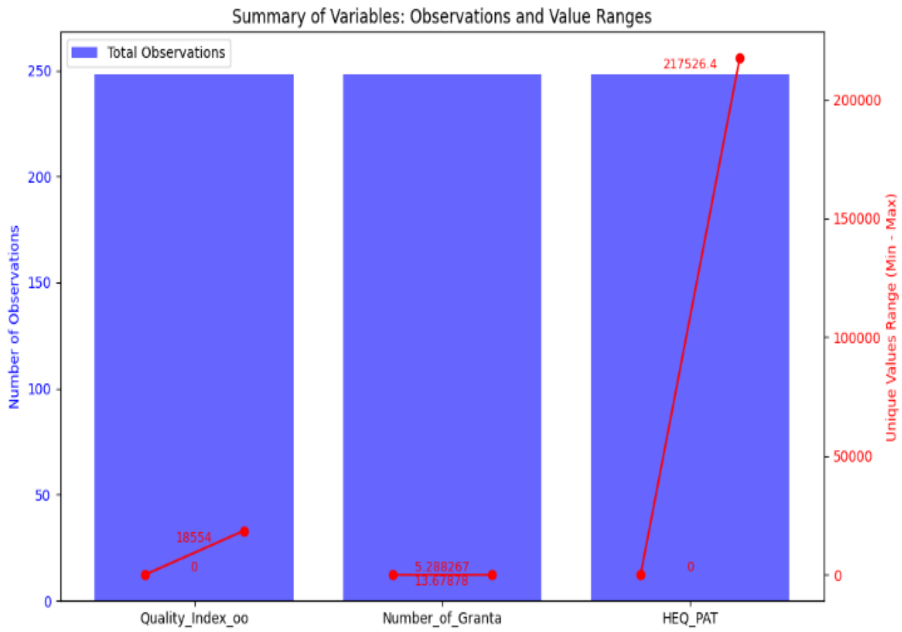

Figure 8. Summary of variables: Observations and value ranges for quality index, number of grants, and HEQ_PAT.

Table 6 reveals that this variable varies between 0 and 217,526.4, possibly signifying a combined index or a weighted evaluation of advanced educational quality in connection to patents, revealing substantial regional disparities in educational quality and patent results.

Table 6. HEQ_PAT summary.

Variable	Observations (Obs)	Mean	Std. dev.
HEQ_PAT	248	47628.56	46225.13

Based on **Table 6** and **Figure 9**, a visual summary of the HEQ_PAT variable showcases the key statistical measures: mean, standard deviation, and the full range of observed values.

Numbered lists can be added as follows:

a) Mean (Blue Bar): The blue bar represents the mean value of the HEQ_PAT variable, which is approximately 47,628.56. This is the average value across all 248 observations.

b) Standard Deviation (Red Error Bar): The red error bar indicates the standard deviation, which is 46,225.13. This represents the average amount by which the HEQ_PAT values differ from the mean, indicating a high level of variability in the data.

c) Range (Min and Max Values): Minimum value: 0; maximum value: 217,526.4. This wide range shows that while the average HEQ_PAT value is around 47,628.56, there are significant variations in the data, with some observations reaching very high values.

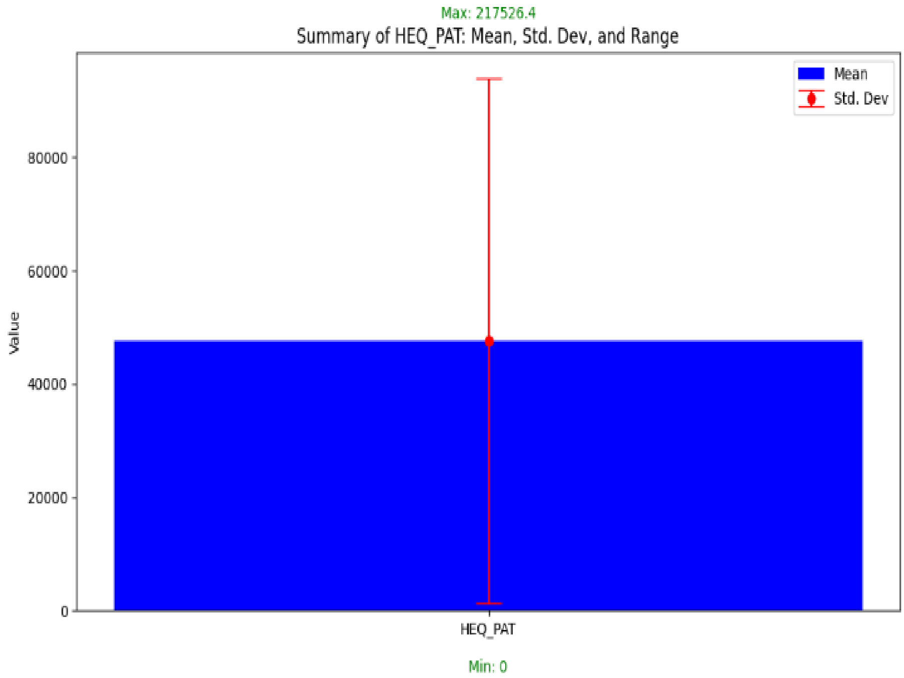

Figure 9. HEQ_PAT summary: Distribution and variability.

The visual representation clearly illustrates that the HEQ_PAT variable exhibits a notable average yet also significant fluctuations, as shown by its extensive standard deviation and the extensive variation between its lowest and highest values.

As shown in **Table 7**, the STATA chart displays the figures for various critical economic and educational measures for the initial 10 observations. The subsequent items are the alterations in these signs and their potential interpretations.

Table 7. Sample data (first 10 observations).

GDP per capitayn	Quality Indexoo	Number of Granta	HEQ PAT	Research experm	Employed persons	Gross fixed Cap1	Market openness	Urbanizationre	Highway mileagf
39,692	656	10.9860	7207	133,558.4	4342.1	24,385.968	0.125076	0.509732	186,940
43,686	1402	11.0184	1545	135,829.3	4361.6	27,033.378	0.112097	0.526272	197,588
49,092	3485	10.9719	3824	140,452	4377.9	29,275.062	0.122875	0.542843	203,285.3
56,063	5228	11.2866	5901	147,148.8	4385.3	32,729.519	0.122315	0.556452	208,826.3
60,561	4664	11.3208	5280	175,318.1	4384	35,675.176	0.128710	0.570256	218,294.6
62,411	5919	11.6927	6921	194,688.1	3243	36,460.029	0.142679	0.583292	236,483
69,676	6375	11.9413	7613	235,292.1	3215	39,887.272	0.162177	0.593980	237,411
72,888	6811	11.9614	8147	252,476	3176	43,477.127	0.170521	0.601599	237,967.2
113,692	2714	11.4514	3108	245,728	1186.1	7495.9934	0.803142	0.867002	21,885

The per capita GDP increased from $39,692 to $113,692, signaling economic expansion and better living conditions. The substantial rise in the Quality Index (from 656 to 6811) and the number of research and development staff (from 133,558.4 to 252,476) mirrors the continuous funding in education and research. Nevertheless, the variable nature of the patents awarded and the complexities of upholding standards in higher education (HEQ_PAT) suggest fluctuations. Job figures rose marginally, indicating a steady employment sector, whereas the significant escalations in fixed asset funding ($24,385.968 to $43,477.127) and road distance (186,940 km to 237,967.2 km) demonstrate progress in infrastructure. Both market openness and urban expansion rose, reflecting diverse regional receptiveness and accelerated city development.

The STATA table displays the various essential economic and educational metrics used for the initial 10 observations. This information showcases the intricate interplay among the economic, educational, innovative, infrastructural, and market liberalization aspects, which collectively impact regional economic well-being.

As outlined in **Table 8**, the STATA data for the Quality Index (average: 4156.718, standard deviation: 3751.467, range: 0–18554) reveal notable variations in economic and social standards across different Chinese provinces. The extensive spread and significant standard deviation reveal notable variances in regional development rates, whereby certain areas exhibited negligible or no quality index figures while other areas significantly surpassed them. The disparities underscore the necessity for specific policies to address irregular development across regions, with policymakers advised to concentrate on underdeveloped areas to mitigate these differences (Aziz and Samudra, 2023). Generally, the findings emphasize the need for regional cooperation and the distribution of resources to foster equitable development.

Table 8. Summary of multiple variables.

Variable	Obs	Mean	Std. dev	Min-Max
Quality Indexoo	248	4156.718	3751.467	0–18554

Table 9 supports the null hypothesis (H_0), suggesting the panel data comprise unit roots. There are 31 panels in total. The substitute hypothesis (Ha) proposes the smoothness of the panel data. There are eight different times. The AR (autoregressive) parameter is openly available. The ultimate state is when N divided by T nears zero. Included are both the mean of the panel data and the temporal trend. The Augmented Dickey-Fuller (ADF) regression model encompasses one lag component.

Table 9. Levin-Lin-Chu unit root test results (GDP per capita yuan).

Test component	Details
Null hypothesis (H0)	Panel data contains unit roots
Alternative hypothesis (Ha)	Smooth panel data
Number of panels	31
Number of time periods	8
AR parameter	Public
Asymptotic	N/T- > 0

Unit Root Test: This examination using panel data serves to detect a unit root in every panel variable. The per capita GDP is either a stable state or comprises a unit root. A static time series implies that its statistical traits (including average and variability) remain consistent over time, a vital aspect for predictive modeling in economic studies.

a) H0: Panel data contains unit roots: The assumption that there are unit roots in the data implies that GDP per capita is more stochastic over time.
b) Ha: Smooth panel data: If the original hypothesis is rejected, it implies that GDP per capita is smooth and has no unit roots.

Evaluative assessment: The raw *t*-value stands at negative fifteen point nine five seven one. The modified *t*-value shows a negative value of six point four zero six one. This pair of statistics reveals that the initial hypothesis (H_0) was disproven by the examination, indicating the absence of a unit root in the data, thus implying they are smooth.

There are 31 panel data points, signifying that per capita GDP was evaluated in 31 different provinces. The duration is eight, signifying that the dataset spans eight distinct epochs, potentially eight years. The AR parameter is accessible to the public. Asymptosis indicates that the ratio of N to T nears zero, reflecting the autoregressive parameters and the asymptotic distributional traits employed. The average of the panel data and the temporal trend have been incorporated.

The parameters of the Bartlett Kernel and 1 Lag, among others, reveal the precise statistical techniques and modifications utilized to perform the LLC unit root test.

According to **Table 4**, the data reveal a positive correlation between economic development and education level, with a higher GDP per capita leading to more years of schooling. For instance, regions with a GDP per capita of $39,692 have 8.80 years of schooling on average, while those with $113,692 as the GDP per capita have 12.08 years. However, the quality of tertiary education does not always align with the level of GDP. Some regions with medium levels of GDP (e.g., $69,676) have higher education quality (HEQ) indices, suggesting that factors beyond economic development, such as specific policies, influence education quality. Regions with balanced economic growth tend to show closer alignment between the years of schooling and higher education quality (HEQ), indicating a balanced investment in both.

Regression analysis was conducted, as detailed in **Tables 1–9**. This involved testing for robustness and substitutions of variables. Generally, the level of education and the investment in research and development are crucial for economic expansion, with these having joint significance. This forms a foundation on which decision-makers can concentrate in order to enhance educational standards and channel R&D funds toward fostering sustainable economic development.

For an all-encompassing examination, we performed endogeneity analyses to mitigate issues related to endogeneity between the quality of higher education and economic development, utilizing the instrumental variables (IV) technique and the generalized method of moments estimation (GMM).

As stated in **Table 10**, the OLS regression outcomes allow us to infer several points. First, the regression analysis reveals the model's significance, as evidenced by an *F*-value of 212.01 and an R-squared of 0.4629, indicating that the quality_index accounts for 46.29% of the per capita GDP variability. A regression index coefficient of 5.745988 signifies that every increment in the quality_index enhances the per capita GDP by about $5,746. The significance of this coefficient is statistical, as indicated by a *t*-value of 14.56 and a *p*-value of 0.000. The model's reliability is reinforced by the slim 95% confidence ranges for both the quality index and the fixed term. The quality index markedly enhances the per capita GDP, with its estimations exhibiting remarkable reliability.

Table 10. OLS regression results.

Source	**SS**	**df**	**MS**	**-**
Number of obs	-	-	-	= 248
Model	1.1477e + 11	1	1.1477e + 11	F (1246) = 212.01
Residual	1.3317e + 11	246	541350506	Prob > F = 0.0000
Total	2.4794e + 11	247	1.0038e + 09	R-squared = 0.4629
Adj R-squared = 0.4607	-	-	-	-
Root MSE = 23267	-	-	-	-

Table 11 shows the analysis of the instrumental variable (2SLS) regression findings. Given the outcomes of the instrumental variable regression (also known as two-stage least squares, or 2SLS), the following conclusion was derived: An instrumental variable regression, encompassing 248 data points and a Wald chi-squared figure of 263.96, signifies the statistical significance of the model. With an R-squared of 0.4352, it appears that the quality index accounts for 43.52% of the variability in the per capita GDP. With a quality index regression coefficient of 7,152, it is evident that every increment in the index boosts the per capita GDP by roughly $7,152. The given coefficient holds statistical importance, as evidenced by a z-value of 16.25 and a *p*-value of 0.000. The 95% confidence range for the quality index, ranging from [6289; 8015], signifies its elevated precision. Overall, the study establishes that the quality index significantly enhances per capita GDP, corroborating earlier results from an ordinary least squares (OLS) regression analysis.

Table 11. IV regression using 2SLS.

Instrumental variables (2SLS) regression	**-**
Number of obs	= 248
Wald chi2(1)	= 263.96
Prob > chi2	= 0.0000
R-squared	= 0.4352
Root MSE	= 23763

Table 12 shows GMM estimation results describing the relationship between the GDP per capita and the quality index, using an instrumental variables approach. The results are interpreted below in the context of the relevant data from the dataset.

Table 12. GMM estimation.

Instrumental variables (GMM) regression	**-**
Number of obs	= 248
Wald chi2(1)	= 267.99
Prob > chi2	= 0.0000
R-squared	= 0.4332

Table 12. (*Continued*).

Instrumental variables (GMM) regression	**-**
GMM weight matrix	Robust
Root MSE	= 23806
GDP_per_capita	Coefficient Std. Err.
Quality_index	7.186024
_cons	37,125.06

a) Coefficient of Quality Index (7.186): This coefficient indicates that when holding other factors constant, a one-unit increase in the quality index would increase the GDP per capita by approximately 7.19 units. This positive and statistically significant relationship (p-value = 0.000) suggests that an increase in the quality index is closely associated with a rise in GDP per capita.
b) Intercept (_cons = 37,125.06): An intercept of 37,125.06 indicates that when the quality index is zero, the GDP per capita is about 37,125 units. This represents the baseline GDP per capita without the contribution of the quality index.
c) Indicators of Model Fit: R2 = 0.4332. The R^2 value indicates that approximately 43.32% of the variation in the GDP per capita is explained by the quality index. These values—Wald x^2 = 267.99, p-value = 0.0000—indicate that the overall model is highly significant.

The GMM calculations align with the CSA data, revealing that regions with superior quality metrics typically exhibit a greater GDP per person. Beijing, for instance, boasts a superior quality of life and a high per capita GDP, indicating a positive relationship in the GMM model. This implies that initiatives focusing on elevating lifestyle quality, including creating better education, healthcare, and infrastructure, play a substantial role in fostering economic expansion, as evidenced by the robust statistical links between these factors. **Tables 13** and **14** display the endogeneity examination.

a) H_0: Variables are exogenous, which implies that the original hypothesis is that the variables are exogenous; i.e., there is no endogeneity problem.
b) The GMM statistic chi2(1) = 18.936, p = 0.0000 means that the chi-squared test using generalized method of moments (GMM) has a statistic of 18.936, which corresponds to a p-value of 0.0000. Since the p-value is much less than 0.05 (the usual level of significance), we can reject the original hypothesis.

According to **Table 13**, the over-identification restriction test and the Hansen's J test are as follows:

a) H0: The instruments are valid. The original hypothesis is that the instrumental variables are valid, i.e., the instrumental variables are not correlated with the error term and the model is not mis-specified.

Hansen's J chi-squared statistic with 1 degree of freedom is equal to 1.21278 (p-value is equal to 0.2708). The chi-squared statistic of Hansen's J test is 1.21278, and the p-value is 0.2708.

Table 13. Testing for endogeneity.

Test description	Result
Test of endogeneity (orthogonality conditions)	-
Null hypothesis (H0)	Variables are exogenous
GMM C statistic (chi2(1))	18.936
p-value	0.0000

Table 14. Testing for overidentifying restrictions (Hansen J test).

Test description	Result
Test of overidentifying restrictions	-
Hansen's J statistic chi2(1)	1.21278
p-value	0.2708

Analysis of the *p*-value: With a value of 0.2708, the standard significance level of 0.05 is surpassed. This implies that the null hypothesis cannot be dismissed, which would confirm the validity of the instrumental variables.

Put differently, the Hansen test demonstrates the insufficiency of proof linking the instrumental variables employed in the model with the error element. Consequently, the model's instrumental variables are deemed suitable, ensuring the model remains unaffected by excessive identification.

Earlier data compilations encompass regional metrics like the per capita GDP, Research & Development teams, patent filings, and infrastructure index.

When employing these as tools, Hansen's test verifies their lack of significant correlation with the error term in the model, thus confirming the selection process. This confirms this is essential for developing solid models, especially when examining the effects on provincial economic growth and policy decisions.

This research employs econometric techniques such as EGLS regression, robustness, and endogeneity evaluations to examine the impact of enhanced higher learning quality on China's economic development. The findings reveal that improvements in higher education contribute to economic expansion both directly and indirectly via scientific and technological advancements, as confirmed by the resilience and GMM endogeneity assessments. Essential factors like per capita GDP, education duration, and the quality index of higher education were validated as uniform through ADF, LLC, and PP tests, rendering these factors appropriate for regression using panel data. Analysis via EGLS regression reveals how the quality of higher education notably benefits economic expansion, particularly when integrated with technological advancements. The model's dependability is affirmed by tests of robustness and endogeneity, underscoring the critical roles of tertiary education excellence and R&D investment in propelling economic expansion. This establishes a robust base for creating educational and technological policies.

Research studies show a strong, positive link between the caliber of higher education and the regional economic expansion in every Chinese province from 1999 through 2022. In particular, the regression findings reveal that each unit elevation in the higher education quality (HEQ) index (HEQ) correlates with an estimated per capita GDP growth of 5.75 units (refer to **Table 11**).

Study Outcome 1: This implies that areas boasting superior higher education quality (HEQ) exhibit enhanced economic outcomes, underscoring the critical influence of educational quality in promoting economic expansion. Additionally, the research underscores the secondary effect of HEQ on economic expansion, fostered by the encouragement of STI. By employing the quantity of patents issued as a stand-in for innovation, the researchers discovered that the interplay between HEQ and patents markedly boosted economic expansion. The combined impact of HEQ and the ability to innovate underscores the significance of collaborative investment in both education and technology.

Research Outcome 2: There were noteworthy regional disparities in the ways higher education quality (HEQ) affects economic expansion. Coastal areas in the east, like Beijing and Jiangsu, exhibit considerably elevated per capita GDP and HEQ levels compared to the central and western zones, including Tibet and Qinghai. The unequal allocation of educational resources results in varied economic consequences, underscoring the urgency of policy development to foster equitable regional growth.

Study Outcome 3: The dependability of the outcomes was validated through tests for robustness, encompassing generalized method of moments estimation (GMM) and endogeneity evaluations. The GMM results also show that tertiary education quality significantly boosts per capita GDP, as evidenced by a 7.19 unit rise in per capita GDP for each increment in HEQ (refer to **Table 13**).

Study Outcome 4: Sequential studies reveal marked enhancements in higher education quality (HEQ) across most regions during the study, alongside rising economic expansion. Nevertheless, the recent decrease in HEQ within areas of China implies that maintaining educational quality presents hurdles, potentially impeding any forthcoming economic expansion. The research underscores how vital the quality of higher education is for propelling China's regional economic progress. According to the research, enhancing higher education quality (HEQ) directly boosts economic productivity and indirectly fosters economic expansion via innovation. Tackling local variances in educational facilities is vital for realizing equitable and enduring economic nationwide growth in China.

4. Discussion

This study clearly reveals the critical role of higher education quality (HEQ) in regional economic growth in China. The research demonstrates that HEQ not only directly affects regional per capita GDP, thereby enhancing economic development levels, but also indirectly drives economic growth by improving innovation capabilities. The eastern regions benefit from higher HEQ and favorable research environments, so they lead in terms of economic and innovation outcomes, while the central and western regions face development challenges due to a lack of educational resources. Therefore, promoting balanced HEQ improvements across different regions is crucial for achieving sustainable nationwide economic development. In addition, the robustness test results demonstrate the significant positive impact of HEQ on per capita GDP, especially through enhancing innovation outcomes. While HEQ has improved in China overall, some regions have seen a decline, posing challenges for regional economic development and necessitating policy interventions to ensure balanced regional development in education and the economy. This study provides scientific support for policymakers, emphasizing the necessity and feasibility of achieving sustainable economic growth by improving the quality of higher education.

Discussion 1: The Role of Higher education quality (HEQ) in Driving Economic Growth.The first research finding highlights the importance of higher education quality (HEQ) in driving regional economic expansion in China. Improving HEQ directly affects regional per capita GDP while also indirectly promoting economic development by enhancing innovation capabilities. Comparing the literature, it can be seen that while many studies emphasize the importance of access to education in economic development, this study further emphasizes the decisive role of educational quality, noting that the quality of higher education has a deeper impact on economic development than the scale of education. By cultivating highly qualified researchers and technical experts, quality higher education enhances regional innovation capabilities, drives technological advancement, and ultimately promotes sustainable economic development. Unlike early scholars such as Schultz, who primarily focused on the quantity of human capital accumulation, this study emphasizes the importance of improving its quality. In addition, synergistic investment in education and technology is particularly important, with both factors jointly contributing to sustainable regional economic growth and reduced regional disparities. Therefore, this study provides new empirical evidence that improves the understanding of the relationship between HEQ and economic growth, emphasizing the importance of educational quality in promoting balanced regional economic development.

Discussion 2: Differences in Economic Growth Across Regions.The second research finding reveals significant differences in economic growth across China’s eastern, central, and western regions, primarily due to differences in higher education quality (HEQ). Due to their higher HEQ, superior research resources, and economic foundations, the eastern regions (e.g., Beijing, Shanghai, and Jiangsu) have significantly higher levels of per capita GDP and innovation outcomes than the central and western regions. The eastern regions benefit from continuous government investment in education and infrastructure, enabling them to effectively leverage the benefits of economic growth brought by HEQ. Meanwhile, the central and western regions, constrained by their insufficient educational resources and geographic factors, struggle to achieve the same levels of educational quality as those in the east, making it difficult for them to leverage HEQ for innovation and economic growth. This finding aligns with the observation by Bouhajeb et al. that an imbalance in educational resources hinders regional economic development. This study suggests that through policy interventions (such as increased investment in education in the central and western regions, improved teacher compensation, and the development of local universities), HEQ in these regions could be effectively enhanced, reducing the regional disparities in economic growth and promoting fair and sustainable development across the country. These are crucial if the goal of “common prosperity” is to be achieved, and the issues must be addressed systematically through policy solutions to reduce the disparities in educational quality and economic growth.

Discussion 3: Robustness Test Results and Policy Recommendations. The robustness tests further confirm the significant impact of higher education quality (HEQ) on economic growth. This study employed methods such as generalized method of moments (GMM) estimation and endogeneity assessments, with the results showing that each unit increase in HEQ leads to a significant increase in per capita GDP of approximately 7.19 units, indicating that HEQ improvements play a significant and multidimensional role in promoting economic growth. This aligns with previous studies on the importance of higher education quality (HEQ), but this study emphasizes the impact of HEQ on enhancing innovation outcomes and demonstrates the reliability of the results through robustness testing. In terms of policy recommendations, the study points out that the government should invest more in education in the underdeveloped regions of central and western China, improve the educational infrastructure, and enhance the education quality to attract higher-quality teaching resources and improve students' learning opportunities. These policy measures would help to not only improve the HEQ in underdeveloped regions but also promote economic growth in these regions through innovation, driving coordinated development and common prosperity across the country.

Discussion 4: Trends in Higher education quality (HEQ) and their impact. Finally, the study focuses on the recent changes in higher education quality (HEQ) in different regions and their impacts on economic growth. While HEQ and economic development levels have improved in most provinces over the past few decades, some regions have seen a decline in HEQ, particularly the central and western areas. This decline may be related to the insufficient allocation of funds for education, aging educational facilities, and other local issues. Comparing these new findings to those across the literature, this study found that a decline in HEQ may hinder long-term economic development, which aligns with the findings obtained by Nguyen et al. on the impact of educational quality on long-term economic growth. Therefore, to ensure that HEQ continues to drive economic development, especially in underdeveloped regions, policy interventions must be introduced, including more equitable funding distribution, a balanced allocation of educational resources, improvements to educational facilities, and a strengthening of teaching staff. In addition, the study points out that HEQ indirectly drives economic growth by promoting innovation outcomes. In terms of patent applications and technological achievements, the eastern regions are significantly ahead of the central and western regions, further widening the regional economic imbalances. Therefore, adjustments to education and innovation policies are needed to ensure that HEQ improvements reach all regions, thereby achieving more balanced and sustainable economic growth, which is crucial for reducing the regional disparities and achieving both national economic prosperity and long-term development.

5. Conclusion

This study investigates the influence of higher education quality (HEQ) improvements on economic development, using panel data spanning 31 Chinese provinces and covering the period 1999 to 2022. It identifies how higher education quality (HEQ) has both direct and indirect impacts on economic growth by fostering scientific and technological progress and accumulating human capital. The findings confirm that enhancing the quality of higher education significantly contributes to economic development, particularly by advancing science and technology.

The research highlights that region with superior levels of higher education, especially the eastern coastal provinces, experience significantly greater per capita GDP compared to the central and western regions. This disparity suggests that improvements in higher education standards could effectively boost economic output, underscoring the critical role of higher education as an investment in human capital. The findings reaffirm that raising the quality of higher education is crucial for economic growth because it directly enhances productivity and regional economic outputs. This conclusion aligns with earlier theories about the role of education in human capital development, as presented by Schultz and other scholars, but places a stronger emphasis on the quality aspect.

Moreover, the study finds that higher education quality (HEQ) indirectly accelerates economic development by encouraging scientific and technological innovation. By acting as a catalyst for increased patent issuance and other technological advancements, improved education quality supports innovation, which subsequently contributes to sustainable economic growth. The research demonstrates that higher education not only equips the workforce with enhanced skills but also plays a key role in supporting ongoing economic development by boosting innovation capabilities.

The uneven economic growth across different regions in China highlights the significant role of regional disparities in higher education quality (HEQ). The eastern regions, characterized by their better-quality education and superior innovation capacity, have performed better economically compared to the central and western regions. This imbalance underscores the need for increased policy investments in educational resources in less-developed regions to achieve harmonized nationwide development. Addressing this gap is essential for promoting equitable economic development and achieving the goal of "common prosperity".

Policy Implications

1) Increase Educational Investment in Central and Western Regions: The findings suggest that policy measures should be implemented to enhance investment in higher education in the central and western regions. Increasing the funding for educational infrastructure, attracting quality faculty members, and improving the research facilities are crucial steps to improving education standards. This would help underdeveloped regions leverage the economic benefits of improved education quality, thus promoting balanced regional development.
2) Enhance Educational Quality through Technological Integration: Given the strong link between higher education quality (HEQ) and scientific and technological advancements, it is recommended that government policies focus on integrating technology into educational frameworks. Promoting partnerships between universities and technology companies could improve innovation outputs, including patent registrations, thereby boosting economic growth. Policies that incentivize R&D investments in higher education would help foster an environment conducive to technological advancements.
3) Balance Resource Allocation across Regions: To address the disparities in educational quality between different regions, policies should prioritize balanced resource allocation across all provinces. Government initiatives could include targeted funding programs to improve the quality of higher education in less

developed areas, which would help bridge the economic gaps between regions. This could include the allocation of special funds to strengthen universities in central and western China, as well as programs aimed at enhancing the quality of teaching and research in these areas.

4) Strategic Support for Innovation: The research shows that scientific and technological innovation serves as a crucial link between higher education quality (HEQ) and economic growth. Policies should aim to support innovation by enhancing R&D funding and encouraging the establishment of technology transfer centers at universities. This would provide greater support for translating research outcomes into economic benefits, particularly in regions where innovation is lagging.

Future studies should explore the diverse aspects of higher education—such as teaching quality, faculty members' qualifications, and research investments—to better understand their individual impacts on economic growth. By examining these elements in detail, subsequent research could provide more nuanced policy recommendations. Specific areas that warrant further exploration include:

- The impact of faculty development programs on regional innovation capacity.
- The effectiveness of different funding models in improving educational quality and outcomes.
- A comparative study of public versus private investment in higher education, as well as the respective impacts of these types of investment on economic expansion.

Such future studies could help policymakers design targeted measures to improve different facets of higher education, ultimately fostering more sustainable and inclusive economic growth across all regions of China.

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