Прикладная эконометрика, 2024, т. 75 с. 5–32.
Applied Econometrics, 2024, v. 75, pp. 5–32.
DOI: 10.22394/1993-7601-2024-75-5-32

J. Huang, P. Rangkakulnuwat [1]

Does years of schooling matter for economic growth at different development levels? New evidence from China

This research paper investigates the relationship between education and economic growth in China from 1989 to 2019 across 27 provinces. The study classifies education into two categories: aggregate education (average years of schooling) and disaggregated education (education divided into compulsory, high school, and higher education). The data is analyzed based on pre- and mid-industrialization periods, and East and West regions, with and without pre- and mid-industrialization, for both levels of education. The findings indicate that the impact of education on China's economic growth varies by period (pre- and mid-industrialization), region (East and West), and regions with periods (Eastern pre-industrialization, Western pre-industrialization, East mid-industrialization, and West mid-industrialization) in both aggregate and disaggregated education. According to the research results, the central government should revise its current educational policies to prioritize compulsory education and increase investment. Furthermore, local governments should have more administrative authority to create local educational policies catering to the specific needs of each locality.

Keywords: China; education; years of schooling; economic growth; industrialization.
JEL classification: E24; O47; O14.

1. Introduction

Since the early 1960s, when the American economist Theodore Schultz (1961) developed the human capital theory, it has been widely proven that human capital plays a significant role in economic growth. According to Schultz (1961) and Becker (1964), human capital can be understood as the collection of knowledge, skills, competencies, and abilities inherent in individuals and acquired through various means, such as health, migration, and education[2]. Education is widely recognized as a critical investment in human capital linked to economic growth through

[1] **Huang, Juan** — Hezhou University, Guangxi, China; alinhuang@foxmail.com.
Rangkakulnuwat, Poomthan — Kasetsart University, Bangkok, Thailand; poomthan.r@ku.th.

[2] Education can be measured by various factors, including years spent in schooling, e.g. (Zhang, Zhuang, 2011; Yan, Yudong, 2003). Intuitively, the more years a person spends in school, the more knowledge, skills, competencies, and abilities they acquire. In other words, there is a positive correlation between education and the number of years spent in schooling. For more detailed information on the measurement of education, see Appendix B. However, other indicators of human capital, such as health and migration, are outside the purview of this study. For more information, refer to (Bloom et al., 2018; Monterubbianesi et al., 2017; Faggian et al., 2018; Gagliardi, 2015).

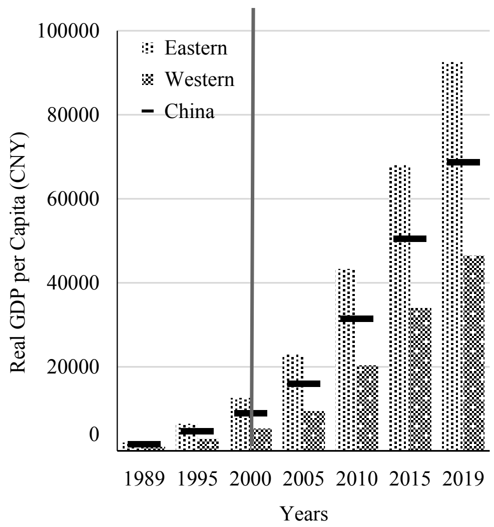
the augmented neoclassical model and the new endogenous growth theories. The former model includes education as an additional input (Adnans, Muda, 2018; Mankiw et al., 1992; Masoud, 2013), and the latter argues that an increase in education leads to an increase in productivity growth rate (Benhabib, Spiegel, 1994; Li, Wang, 2018). Further research has shown that education impacts economic growth through three channels. Firstly, through factor accumulation and labor productivity improvement (Adnans, Muda, 2018; Mankiw et al., 1992), an increase in the population's educational attainment directly increases labor productivity. Secondly, through technological innovation (Aghion et al., 2005; Cinnirella, Streb, 2017; Li, Wang, 2018), where access to education enhances the innovation capacity of workers for economic growth. Lastly, by applying science and technology and knowledge diffusion, education facilitates the diffusion of knowledge necessary to understand and process new information and successfully apply new technologies (Benhabib, Spiegel, 1994; Li, Wang, 2018).

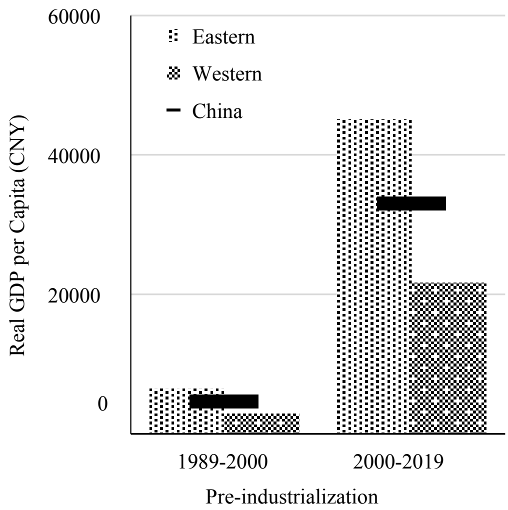
Despite the literature's well-documented relationship between education and economic growth, there has been an ongoing debate regarding the nature of this relationship and the role of different levels of education (Cheek et al., 2015; Sianesi, van Reenen, 2003). This raises the question, "What factors lead to the different impacts of education on economic growth?" A potential factor contributing to this difference is the role of economic development level in the impact of education on economic growth.

Studies by Mingat and Tan (1996), Petrakis and Stamatakis (2002), Sianesi and van Reenen (2003) have shown that the impact of aggregate education, as well as of each disaggregated education level, on economic growth varies depending on the economic development level. In the early stages of economic development, primary education contributes more significantly to economic growth due to limited opportunities for labor specialization. Higher education becomes more valuable to economic growth as production techniques, economic processes, and business models become more complex. Therefore, as a country's economic development level increases, the benefits of education can be realized to a greater extent, and the contribution of higher education to economic growth will become more prominent.

China's over 40-year reform and opening to the global market has brought about significant progress but also resulted in uneven development across its province (Lu et al., 2019). Over time, China's industrialization has transitioned from a pre-industrialization period (1978–2000) dominated by the light industry to a mid-industrialization period (2000-present), where heavy industry has taken the forefront (Lin, Jiang, 2021). Real GDP per capita is a reliable indicator of the shift in the industrialization and economic development stages. As illustrated in Fig. 1, China's real GDP per capita grew steadily from 1989 to 2000 and increased after 2000. In the pre-industrialization period, China's real GDP per capita was 4650 CNY. However, during the mid-industrialization period, it increased over seven times (refer to Fig. 2).

The Eastern provinces had a competitive advantage in policy and geography, thus leading to their development and becoming the most developed regions of China. Meanwhile, Western provinces have remained underdeveloped (refer to Fig. 1) (Rong, 2010). The unbalanced development has continued throughout industrialization, with the Eastern region developing significantly better than the Western region (refer to Fig. 2). Education has been identified as a crucial factor contributing to this disparity (Zhang, Zhuang, 2011). These raise the question of whether education matters for economic growth differently across various stages of development and to what extent each education level affects economic growth at different levels of development. Our data shows that the education years and each level in China vary across industrialization periods and regions





Data source: China Statistical Yearbook (1989–2019).

Fig. 1. Regional divide in real per capita GDP

Fig. 2. Real GDP per capita in different stages of industrialization

(refer to Table 1). This makes it necessary to investigate the role of economic development level in the impact of education on economic growth across China.

To our knowledge, only one study has delved into the impact of economic development level on the correlation between education and economic growth in a single-country context. Zhang and Zhuang (2011) conducted a study spanning 31 provinces in China from 1997 to 2006, where they concluded that higher education is essential to China's economic growth. Additionally, they found that more developed provinces benefited more from higher education, and less developed provinces relied more on primary and secondary education. However, their finding did not align with that of Whalley and Zhao (2014), who found that despite an almost fivefold increase in university enrollment in China between 1997 and 2007, GDP growth rates remained virtually unchanged after 1999. This inconsistency may stem from China's shift from pre-industrialization to mid-industrialization in 2000 (Lin, Jiang, 2021). Therefore, analyzing this relationship in this narrow timeline (1997–2006) amid a significant economic transition in 2000 could lead to misleading results. Thus, the role of different economic development levels in the relationship between education and economic growth needs to be further explored.

There are three contributions to this paper. First, we examine the relationship between education and economic growth in China, emphasizing the impact of economic development levels, as measured by industrialization development, on this relationship, which has been overlooked in previous studies. To accomplish this objective, we use the interaction between industrialization development and schooling years to examine the role of the economic development level in the impact of education on economic growth, and both aggregate and disaggregated education data are utilized in the empirical model.

Second, compared to most empirical studies using the provincial panel data of China (Li, Wye, 2023; Liu et al., 2021; Zhang, Zhuang, 2011), which cover between 9 and 19 years, our dataset is a much longer panel containing 31 years of time horizon. Using this long panel data allows us to account for the cumulative impact of education over time since it may take numerous years to sufficiently influence the much larger stock of human capital in society, which in turn affects GDP (McMahon, 2000). Therefore, compared to most empirical studies using provincial-level panel data, this long panel data gives us greater confidence in obtaining more trustworthy and realistic results. Moreover, this long panel data covers two landmark eras of industrialization, which opens up new ground from a substantive point of view in exploring whether the impact of education on growth differs across subsamples based on the level of economic development.

Third, the data is categorized based on the significant shifts in China's industrialization, with the pre-industrialization (1989–2000) and mid-industrialization (2000–2019) periods analyzed. We also group the data into the Eastern and Western regions, with and without dividing the data into pre- and mid-industrialization, providing insight into the role of industrialization in the relationship between education and economic growth across regions. In contrast to most studies that group provincial data based on the location (Fleisher et al., 2010; Fraumeni et al., 2019; Zhang, Zhuang, 2011), our approach includes grouping the provincial data with and without dividing the data into pre- and mid-industrialization stages, which helps identify the possible heterogeneous effects of the economic development level of a region or the different stages of its development level on the relationship between education and growth. The study's findings can aid the government in devising national education policies for different regions in different development stages.

2. Literature review

Numerous studies have been conducted to determine the impact of education on growth but have produced conflicting results. The majority of this literature deals with cross-country economic growth regressions. It uniformly considers the impact of using average years of schooling as a proxy for an economy's human capital. For extensive reviews of the literature, see (Kubík, 2015; Krueger, Lindahl, 2001; Pritchett, 2006).

After analyzing various studies, it has become clear that there are mixed findings regarding the connection between education and economic growth. To clarify this relationship, we have considered the role of economic development level (measured by industrialization) on the relationship between education and growth, previously overlooked in the literature. Psacharopoulos (1994) compared the return on investment for each level of education for 78 regions classified as low-, lower-middle-, upper-middle-, and high-income regions. The study revealed that primary education was a high-priority investment for developing countries and that social and private education returns decrease as national per capita income increases. This relationship between education and economic growth has been confirmed by Mingat and Tan (1996), who found that investments in primary, secondary, and tertiary education yield the highest returns in low-, middle- and high-income countries, respectively. They further argue that the benefits of education are best realized when a skilled workforce can be fully exploited. Petrakis and Stamatakis (2002) found that while primary and secondary education plays a more significant role in the economic growth of the least developed countries, OECD countries are largely dependent on higher education. Similarly, Deme and Mahmoud (2020) found that primary education was significantly related to economic growth in low and middle-income African countries. Pedroni (1999) and Psacharopoulos and Patrinos

(2004) also found that the impact of educational investment varied with the countries' development levels.

To our knowledge, only one study investigated how a country's economic development level affects the relationship between education and economic growth. Zhang and Zhuang (2011) carried out an inquiry covering 31 Chinese provinces from 1997 to 2006, aiming to scrutinize the effects of human capital on economic growth across regions with varying levels of development. Their discoveries imply that, while higher education holds greater significance for China, more developed provinces exhibit more benefits from it, while less developed provinces depend more on primary and secondary education. This contradicts the findings of Whalley and Zhao (2014), according to which, despite a nearly fivefold increase in university enrolment in China between 1997 and 2007, GDP growth rates remained virtually unaltered after 1999. It must be noted that these conflicting outcomes could be attributed to the criteria for classification adopted by the World Bank and China's economic status in transition during this period, which may lead to erroneous results when assessing the relationship between education and economic growth over such a limited timeline (1997–2006) featuring a significant economic transition.

Most education-to-growth studies in China have used panel data at the provincial level. For example, from a financial development perspective, Li and Wye (2023) explore the impact of education on economic growth using data from 31 provinces in China from 2005 to 2019. Many other studies similarly used provincial-level panel data to study education and growth (Haini, 2020; Liu et al., 2021; Zhang, Zhuang, 2011), and one of their commonalities is that the time horizon of the study was limited to the period between 9 and 19 years. On the other hand, the instantaneous impacts of education are minimal, even in the short term. Education takes a long time to accumulate before its impact is significant enough to affect society's more extensive stock of human capital and then impact GDP. These periods are sometimes as long as 10 to 25 years, as it takes time for individuals to graduate and gain experience and productivity (Appiah, McMahon, 2002; McMahon, 2000).

Research on the connection between education and economic growth has predominantly utilized the Generalized Methods of Moments (GMM) method to address potential endogeneity issues (Deme, Mahmoud, 2020; Zhang, Zhuang, 2011). Studies have also employed the autoregressive distributed lag model or autoregressive distributed lag cointegration technique to analyze the short and long-run relationship between education and economic growth (Bassanini, Scarpetta, 2002; Ishchy, 2019). Additionally, some scholarly works have implemented fixed effects models (FE) and the feasible generalized least squares (FGLS) approach (Akbari, Haider, 2018; Gyimah-Brempong et al., 2006; Kocourek, Nedomlelová, 2017). As this paper deals with long panel data, we have used the FE and FGLS methods instead of the GMM method, which is more suitable for studying short panel data. The subsequent section will discuss the estimation methods employed in this study.

3. Data and empirical model

3.1. Data

We gathered data from three primary sources: the China Statistical Yearbook, the China Foreign Economic Statistical Yearbook, and the China Population and Employment Statistical Yearbook. However, we only obtained a comprehensive long-panel dataset that spans 31 years (1989–2019)

Table 1. Descriptive statistics for the overall data, pre- and mid-industrialization periods classified by regions

Variables		All regions			Eastern region			Western region		
		Overall data	Pre-industrialization	Mid-industrialization	Overall data	Pre-industrialization	Mid-industrialization	Overall data	Pre-industrialization	Mid-industrialization
y (%)	Mean	14.01	17.30	11.74	14.09	18.09	11.44	13.93	16.57	12.03
	Std. Dev.	7.417	9.008	5.190	7.359	8.661	4.883	7.478	9.283	5.452
AE (years)	Mean	7.917	6.743	8.585	8.376	7.148	9.079	7.490	6.367	8.126
	Std. Dev.	1.397	0.981	1.115	1.423	0.930	1.130	1.228	0.873	0.883
HE (years)	Mean	1.215	0.480	1.630	1.598	0.659	2.129	0.859	0.315	1.167
	Std. Dev.	1.111	0.449	1.149	1.375	0.572	1.402	0.602	0.170	0.529
HSE (years)	Mean	1.650	1.351	1.821	1.882	1.592	2.050	1.434	1.126	1.608
	Std. Dev.	0.562	0.546	0.492	0.568	0.603	0.468	0.461	0.364	0.412
CE (years)	Mean	5.114	5.072	5.133	4.971	5.092	4.899	5.247	5.054	5.350
	Std. Dev.	0.605	0.605	0.599	0.609	0.460	0.665	0.570	0.715	0.428
IN (%)	Mean	37.30	37.87	36.91	39.05	40.33	38.28	35.68	35.59	35.64
	Std. Dev.	8.064	8.164	7.983	8.280	8.274	8.131	7.510	7.384	7.639
N		837	324	540	403	156	260	434	168	280

Note. y — annual growth rate of real GDP per capita;
AE — aggregate average years of schooling;
HE — stock of schooling years resulting from higher education;
HSE — stock of schooling years resulting from high school education;
CE — stock of schooling years resulting from compulsory education;
IN — ratio of industrial added value to GDP.
Appendix A shows the descriptive statistics for the rest of the variables in the empirical model.

and 27 provinces due to limited data availability for all provinces in China[3]. Table 1 reports descriptive statistics for the key variables used in this study[4].

To measure economic growth (y), we use the annual growth rate of real GDP per capita. During the 31-year period, China has maintained a high trend in real GDP per capita growth rate, especially in the pre-industrialization period, with an average growth rate of 17.3%. China's economy has also seen a significant increase in the aggregate years of education, with an average of 7.9 years over the 31-year period, compared to less than seven years in the pre-industrialization period[5]. During the mid-industrialization period, the average years of schooling increased significantly, especially for higher education; the average years increased 3.4 times for all regions, 3.2 times for the East, and 3.7 times for the West. High school education increased 1.3 times for all regions, 1.3 times for the East, and 1.4 times for the West. Compulsory education increased 1.01 times for all regions, 0.96 times for the East, and 1.06 times for the West. However, the industrialization

[3] This study uses the China Statistical Yearbook as an official data source for China's economic growth. Although other sources are available, such as the Total Economy Database, we could not obtain provincial data from it as it only provides national-level information. For further details, please refer to Appendix C.

[4] Appendix A shows the descriptive statistics for the rest of the variables in the empirical model.

[5] See Appendix B for details on measuring average years of schooling.

development level during this period was 0.96% lower for all regions and 2.05% lower for the East than the pre-industrialization period. The Western region had a similar industrialization development level to the pre-industrialization period. Overall, the Eastern region outperforms the Western region in all economic development and education aspects.

3.2. Empirical model

Based on the augmented neoclassical growth model by Mankiw et al. (1992), founded on the production function, education is regarded as a production factor that can enhance labor productivity, promote factor accumulation, and lead to economic growth. Many papers support this concept, including Deme, Mahmoud (2020), Mankiw et al. (1992), and Zhang, Zhuang (2011). It can be written as:

$$Y_{it} = A_{it} F(H, K, L) = A_{it} H_{it}^{\alpha} K_{it}^{\beta} L_{it}^{\gamma}, \quad (1)$$

where Y represents output, A is the total factor productivity (TFP), H denotes education, K is capital, and L is labor, the subscript it represents cross-section unit i at time t. We assume that $\alpha + \beta + \gamma = 1$, which means the equation (1) follows the constant return to scale. Then, the per capita production function derived from (1) is:

$$y_{it} = A_{it} f(h, k) = A_{it} h_{it}^{\alpha} k_{it}^{\beta}, \quad (2)$$

where y is output per capita, h is education per capita, and k is capital per capita. Based on the assumption of equation (1), equation (2) also operates in constant return to scale[6]. According to Abramovitz (1986), TFP growth consists of multiple factors, such as technological progress, institutional change, omitted variables, and measurement errors. As a result, equation (2) shows that any omission of independent variables or errors in measuring the variables will directly spill over into the TFP growth.

Based on the model (2), some studies reported a positive correlation between education and growth (Ishchy, 2019; Yang et al., 2006). In contrast, studies conducted by Pritchett (2001), Abdullah (2013), and Hamdan et al. (2020) have presented evidence that there is little to an insignificant or negative relationship between education and economic growth. The mixed findings may stem from neglecting the role of economic development level in the relationship between education and economic growth (Deme, Mahmoud, 2020; Petrakis, Stamatakis, 2002; Sianesi, van Reenen, 2003). The primary contribution of this paper is to investigate the role of economic development level on the relationship between education and economic growth. To achieve this, we extended model (2) by adding an interaction term between education and industrialization, which measures the level of economic development, to assess the role of economic development level on the relationship between education and economic growth.

[6] Assuming a constant return to scale with $\alpha + \beta + \gamma = 1$, we can derive $L^{\gamma} = L^{1-\alpha-\beta}$. By substituting $L^{\gamma} = L^{1-\alpha-\beta}$ in model (1), we obtain model (2), which also assumes a constant return to scale. Models (3) and (4) are extensions of model (2) and also operate under the assumption of constant return to scale.

Our model incorporates two methods of measuring education, aggregate and disaggregated education, along with control variables to minimize bias. Equations (3) and (4) represent the aggregate and disaggregated education models, respectively.

$$y_{it} = C + \alpha_1 Y_{i(t-1)} + \alpha_2 I_{it} + \alpha_3 AE_{it} + \alpha_4 AE_{it}^2 + \alpha_5 (AE_{it} \times IN_{it}) + \alpha_6 IN_{it} + \beta X_{it} + \eta_i + \varepsilon_t + \nu_{it}, \quad (3)$$

where y_{it} represents the annual growth rate of real GDP per capita. $Y_{i(t-1)}$ is the logarithm of one-period lagged real GDP per capita and is generally incorporated into growth models to examine conditional convergence to steady-state growth, as in (Deme, Mahmoud, 2020; Zhang, Zhuang, 2011). I_{it} denotes the physical capital per capita and is calculated by the ratio of the total investment in fixed assets and GDP. AE_{it} is aggregate education, measured by the average years of schooling (as described in Appendix B), while AE_{it}^2 is the square term of aggregate education used to capture the potential non-linearly (Ramcharan, 2004). Additionally, to investigate the role of industrialization development in the impact of education on economic growth, this specification includes an interaction of aggregate education (AE_{it}) and the level of industrial development (IN_{it}), which is measured by the ratio of industrial value-added and GDP. X_{it} is a vector of control variables, including import and export (XM_{it}), foreign direct investment (FDI_{it}), government expenditure (G_{it}), birth rate (b_{it}), and inflation rate (Inf_{it}). It is crucial to note that each control variable is measured by its ratio value to GDP.

We used equation (4) to analyze how different levels of education impact economic growth. The variables used are the same as those in (3), but the AE_{it} variable is separated into three levels: compulsory, high school, and higher education. This specification helps determine if the impact of the level of disaggregated education on economic growth depends on industrialization development.

$$\begin{aligned} y_{it} = C + \alpha_1 Y_{i(t-1)} + \alpha_2 I_{it} + \alpha_3 HE_{it} + \alpha_4 HSE_{it} + \alpha_5 CE_{it} + \alpha_6 HE_{it} \times IN_{it} + \\ + \alpha_7 HSE_{it} \times IN_{it} + \alpha_8 CE_{it} \times IN_{it} + \alpha_9 IN_{it} + \beta X_{it} + \eta_i + \varepsilon_t + \nu_{it}, \end{aligned} \quad (4)$$

where HE_{it}, HSE_{it}, and CE_{it} are the stock of schooling years resulting from higher education, high school, and compulsory education correspondingly (as described in Appendix B). η_i are the time-invariant unobserved effects such as geographic landscape and administrative systems. ε_t are the time-variant unobserved effects such as total factor productivity, education quality, health, skill, experience, and behavior of the age cohort.

The correlation between the unobserved effects and the independent variables, e.g., education level, results in the endogeneity problem (Martin, 2017). Thus, the two-way fixed effects (TWFE) model is appropriate, see (Baltagi, 2005). Moreover, for long panel data, due to the extensive time span, the random shock or idiosyncratic disturbance term (ν_{it}), such as changes in education policies, financial crises, or industrial policies, can induce the problem of heteroskedasticity, autocorrelation, and cross-sectional correlation (Chen, 2014). For example, changes in education policies may affect household education investment, or a financial crisis reduces household education investment; these random shocks would spill over to the next period. Furthermore, any modifications made to policies, including adjustments to different industrial development plans across various provinces, have the potential to boost growth and stimulate labor migration significantly. Conversely, a decline in growth in certain provinces may trigger labor emigration. Hence, heteroscedasticity, autocorrelation, and cross-sectional correlation problems must be tested to ensure reliable estimation results. To that end, the Modified Wald test (Laskar, King, 1997), the Wooldridge test (Wooldridge, 2003), and Pesaran's test (Pesaran, 2004) are employed to detect these issues, respectively. If the problems are present, two-way fixed effects of the feasible generalized least squares (FGLS) will be adopted as in Chen (2014) and Akbari, Haider (2018).

4. Empirical results

4.1. Results of using overall data 1989–2019

Table 2 displays the estimation results using overall data, demonstrating the TWFE results of aggregate and disaggregated education models in the first and second columns, respectively[7]. For both models, the Modified Wald test results indicate that the p-value is 0.000, leading to the strong rejection of the hypothesis of homoskedasticity and the acceptance of heteroskedasticity. The Wooldridge test also has a p-value of 0.000, which means the hypothesis of no autocorrelation can be rejected, suggesting the presence of autocorrelation. Similarly, Pesaran's test has a p-value of 0.000, leading to rejecting the hypothesis, and the presence of the cross-sectional correlation can be inferred. Hence, the FGLS with two-way fixed effects is utilized to overcome these issues, providing reliable results for the empirical model, as shown in the third and fourth columns of Table 2.

Regarding the findings of the aggregate model in column three, it is observed that the coefficient of aggregate education is positive and significant. In contrast, the coefficient of the square term of aggregate education is significantly negative. That is, aggregate education positively impacts economic growth but is diminishing. Additionally, industrialization has a significant positive effect on economic growth. The coefficient of the interaction term between aggregate education and industrialization is significantly negative, indicating that the effect of education on economic growth depends on the level of industrialization. This is because when higher industrialization in the economy leads to the adoption of more sophisticated equipment and machinery, ceteris paribus, these can substitute labor, forcing this human capital to transfer to lower-level production sectors, self-employment, or even unemployment (Farmer, Schelnast, 2021).

Based on the findings derived from the disaggregated model presented in column four, the coefficients of each level of disaggregated education are positive and significant. In particular, compulsory education exhibited the greatest effect on economic growth, followed by higher education, while high school had the weakest positive effect on economic growth. This indicates a diminishing effect of education from compulsory to high school education. Industrialization development still has positive effects on China's growth. The results show that the coefficient of the interaction term between industrialization level and higher education is insignificant, implying that the impact of higher education on China's economic growth does not depend on the industrialization level. Conversely, the interaction terms between industrialization level

[7] This study focuses on examining the impact of education, industrialization development levels, and education interaction with industrialization on China's economic growth. Therefore, the results will solely display the influence of education and industrialization development levels. The complete results are available upon request.

and disaggregated education in high school and compulsory education have a significant negative and positive coefficient, respectively. This result indicates that a higher high school education level leads to higher reductions in economic growth when industrialization is higher. This confirms the results from Min and Xiuwen (2001) and Li et al. (2012) that skills acquired in high school education under a test-oriented education system are less productive in the workplace. In contrast, a higher compulsory education level leads to higher enhanced economic growth when industrialization increases. It confirms that the status of China's industrial is labor intensive, or China is known as the "World Factory", hence, low-skilled labor (e. g., compulsory education) plays a critical role in driving economic growth (Deme, Mahmoud, 2020; Hatakenaka, 2008; Petrakis, Stamatakis, 2002).

Table 2. Parameters estimate using overall data 1989–2019

Variables	TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	7.240***		5.765***	
	(1.864)		(0.498)	
AE^2	–0.263**		–0.190***	
	(0.127)		(0.030)	
AE×IN	–0.041		–0.018***	
	(0.030)		(0.007)	
IN	0.263***	0.272***	0.327***	0.330***
	(0.072)	(0.076)	(0.017)	(0.015)
HE		2.298**		2.066***
		(0.921)		(0.147)
HSE		1.002		0.814***
		(1.466)		(0.178)
CE		5.410***		4.595***
		(0.826)		(0.172)
HE×IN		0.008		0.001
		(0.038)		(0.007)
HSE×IN		–0.123		–0.076***
		(0.092)		(0.013)
CE×IN		0.080		0.049***
		(0.092)		(0.014)
N	810	810	810	810
Modified Wald test (*p*-value)	248.7 (0.000)	249.0 (0.000)		
Wooldridge test (*p*-value)	76.95 (0.000)	69.38 (0.000)		
Pesaran's test (*p*-value)	28.11 (0.000)	24.62 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. Following Hayes (2013), we centralize the interaction terms to improve interpretation and reduce the correlation between explanatory variables and the influence of multicollinearity. The observations in the table are 27 fewer than those shown in the descriptive statistics in Table 1 because we used a lagged term of one period lagged by the real GDP in our model. This is true for all observations shown in other tables in the paper.

4.2. Results of pre- and mid-industrialization periods

After reform and opening to the world, China's industrialization development can be categorized into two distinct stages, namely, the pre-industrialization (1978–2000) and the mid-industrialization (2000–present) (Lin, Jiang, 2021). Economic growth in the pre- and mid-industrialization periods was dominated by light and heavy industry, respectively. China's industrialization history clearly shows that the demand for human capital and technology research and development varied during different phases of development. In the pre-industrialization period, primarily dominated by the light industry, there wasn't much need for human capital or technology. However, in the mid-industrialization period, China implemented a new industrialization strategy that emphasized high technological content, good economic efficiency, low resource consumption, and less environmental pollution while maximizing the advantages of human resources. As a result, higher human capital and technology requirements were put in place. Hence, it is crucial to investigate whether the impact of education on economic growth varied based on the stage of industrialization development.

4.2.1. Results of pre-industrialization periods

Table 3 reports the results of the aggregate and disaggregated models for the pre-industrialization period (1989–2000). Similar to the overall data results, the TWFE results exhibit heteroskedasticity, autocorrelation, and cross-sectional correlation problems for both models. Therefore, the FGLS with two-way fixed effects is used to achieve reliable results for both models, and the results are shown in the third and fourth columns of Table 3.

Based on the data obtained from the pre-industrialization period, the results derived from the aggregate model indicate that the coefficients of both aggregate education and its square are insignificant, which implies that in the early stages of industrialization development, the impact of aggregate education on economic growth was not critical. Furthermore, the coefficients of the industrialization level and its interaction term with aggregate education are negatively significant, implying that industrialization during the early stages of economic development may not be sufficient to translate into growth during the period under review. In other words, the early development of the industry did not meet the economic growth of China's massive population.

The results of the disaggregated education model indicate that the impact of education is diminishing, with compulsory education having the highest positive impact on economic growth. While high school education does not impact growth, higher education negatively impacts economic growth. These findings are consistent with previous studies, which suggest that compulsory education is more effective in promoting economic growth in the early stages of economic development (Keller, 2006; McMahon, 1998). The negative impact of higher education on economic growth may be due to limited opportunities for labor specialization and relatively simple production technologies and businesses in the early stages of economic development (Mingat, Tan, 1996). Thus, the increase in the number of highly educated people may hurt overall economic performance. Krueger and Lindahl (2001) point out further possibilities that higher education in developing countries is positively associated with unemployment and that higher levels of education may reduce output. The coefficients of the interaction terms between each disaggregated education and industrialization are insignificant, indicating that the effect of disaggregated education on economic growth is not associated with the industrialization level in the pre-industrialization period.

Table 3. Parameters estimate of pre- industrialization periods (1989–2000)

Variables	TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	3.447		5.320	
	(6.249)		(3.447)	
AE^2	–0.026		–0.229	
	(0.406)		(0.252)	
AE×*IN*	–0.082		–0.185**	
	(0.076)		(0.084)	
IN	–0.261	–0.454**	–0.286***	–0.009
	(0.184)	(0.199)	(0.096)	(0.168)
HE		0.692		–2.882*
		(2.739)		(1.538)
HSE		–0.380		2.453
		(2.600)		(2.309)
CE		2.354		2.557**
		(2.183)		(1.229)
HE×*IN*		–0.389**		0.182
		(0.153)		(0.221)
HSE×*IN*		0.071		–0.180
		(0.236)		(0.166)
CE×*IN*		0.208		0.175
		(0.149)		(0.187)
N	297	297	297	297
Modified Wald test (*p*-value)	227.8 (0.000)	147.9 (0.000)		
Wooldridge test (*p*-value)	41.84 (0.000)	27.42 (0.000)		
Pesaran's test (*p*-value)	21.60 (0.000)	22.44 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. In the empirical model, the independent variable has a one-period lag. This means there were 297 observations during the pre-industrialization period from 1989 to 2000 across 27 provinces.

4.2.2. Results of mid-industrialization periods

Table 4 shows TWFE and FGLS with two-way fixed effects results for aggregate and disaggregated models for the mid-industrialization period (2000–2019). Similar to the pre-industrialization periods, the previously mentioned econometrics problems occur by the method of TWFE; hence, the results of the FGLS with two-way fixed effects are used and presented in the third and fourth columns of Table 4. The findings indicate that the results of the mid-industrialization period for aggregate education are consistent with the overall data. For the disaggregated education model, the diminishing effect of education exists in this period, where compulsory education has the highest positive impact on economic growth, followed by high school and higher education. As a country becomes more industrialized, high school education becomes more critical for economic growth. It is a foundation for higher education, which is essential for high-technology industries. We find that industrialization development still has a positive effect on China's economic growth, and only the interaction of compulsory education with industrialization has a significant positive impact on China's economic growth.

Table 4. Parameters estimate of mid-industrialization periods (2000–2019)

Variables	TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	13.216**		13.120***	
	(5.484)		(0.914)	
AE^2	–0.742**		–0.662***	
	(0.304)		(0.052)	
AE×IN	–0.093*		–0.050***	
	(0.053)		(0.015)	
IN	0.585***	0.540***	0.726***	0.739***
	(0.112)	(0.118)	(0.031)	(0.045)
HE		1.199		2.157***
		(1.102)		(0.378)
HSE		0.786		2.618***
		(1.411)		(0.616)
CE		5.354***		5.715***
		(1.674)		(0.606)
HE×IN		–0.032		–0.001
		(0.059)		(0.020)
HSE×IN		–0.079		–0.032
		(0.090)		(0.041)
CE×IN		0.044		0.009***
		(0.129)		(0.002)
N	513	513	513	513
Modified Wald test (*p*-value)	165.4 (0.000)	142.7 (0.000)		
Wooldridge test (*p*-value)	41.54 (0.000)	40.22 (0.000)		
Pesaran's test (*p*-value)	23.96 (0.000)	21.69 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. In the empirical model, the independent variable has a one-period lag. This means there were 513 observations during the mid-industrialization period from 2000 to 2019 across 27 provinces.

4.3. Results of Eastern and Western regions

China has witnessed rapid growth over the past four decades by embracing globalization; however, the distribution of this growth across provinces is uneven (Lu et al., 2019). Eastern provinces have benefited from competitive advantages in policy and geography, soared in development, and become the most developed regions of China. Nevertheless, Western provinces need to catch up in development and remain backward in Chinese regions (Rong, 2010). With the apparent regional disparities, it is desirable to examine the impact of education and its interaction with industrialization on the economic growth of regions at different development levels and industrialization periods.

4.3.1. Results of Eastern region

Table 5 reports the estimation results of the Eastern region for overall data. As in the previous analysis, we utilize the FGLS with two-way fixed effects results to interpret our empirical model, and the results are shown in the third and fourth columns.

Table 5. Estimation results of Eastern region overall data

Variables	TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	–0.321		–1.571	
	(5.463)		(2.556)	
AE^2	0.231		0.239*	
	(0.281)		(0.139)	
AE×IN	–0.011		0.013	
	(0.044)		(0.021)	
IN	0.296*	0.312**	0.255***	0.306***
	(0.149)	(0.110)	(0.062)	(0.055)
HE		3.065***		1.531*
		(0.982)		(0.813)
HSE		3.443***		2.121**
		(1.062)		(0.967)
CE		3.310		1.341
		(2.005)		(1.178)
HE×IN		0.010		–0.008
		(0.062)		(0.025)
HSE×IN		–0.305**		–0.251***
		(0.102)		(0.056)
CE×IN		0.073		0.042
		(0.118)		(0.055)
N	390	390	390	390
Modified Wald test (*p*-value)	59.96 (0.000)	109.8 (0.000)		
Wooldridge test (*p*-value)	49.33 (0.000)	30.30 (0.000)		
Pesaran's test (*p*-value)	10.97 (0.000)	10.85 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. The empirical model utilized a one-period lag for the independent variable. This resulted in a total of 390 observations being collected from 1989 to 2019 across 13 provinces in the Eastern region.

Based on the results of the aggregate education model in column three, the industrialization level positively affects economic growth in the Eastern region. The results show that while the impact of aggregate education on economic growth in the Eastern region is not statistically significant, the positive effect of the square term of aggregate education suggests a rising trend in the relationship between aggregate education and economic growth in this area. This may be attributed to the Eastern region's status as China's most advanced region, with a concentration of cutting-edge technology and significant physical capital. The combination of aggregated education and advanced technology has the potential to accelerate economic growth in this region. Additionally, the interaction term coefficient between aggregate education and industrialization is insignificant, indicating that the impact of aggregate education on economic growth in the Eastern region is not dependent on the level of industrialization development.

The results of the disaggregated education model are presented in column four. It is consistent with the finding in the aggregate education model in that there is an increasing pattern of education on economic growth; in other words, the impact of higher education and high school education are positive and significant for the Eastern region, while the impact of compulsory education is insignificant. Regarding the interaction terms, only the interaction term between high school education and industrialization is negatively significant, indicating that the contribution of high school education to economic growth decreases as the industrialization level increases. Consequently, higher and high school education levels bolster the Eastern region's economic growth.

Table 6 shows the results of the Eastern region during the pre-industrialization and mid-industrialization periods. Based on the FGLS with two-way fixed effects results of pre-industrialization in columns three and four, the aggregate education model indicates that the impact of aggregate education on economic growth is not significant in the initial stage of economic development, given insignificance of aggregate education, its square term, and the interaction term. The coefficients of disaggregated education levels are negatively significant for higher and compulsory education, while interaction terms of all education levels and industrialization are also negatively significant. Industrialization still harmed economic growth in the pre-industrialization period.

Columns seven and eight in Table 6 report the FGLS with two-way fixed effects results of the mid-industrialization period for the Eastern region. Consistent with all regions' results in Table 4, the relationship between aggregate education and economic growth for the Eastern region in the mid-industrialization period is positive, significant, and diminishing. Additionally, the interaction term of aggregate education and industrialization is significantly harmful. The results of the disaggregated education model are consistent with all regions' results in the mid-industrialization period of Table 4, except that the interaction term between industrialization and higher education of the East region in the mid-industrialization is positively significant. Compulsory education greatly impacts economic growth, followed by high school and higher education. The positively significant interaction between the industrialization level and the higher and compulsory education implies that when industrialization increases, more people with higher and compulsory education are the key factors driving the economic growth of the East region of China.

4.3.2. Results of Western region

Table 7 reports the estimation results of the Western region using overall data. The FGLS with two-way fixed effects of the aggregate and disaggregated education models gives reliable results, shown in columns three and four, respectively. Similar to the finding in Table 2, we find that the effect of aggregate education is increasing at a diminishing rate in the Western region. We also find

Table 6. Results of Eastern region for pre- and mid-industrialization periods

Variables	Pre-industrialization Periods (1989–2000)				Mid-industrialization Periods (2000–2019)			
	TWFE		FGLS with TWFE		TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	–7.531		–4.652		18.518*		20.517***	
	(12.069)		(6.383)		(10.025)		(3.432)	
AE^2	0.499		0.320		–0.903		–1.017***	
	(0.745)		(0.406)		(0.514)		(0.186)	
AE×*IN*	–0.082		–0.050		–0.113		–0.121***	
	(0.068)		(0.045)		(0.076)		(0.031)	
IN	–0.410*	–0.569**	–0.424***	–0.478***	0.871***	0.763***	0.944***	0.804***
	(0.199)	(0.217)	(0.0835)	(0.103)	(0.1674)	(0.178)	(0.057)	(0.068)
HE		–2.253		–3.793*		1.768		2.184***
		(3.324)		(1.941)		(1.024)		(0.623)
HSE		–2.570		–0.168		2.217		3.747***
		(3.620)		(1.572)		(1.586)		(0.813)
CE		–4.122		–5.411***		3.976		5.123***
		(2.877)		(1.815)		(2.555)		(1.074)
HE×*IN*		–0.313*		–0.282***		0.157*		0.068***
		(0.161)		(0.090)		(0.077)		(0.026)
HSE×*IN*		–0.191		–0.223**		0.073		0.048
		(0.237)		(0.111)		(0.157)		(0.077)
CE×*IN*		–0.336*		–0.205**		0.435**		0.225*
		(0.170)		(0.088)		(0.169)		(0.123)
N	143	143	143	143	247	247	247	247
Modified Wald test (*p*-value)	65.00 (0.000)	67.12 (0.000)			111.4 (0.000)	83.41 (0.000)		
Wooldridge test (*p*-value)	49.33 (0.000)	30.30 (0.000)			49.33 (0.000)	30.30 (0.000)		
Pesaran's test (*p*-value)	9.271 (0.000)	10.91 (0.000)			7.419 (0.000)	5.788 (0.000)		

Note: Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. The East had 13 provinces from 1989–2000 and 2000–2019. Due to the one-period lag of an independent variable, one fewer observation for 13 provinces was used to estimate the empirical model during both periods.

Table 7. Results of Western region overall data

Variables	TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	17.595***		15.224***	
	(5.429)		(1.514)	
AE^2	–1.180***		–0.946***	
	(0.374)		(0.116)	
AE×IN	0.075		0.128***	
	(0.070)		(0.029)	
IN	0.343***	0.341***	0.360***	0.319***
	(0.109)	(0.103)	(0.048)	(0.048)
HE		–1.158		0.540
		(1.781)		(1.042)
HSE		1.318*		2.075**
		(1.860)		(1.011)
CE		5.116***		4.457***
		(1.011)		(0.647)
HE×IN		0.081		0.071
		(0.147)		(0.068)
HSE×IN		–0.036		–0.004
		(0.204)		(0.074)
CE×IN		0.027		0.084*
		(0.153)		(0.051)
N	420	420	420	420
Modified Wald test (*p*-value)	62.73 (0.000)	57.71 (0.000)		
Wooldridge test (*p*-value)	46.77 (0.000)	42.997 (0.000)		
Pesaran's test (*p*-value)	19.70 (0.000)	18.27 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. The empirical model utilized a one-period lag for the independent variable. This resulted in 420 observations being collected from 1989 to 2019 across 14 provinces in the Western region.

the coefficient of the interaction term between aggregate education and industrialization is significantly positive, which means that industrialization plays a great role in moderating the impact of education on economic growth in the Western region; the higher level of aggregate education in a higher level of industrialization will lead to a faster enhance economic growth. Furthermore, the impact of industrialization on economic growth is significantly positive.

Based on the results of the disaggregated education model in the fourth column, we find that compulsory education and high school education have a positive and significant effect on economic growth, with compulsory education having a greater effect. For the interaction terms, only the interaction term between compulsory education and industrialization is significantly positive, indicating that the higher compulsory education level leads to higher enhanced economic growth when industrialization increases. Therefore, in the Western region, the contribution of compulsory education to economic growth is outstanding and critical.

Table 8. Results of Western region for pre- and mid-industrialization periods

Variables	Pre-industrialization periods (1989–2000)				Mid-industrialization periods (2000–2019)			
	TWFE		FGLS with TWFE		TWFE		FGLS with TWFE	
	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education	Aggregate education	Disaggregated education
AE	11.100		13.329**		29.880***		31.189***	
	(14.379)		(6.087)		(4.921)		(2.368)	
AE^2	–0.279		–0.413		–2.009***		–1.961***	
	(1.204)		(0.495)		(0.304)		(0.155)	
AE×*IN*	0.154		0.052		0.009		0.077**	
	(0.112)		(0.130)		(0.078)		(0.036)	
IN	0.215	0.043	0.313*	0.325	0.372**	0.430***	0.488***	0.571***
	(0.287)	(0.209)	(0.178)	(0.268)	(0.139)	(0.121)	(0.043)	(0.054)
HE		1.024		–2.206		–2.269		–0.031
		(6.966)		(4.342)		(1.907)		(0.771)
HSE		–5.113		0.675		–0.473		1.260
		(4.504)		(3.434)		(1.961)		(0.826)
CE		8.199**		6.904***		4.934***		4.594***
		(2.931)		(1.721)		(1.468)		(0.859)
HE×*IN*		–0.414		–0.388		0.118		0.074
		(0.561)		(0.481)		(0.166)		(0.068)
HSE×*IN*		0.776		0.595**		–0.360**		–0.176**
		(0.460)		(0.277)		(0.126)		(0.074)
CE×*IN*		–0.068		–0.107		–0.019		–0.059
		(0.243)		(0.113)		(0.137)		(0.058)
N	154	154	154	154	266	266	266	266
Modified Wald test (*p*-value)	343.4 (0.000)	88.82 (0.000)			57.69 (0.000)	95.72 (0.000)		
Wooldridge test (*p*-value)	46.77 (0.000)	42.99 (0.000)			46.77 (0.000)	42.99 (0.000)		
Pesaran's test (*p*-value)	11.32 (0.000)	9.735 (0.000)			12.54 (0.000)	11.42 (0.000)		

Note. Standard errors are in parentheses. *, **, *** denote significance at 10, 5, and 1%, respectively. The West had 14 provinces from 1989–2000 and 2000–2019. Due to the one-period lag of an independent variable, one fewer observation for 14 provinces was used to estimate the empirical model during both periods.

Table 8 shows the results of the Western region during the pre-industrialization and mid-industrialization periods. Based on the FGLS with two-way fixed effects results in columns three and four, only the coefficients of aggregate education and industrialization are significant and positive for the Western region in the pre-industrialization period. For the results of the disaggregated education model in column four, only compulsory education has a significant positive effect on economic growth. Additionally, the interaction between high school education and industrialization showed significantly positive, indicating that as industrialization increases, high school education contributes more to economic growth. This can be explained by the fact that China implemented nine-year compulsory education in 1986, significantly impacting the Western region that previously lacked access to education and quality of education. Improving educational opportunities in the Western region resulted in better access to and quality of high school education, thereby explaining the higher positive effect of high school education during the early stages of industrialization in the Western region.

Columns seven and eight in Table 8 report the FGLS with two-way fixed effects results of the mid-industrialization period for the Western region; the impact of education on economic growth became more pronounced in the mid-industrialization period than in the pre-industrialization period, and the results of the aggregate education model are consistent with the overall data of the Western region in Table 7, where the aggregate education has a positive but diminishing impact on economic growth. This relationship is contingent on the level of industrialization development. Notably, the coefficient of the interaction terms between high school education and industrialization turns significantly negative during the mid-industrialization period, suggesting that the impact of high school education on economic growth weakens as industrialization increases. The impact of aggregate education on economic growth in China over three periods and regions is summarized in Table 9. Table 10 shows the effects of different education levels on economic growth in various regions and periods.

5. Conclusions and discussion

This research delves into how education impacted China's economic growth in 27 provinces from 1989 to 2019. The study categorizes education into aggregate education (average years of schooling) and disaggregated education (education grouped by compulsory, high school, and higher education). Moreover, the data is analyzed based on pre- and mid-industrialization periods, and East and West regions with and without pre- and mid-industrialization for both aggregate and disaggregated education levels. The two-way fixed effect feasible generalized least square is the appropriate method to estimate the parameters for both models.

In the study of the impact of aggregate education on economic growth in China over three distinct periods and regions, the findings suggest that education had a diminishing impact on economic growth during the 31-year and mid-industrialization periods but no effect on pre-industrialization. However, when combined with industrialization development, aggregate education negatively impacted economic growth, suggesting a misalignment between aggregate education and industrialization development in China.

When comparing the Eastern and Western regions, the study found that the impact of aggregate education on economic growth is diminishing in the Western rather than in the Eastern. That is, the success of management in aggregate education in the Eastern region supports economic

Table 9. Summary of signs across periods and regions of aggregate education model from FGLS with TWFE

Variables	Periods			Regions		Regions with different industrialization periods			
	1989–2019	Pre-industrialization	Mid-industrialization	Eastern	Western	Eastern pre-industrialization	Western pre-industrialization	Eastern mid-industrialization	Western mid-industrialization
AE	+	NS	+	NS	+	NS	+	+	+
AE^2	–	NS	–	+	–	NS	NS	–	–
AE×IN	–	–	–	NS	+	NS	NS	–	+

Note. NS represents the non-significant coefficient.

Table 10. Summary of signs across periods and regions of disaggregated education model from FGLS with TWFE

Variables	Periods			Regions		Regions with different industrialization periods			
	1989–2019	Pre-industrialization	Mid-industrialization	Eastern	Western	Eastern pre-industrialization	Western pre-industrialization	Eastern mid-industrialization	Western mid-industrialization
HE	$+^{aa}$	–	$+^{a}$	$+^{a}$	NS	$-^{a}$	NS	$+^{a}$	NS
HSE	$+^{a}$	NS	$+^{aa}$	$+^{aa}$	$+^{a}$	NS	NS	$+^{aa}$	NS
CE	$+^{aaa}$	+	$+^{aaa}$	NS	$+^{aa}$	$-^{aa}$	+	$+^{aaa}$	+
HE×IN	NS	NS	NS	NS	NS	$-^{\#\#\#}$	NS	$+^{\#}$	NS
HSE×IN	–	NS	NS	–	NS	$-^{\#\#}$	+	NS	–
CE×IN	+	NS	+	NS	+	$-^{\#}$	NS	$+^{\#\#}$	NS

Note. NS represents the non-significant coefficient.
^{a}, ^{aa}, ^{aaa} indicate the magnitude of the disaggregated education coefficients from low to high.
$^{\#}$, $^{\#\#}$, $^{\#\#\#}$ indicate the magnitude of the interaction term coefficients from low to high.

growth, although there is no significant effect on the interaction between aggregate education and industrialization level in the Eastern region. On the other hand, in the Western region, the positive significance of their interaction terms indicates that aggregate education is in line with industrialization development. However, in the pre-industrialization period, education had no impact on economic growth in both Eastern and Western regions, except for a positive linear relationship between aggregate education and economic growth in the Western region. In the mid-industrialization, education had a diminishing impact on economic growth in both Eastern and Western regions. Nevertheless, the aggregate education in the Western region aligned with industrialization, but not for the Eastern region.

The study of the effects of different education levels on economic growth in various regions and periods found that compulsory, high school, and higher education all positively impacted economic growth during the 31-year and mid-industrialization periods. However, during the pre-industrialization period, compulsory education had a positive impact, while higher and high school education had a negative and no impact on economic growth, respectively. When looking at each education skill combined with the industry, it was discovered that higher education did not affect economic growth, while high school education does not align with the industry. On the other hand, compulsory education skills align with industry, particularly in the mid-industrialization periods, indicating a need for a low-skill labor force during this time.

Higher and high school education positively affected economic growth in the Eastern region, but compulsory education did not. Skill in high school education indicated a misalignment with industry, negatively impacting economic growth. Neither higher nor compulsory education was aligned with industry, with no impact on economic growth. The study suggests that the government should adjust the skill levels of all education levels to better align with industrialization. In the Western region, higher education did not impact economic growth, but high school and compulsory education had a positive impact. This indicates that low-skill labor was needed in the Western region. Only compulsory education, when combined with industrial development, positively impacted economic growth, confirming the need for low-skill labor in the Western region.

In the pre-industrialization periods of the Eastern region, all education levels had a negative or no impact on economic growth, even when combined with industrialization development. However, during the mid-industrialization period of the Eastern region, all education levels positively impacted economic growth, indicating the success of education in aligning with economic and industrial development. In the Western region, only compulsory education positively impacted economic growth during the pre- and mid-industrialization periods. Skills in high school education had aligned with industry in the pre-industrialization but not in the mid-industrialization.

The research findings emphasize the crucial role of economic development levels in the relationship between education and economic growth. In the case of China, it is recommended to increase investment in compulsory education to align better with the country's level of industrialization. However, China's current educational policy does not align with this recommendation. The central government's funds are mainly directed toward schools beyond compulsory education. While the "Compulsory Education Law" ensures financial support for compulsory education, the county and township governments generate the most funds (Fu, Ren, 2010). Due to China's strict bureaucratic hierarchy, these lower-level governments lack bargaining power with higher-level governments (provincial and central) to allocate educational funds (Wang, 2003). The mismatch of educational investment is evident in Table 1 of our data. Higher and high school education have seen significant improvements with government support, while compulsory education has not received adequate attention. This imbalance in educational investment might be the factor contributing to the mismatch between aggregate education and industrial development in China.

It is essential to consider that for China, which has internal imbalances, education policies should vary based on the economic development of each region. In more developed Eastern regions, investment in higher education should be emphasized to match their advanced level of industrialization, while in less developed Western regions, it is crucial to focus on improving the quality of compulsory education. To achieve this, the central government should grant more administrative power to local governments, allowing them to create education policies tailored to their region's specific needs. This approach will effectively stimulate economic growth.

This study has some limitations. Although we calculated the average schooling years and the three levels of education by the stock of schooling years resulting from higher, high school, and compulsory education completed by the population aged 15 to 64 each year in each province, respectively, the potential effect of human capital heterogeneity in age, or the potential impact of experience accumulation on human capital, may remain unaccounted for. Future research is recommended to consider including these factors in the study. Moreover, our paper concerns the effect of years of schooling on economic growth; we failed to estimate the effect of education quality on economic growth due to a lack of available data. It may be beneficial to consider the effect of education quality in the model for comparison to the results of this study in the future.

Acknowledgments. This study has been supported by the Department of Human Resources and Social Security of Guangxi Zhuang Autonomous Region's Academic Research Program (Grant No. GXRS-2024-352).

References

Abdullah A. J. (2013). Education and economic growth in Malaysia: The issues of education data. *Procedia Economics and Finance*, 7, 65–72. DOI: 10.1016/S2212-5671(13)00219-0.

Abramovitz M. (1986). Catching up, forging ahead, and falling behind. *The Journal of Economic History*, 46 (2), 385–406. DOI:10.1017/S0022050700046209.

Adnans A. A., Muda I. (2018). Neoclassical growth model application to the analysis of human capital for regional development. *Eurasian Journal of Economics and Finance*, 6 (4), 1–13. DOI: 10.15604/ejef.2018.06.04.001.

Afzal M., Rehman H. U., Farooq M. S., Sarwar K. (2011). Education and economic growth in Pakistan: A cointegration and causality analysis. *International Journal of Educational Research*, 50 (5–6), 321–335. DOI: 10.1016/J.IJER.2011.10.004.

Aghion P., Bloom N., Blundell R., Griffith R., Howitt P. (2005). Competition and innovation: An inverted-U relationship. *The Quarterly Journal of Economics*, 120 (2), 701–728. DOI: 10.1093/qje/120.2.701.

Akbari A. H., Haider A. (2018). Impact of immigration on economic growth in Canada and in its smaller provinces. *Journal of International Migration and Integration*, 19 (1), 129–142. DOI: 10.1007/S12134-017-0530-4/METRICS.

Appiah E. N., McMahon W. W. (2002). The social outcomes of education and feedbacks on growth in Africa. *Journal of Development Studies*, 38 (4), 27–68. DOI: 10.1080/00220380412331322411.

Baltagi B. H. (2005). *Econometric analysis of panel data*. Chichester: Wiley.

Bassanini A., Scarpetta S. (2002). Does human capital matter for growth in OECD countries? A pooled mean-group approach. *Economics Letters*, 74 (3), 399–405. DOI: 10.1016/S0165-1765(01)00569-9.

Becker G. S. (1964). *Human capital theory.* Columbia University Press, New York.

Benhabib J., Spiegel M. M. (1994). The role of human capital in economic development evidence from aggregate cross-country data. *Journal of Monetary Economics*, 34 (2), 143–173. DOI: 10.1016/0304-3932(94)90047-7.

Bloom D. E., Kuhn M., Prettner K. (2018). Health and economic growth. *IZA Discussion Papers*, No. 11939. Institute of Labor Economics (IZA), Bonn.

Cinnirella F., Streb J. (2017). The role of human capital and innovation in economic development: Evidence from post-Malthusian Prussia. *Journal of Economic Growth*, 22, 193–227. DOI: 10.1007/s10887-017-9141-3.

Cheek D. W., Santos J., Vaillant N. (2015). Education and economic growth. *International Encyclopedia of the Social & Behavioral Sciences (2nd ed.)*, 121–126. Oxford: Elsevier.

Chen Q. (2014). *Advanced econometrics and Stata applications (2nd ed.)*. Higher Education Press, Beijing.

Deme M., Mahmoud A. M. A. (2020). Effect of quantity and quality of education on per capita real-GDP growth: Evidence from low- and middle-income African countries. *Applied Economics*, 52 (57), 6248–6264. DOI: 10.1080/00036846.2020.1789058.

Faggian A., Rajbhandari I., Dotzel K. R. (2018). The interregional migration of human capital and its regional consequences: A review. *Transitions in Regional Economic Development*, 227–256.

Farmer K., Schelnast M. (2021). Robots, human capital investment, welfare, and unemployment in a digital world economy. In: *Growth and International Trade*. *Springer Texts in Business and Economics*, 223–255. Springer. DOI: 10.1007/978-3-662-62943-7_10.

Fleisher B., Li H., Zhao M. Q. (2010). Human capital, economic growth, and regional inequality in China. *Journal of Development Economics*, 92 (2), 215–231.

Fraumeni B. M., He J., Li H., Liu Q. (2019). Regional distribution and dynamics of human capital in China 1985–2014. *Journal of Comparative Economics*, 47 (4), 853–866.

Fu Q., Ren Q. (2010). Educational inequality under China's rural–urban divide: The hukou system and return to education. *Environment and Planning A*, 42 (3), 592–610. DOI: 10.1068/A42101.

Gagliardi L. (2015). Does skilled migration foster innovative performance? Evidence from British local areas. *Papers in Regional Science*, 94 (4), 773–794. DOI: 10.1111/pirs.12095.

Ganegodage K. R., Rambaldi A. N. (2011). The impact of education investment on Sri Lankan economic growth. *Economics of Education Review*, 30 (6), 1491–1502.

Gyimah-Brempong K., Paddison O., Mitiku W. (2006). Higher education and economic growth in Africa. *Journal of Development Studies*, 42 (3), 509–529. DOI: 10.1080/00220380600576490.

Haini H. (2020). Spatial spillover effects of public health and education expenditures on economic growth: Evidence from China's provinces. *Post-Communist Economies*, 32 (8), 1111–1128. DOI: 10.1080/14631377.2020.1722586.

Hamdan A., Sarea A., Khamis R., Anasweh M. (2020). A causality analysis of the link between higher education and economic development: Empirical evidence. *Heliyon*, 6 (6), e04046. DOI: 10.1016/J.HELIYON.2020.E04046.

Hanushek E. A., Kimko D. D. (2000). Schooling, labor-force quality, and the growth of nations. *American Economic Review*, 90 (5), 1184–1208. DOI: 10.1257/aer.90.5.1184.

Hayes A. F. (2013). Truths and myths about mean centering. In: *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*, 282–288. New York: The Guiford Press.

Hatakenaka S. (2008). The role of higher education in high tech industry development: What can international experience tell us? *Proceedings of the 2008 Annual Bank Conference on Development Economics*. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=93ba7428ef00942280504e52c151df3b5ba6483f.

Ishchy U. B. (2019). The role of education on economic growth: Evidence from Turkey. *International Economic Journal*, 34 (2), 347–369. DOI: 10.1080/10168737.2019.1689284.

Keller K. R. I. (2006). Investment in primary, secondary, and higher education and the effects on economic growth. *Contemporary Economic Policy*, 24 (1), 18–34. DOI: 10.1093/CEP/BYJ012.

Kocourek A., Nedomlelová I. (2017). Three levels of education and economic growth. *Applied Economics*, 50 (19), 2103–2116. DOI: 10.1080/00036846.2017.1388910.

Krueger A. B., Lindahl M. (2001). Education for growth: Why and for whom? *Journal of Economic Literature*, 39 (4), 1101–1136. DOI: 10.1257/jel.39.4.1101.

Kubík R. (2015). What is the real effect of schooling on economic growth? *Prague Economic Papers*, 24 (2), 125–135. DOI: 10.18267/j.pep.504.

Laskar M. R., King M. L. (1997). Modified Wald test for regression disturbances. *Economics Letters*, 56 (1), 5–11. DOI: 10.1016/S0165-1765(97)00128-6.

Li H., Liu P. W., Zhang J. (2012). Estimating returns to education using twins in urban China. *Journal of Development Economics*, 97 (2), 494–504. DOI: 10.1016/J.JDEVECO.2011.05.009.

Li T., Wang Y. (2018). Growth channels of human capital: A Chinese panel data study. *China Economic Review*, 51, 309–322.

Li X., Wye C. K. (2023). The effect of investment in education on China's economic growth: The role of financial development. *The Chinese Economy*, 56 (1), 69–87. DOI: 10.1080/10971475.2022.2058182.

Lin Y., Jiang Y. (2021). Current situation and countermeasures of industrialisation in China. *Wuhan University Journal (Philosophy Social Science)*, 2, 117–125.

Liu Y., Tan Z., Ning X. (2021). Public education expenditure and economic growth: Based on panel data from 2009 to 2019 in China. *World Journal of Advanced Research and Reviews*, 11 (2), 184–192. DOI: 10.30574/wjarr.2021.11.2.0376.

Lu Y., Zhang Y., Cao X., Wang C., Wang Y., Zhang M., Ferrier R. C., Jenkins A., Yuan J., Bailey M. J., Chen D., Tian H., Li H., von Weizsäcker E. U., Zhang Z. (2019). Forty years of reform and opening up: China's progress toward a sustainable path. *Science Advances*, 5 (8). DOI: 10.1126/sciadv.aau9413.

Mankiw N. G., Romer D., Weil D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics*, 107 (2), 407–437. DOI: 10.2307/2118477.

Martin R. (2017). Institutional approaches in economic geography. *A Companion to Economic Geography*, 77–94. DOI: 10.1002/9781405166430.ch6.

Masoud N. (2013). Neoclassical economic growth theory: An empirical approach. *Far East Journal of Psychology and Business*, 11 (3), 10–33.

McMahon W. W. (1998). Education and growth in East Asia. *Economics of Education Review*, 17 (2), 159–172. DOI: 10.1016/S0272-7757(97)00050-2.

McMahon W. W. (2000). *Education and development: Measuring the social benefits*. Clarendon Press.

Min H., Xiuwen Y. (2001). Educational assessment in China: Lessons from history and future prospects. *Assessment in Education: Principles, Policy & Practice*, 8 (1), 5–10. DOI:10.1080/09695940120033216.

Mingat A., Tan J.-P. (1996). *The full social returns to education: Estimates based on countries' economic growth performance*. The World Bank. https://documents1.worldbank.org/curated/en/949711468740209672/pdf/multi-page.pdf.

Monterubbianesi P. D., Grandes M., Dabús C. (2017). New evidence of the health status and economic growth relationship. *Panoeconomicus*, 64 (4), 439–459. DOI:10.2298/PAN150505020M.

Pedroni P. (1999). Critical value for cointegration test in heterogeneous panels with multiple regressor. *Oxford Bulletin of Economics and Statistics*, 61 (S1), 653–670. DOI:10.1111/1468-0084.0610s1653.

Pesaran M. H. (2004). General diagnostic tests for cross section dependence in panels. *SSRN Electronic Journal*. DOI:10.2139/SSRN.572504.

Petrakis P. E., Stamatakis D. (2002). Growth and educational levels: A comparative analysis. *Economics of Education Review*, 21 (5), 513–521. DOI:10.1016/S0272-7757(01)00050-4.

Pritchett L. (2001). Where has all the education gone? *The World Bank Economic Review*, 15 (3), 367–391. DOI:10.1093/wber/15.3.367.

Pritchett L. (2006). Does learning to add up add up? The returns to schooling in aggregate data. *Handbook of the Economics of Education*, 1, 635–695.

Psacharopoulos G. (1994). Returns to investment in education: A global update. *World Development*, 22 (9), 1325–1343. DOI: 10.1016/0305-750X(94)90007-8.

Psacharopoulos G., Patrinos H. A. (2004). Returns to investment in education: A further update. *Education Economics*, 12 (2), 111–134. DOI: 10.1080/0964529042000239140.

Ramcharan R. (2004). Higher or basic education? the composition of human capital and economic development. *IMF Staff Papers*, 002. DOI: 10.5089/9781589063235.024.A005.

Rong L. (2010). Causes of the increasing difference between the East and West of China. *Journal of Hebei Normal University (Philosophy and Social Sciences Edition)*, 10 (5), 37–44.

Schultz T. W. (1961). Investment in human capital. *The American Economic Review*, 51 (1), 1–17.

Sianesi B., van Reenen J. (2003). The returns to education: Macroeconomics. *Journal of Economic Surveys*, 17 (2), 157–200. DOI: 10.1111/1467-6419.00192.

Wang D. (2003). China's rural compulsory education: Current situation, problems and policy alternatives. *WP 36.* Institute of Population and Labor Economics, Chinese Academy of Social Sciences, Beijing.

Whalley J., Zhao X. (2014). The contribution of human capital to China's economic growth. *China Economic Policy Review*, 02 (01), 1350001. DOI: 10.1142/S1793969013500015.

Wooldridge J. M. (2003). Cluster-sample methods in applied econometrics. *American Economic Review*, 93 (2), 133–138. DOI: 10.1257/000282803321946930.

Yan W., Yudong Y. (2003). Sources of China's economic growth 1952–1999: Incorporating human capital accumulation. *China Economic Review*, 14 (1), 32–52.

Yang J., Gong L., Zhang Q. (2006). Human capital formation land its effects on economic growth. *Management World*, 5, 10–18.

Zhang C., Zhuang L. (2011). The composition of human capital and economic growth: Evidence from China using dynamic panel data analysis. *China Economic Review*, 22 (1), 165–171. DOI: 10.1016/J.CHIECO.2010.11.001.

Received 18.06.2023; accepted 16.01.2024.

Appendix A

Descriptive statistics for the rest of the variables in the empirical model

Table A1. Descriptive statistics

		All regions			Eastern region			Western region		
		Overall data	Pre-industrial-ization	Mid-industrial-ization	Overall data	Pre-industrial-ization	Mid-industrial-ization	Overall data	Pre-industrial-ization	Mid-industrial-ization
Y (¥)	Mean	22803	4650	32997	31250	6519	45157	14959	2914	21705
	Std. Dev.	25676	4369	26842	31745	5468	31679	14462	1695	13948
I (%)	Mean	53.89	32.00	66.06	49.32	34.38	57.54	58.14	29.79	73.98
	Std. Dev.	29.48	8.195	29.88	24.37	8.401	26.27	33	7.359	30.88
G (%)	Mean	18.13	12.10	21.50	14.87	10.41	17.36	21.16	13.67	25.34
	Std. Dev.	10.17	4.501	10.84	6.911	3.136	7.156	11.68	4.991	12.20
b (%)	Mean	13.16	16.18	11.32	11.68	14.19	10.12	14.54	18.02	12.43
	Std. Dev.	4.398	4.698	2.940	4.161	4.824	2.702	4.164	3.742	2.711
XM (%)	Mean	30.58	27.17	32.52	52.46	46.20	56.15	10.27	9.497	10.59
	Std. Dev.	38.99	39.52	38.44	47.01	50.21	44.40	4.934	5.293	4.609
FDI (%)	Mean	2.813	3.147	2.635	4.214	5.006	3.785	1.513	1.420	1.567
	Std. Dev.	3.170	4.050	2.492	3.922	5.034	2.991	1.264	1.407	1.147
INF (%)	Mean	4.746	8.484	2.279	4.750	8.693	2.183	4.741	8.290	2.367
	Std. Dev.	6.114	8.259	1.928	6.168	8.256	1.784	6.071	8.283	2.051
N		837	324	540	403	156	260	434	168	280

Note. *Y* indicates the real GDP per capita; *I* implies the ratio of investment in fixed assets to GDP; *G* is the ratio of government expenditure to GDP; *b* is the birth rate; *XM* is the ratio of exports and imports to GDP; *FDI* is the ratio of foreign direct investment to GDP; *INF* indicates the inflation rate.

Appendix B

Measurements of education

Due to the intangible nature of education, the correct measurement of education is still a challenging problem in empirical research. In the experience growth literature, several methods have been used to measure education. Typical indicators are the proportion of enrollment rate, education expenditure, the average years of schooling, student-teacher ratio, literacy rate, or some test (Afzal et al., 2011; Ganegodage, Rambaldi, 2011; Hanushek, Kimko, 2000; Kocourek, Nedomlelová, 2017; Zhang, Zhuang, 2011).

When conducting cross-border data research, utilizing school enrolment and education expenditure to measure education seems to have comparative advantages among countries. However, when analyzing a country's education to economic growth, especially in China, the enrollment rate alone cannot fully encompass interregional education due to the implementation of nine-year free compulsory education and widespread high school and higher education — moreover, using education expenditure to measure education level results in reverse causality, as the region's public education expenditure level is directly affected by the financial resources available to local governments, indicating the more developed the region tends to invest more in education.

Recent studies have shown that ignoring the differences in education quality will significantly distort the correlation between education and economic development. Hanushek and Kimko (2000) emphasized the crucial role of education quality. While compared with the education quantity (such as education enrollment) and investment, education output better reflects a country's education quality. As a result, some researchers measure education quality by metrics such as student-teacher ratios, literacy rates, or test scores (Afzal et al., 2011; Ganegodage, Rambaldi, 2011; Hanushek, Kimko, 2000). Unfortunately, relevant data is lacking, especially at the provincial level used in this paper.

The average years of schooling have been widely used in the literature on education and economic growth in China (Zhang, Zhuang, 2011; Yan, Yudong, 2003). Given the above consideration, we also use it to measure education in this paper to facilitate comparative analysis with the relevant literature. According to the relevant definition in the China Education Monitoring and Evaluation Statistical Indicator System (Education Development [2015]) issued by China's Ministry of Education, China's average years of schooling is calculated by the following formula:

$$AE = \frac{PEstock \times 6 + MEstock \times 9 + HSEstock \times 12 + HEstock \times 16}{POP},$$

where AE is the average years of schooling for a group of people, POP is the total number of people aged 15 to 64, $PEstock$ refers to all people who have completed primary school but not higher levels. $MEstock$ refers to all group members who have completed middle school but not higher levels. $HSEstock$ refers to everyone who has completed high school but not higher levels. $HEstock$ refers to all people who have completed college, university, or higher education. Based on the current Chinese school system, education consists of six years of primary school, three years of middle school, three years of high school, and four years of college or university.

Next, to investigate the impact of the specific level of education on the economic growth of China, we measure higher (HE), high school (HSE), and compulsory education (CE) as the stock of schooling years resulting from higher, high school, and compulsory education completed by the population aged 15 to 64 in each year in each province respectively. It is worth noting that compulsory education in China includes primary and middle school education. Furthermore, these different levels of education would test the non-linearity of schooling. Hence, we have:

$$HE = \frac{HEstock \times 16}{POP},\ HSE = \frac{HSEstock \times 12}{POP},\ CE = \frac{PEstock \times 6 + MEstock \times 9}{POP}$$

As each level of education is not fully accessible to the population, and the higher the level of education, the lower the level of accessibility, it follows that the stock of schooling years resulting from a particular level of education decreases as the level of education increases. Moreover, since the aggregate and disaggregated education levels of individuals in the labor force are determined based on their compulsory education, high school, and higher education, if workers leave a province, it will affect the measurement of education levels in the labor force as they will no longer be included. However, if new workers migrate to a province and join the labor force, their education level will be added to the overall education stock in that province.

Appendix C

Comparing China's economic growth between the China Statistical Yearbook and Total Economy Database

Ideally, we would like to use the growth data in real GDP per capita from the alternative approaches to estimating GDP growth for China, such as the Total Economy Database, to conduct a robustness check on our results. Unfortunately, we could not obtain the provincial data from the alternative datasets, which are generally available only at the national level. Therefore, we compared the difference between the data from the Total Economy Database and the corresponding data from the China Statistical Yearbook we used in this paper. A comparison of the two datasets is shown in the Fig. C1. It should be noted that the dotted line shows the data that we used in our paper, which is calculated by the average of the provincial data of the 27 provinces in mainland China. The solid line presents data from the Total Economy Database.

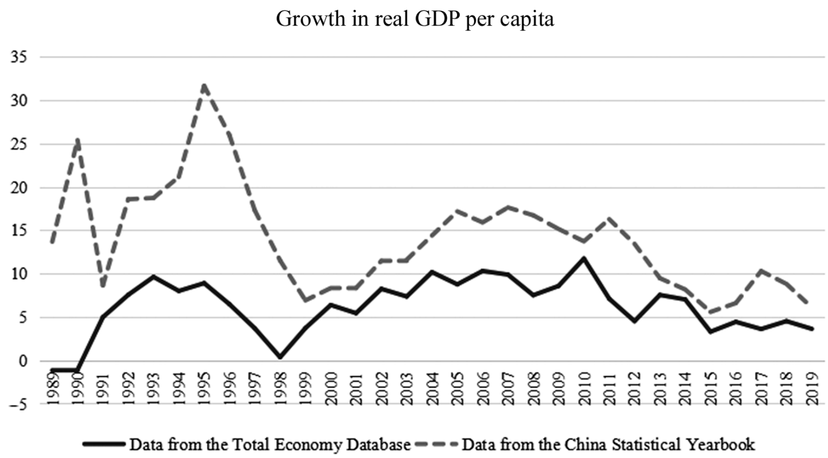


Fig. C1. The growth rate of real GDP per capita in different datasets

Intuitively, it can be seen from the figure that the trends of the two datasets are basically the same. We believe that this similarity in trend does not affect our argument of the role of economic development levels on the relationship between education and growth but may have some effect on the magnitude of the results. As to how large this magnitude of impact is, we encourage further research as future available data allow.

In addition, one of the reasons for the differences between the two datasets may be that we used provincial data for 27 provinces in mainland China, while we lack data for the Xizang Autonomous Region, Sichuan Province, Chongqing Municipality, and Hainan Province. China's provinces have different levels of development, and the four provinces we are missing are among China's less developed regions. Thus, this may partly explain why our dataset has a larger order of magnitude than the Total Economy Database.