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Education and economic growth: Does the East Asian education fever overstate the growth effect?

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ABSTRACT

This paper employs a cross-country regression to investigate the role of education in the growth of nations. The sample includes 101 countries over the period from 1980 to 2015. We have found that education, in general, has significant effects on economic growth. For the robustness of the results, several sensitivity tests were conducted using alternative measures of education, as well as a dummy variable to isolate an East Asian growth effect. The results were generally robust in that the growth effect of the quantity measure of schooling was statistically significant. However, the growth effect of quality measures of education was substantially mitigated and became insignificant when the East Asian effect was segregated from the regression. The results suggest that the significant growth effects of educational quality found in the literature could have been overstated because of the East Asian growth effect which was largely attributed to the education fever in East Asia.

1. Introduction

It is widely accepted in the literature that education plays an important role in economic growth (e.g. Barro and Lee, 2015; Hanushek and Woessmann, 2015). In particular, East Asia's 'education fever' has greatly influenced the rapid economic development of East Asian nations (e.g. Seth, 2002; Permani, 2009). More specifically, parents' enthusiasm for their children's education is exceptionally high in East Asia, so their spending on children's private education is nearly half of the government spending on public education (e.g. Lee, 2005). Their expenditure on private tutoring is relatively high because low-income families strongly believe that education determines children's future wealth, and hence they are willing to spend on education for their children so their children will no longer follow in the footsteps of poverty. High-income families spend much more money on their children's education because sending them to decent universities and, more recently, to prestigious universities abroad is considered a family pride. Such enthusiasm for education increases 'knowledge capital' which improves domestic technology and consequently economic growth (Vandenbussche et al., 2006; Aghion et al., 2009; Hanushek and

Woessmann, 2016; Yu and Jin, 2024).

The impact of education on economic growth has been empirically investigated by many economists and educationalists. Much research has been conducted particularly on the measurement of education. For example, Barro (1991); Mankiw et al. (1992); Barro and Sala-i-Martin (1995), and Barro and Lee (2015), among others, used primary and secondary school enrollment rates as a proxy for the quantity of education across countries and found a positive and significant effect on economic growth. In contrast, Hanushek and Kimko (2000), Hanushek and Woessmann (2008, 2012, 2015, and 2016), among others, argued that educational quality rather than quantity does matter for the growth of nations. More specifically, high school students' test scores in international math and science competitions were found to have significant effects on economic growth, while the growth effect of the quantity measure of schooling was mitigated and became insignificant.¹

The purpose of this paper is to re-examine the role of education in the growth of per capita income across countries. The paper focuses on the following two objectives. The first objective is to confirm Barro's (1991) empirical findings, using an updated dataset for more recent decades from 1980 to 2015. This will strengthen and reaffirm the role of the

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¹ Vandenbussche et al. (2006), Aghion and Howitt (2008), and Aghion et al. (2009), among others, further indicated that the quality of tertiary education rather than secondary education would be more important for the development of 'frontier' technologies that helped lead the growth of the world economy. More recently, time-series techniques were employed to examine such causal relationships for individual countries (e.g. Jin, 2009, 2010; Akinwale and Grobler, 2019).

quantity measure of schooling in recent economic growth. Because the sample period includes the modern globalization era that began in the late 1980s, our empirical model includes a trade openness measure as a control variable.

Our second objective is to reaffirm the effect of Hanushek and Kimko's (2000) quality measures of education on recent economic growth. Hanushek and Kimko found that the quality of the labor force is a better predictor of growth than the quantity of schooling. In this case, the growth effect of the quality measure of education might have been overstated due to the fast economic growth of East Asian economies. To examine these doubts more closely, we have included a dummy variable to isolate the East Asian growth effect. In particular, the 'four little dragons' in East Asia (Hong Kong, Singapore, South Korea, Taiwan) were highly developed in the past decades as a result of economic liberalization and prioritization of educational development (World Bank, 1993); Japan also had fast economic growth in the 1960s that continued until the recession started in the early 1990s (Goto and Odagiri, 2003); China has had substantial economic growth since the early 1990s (Yao, 2003). All these fast growth in East Asia could have overstated the role of educational quality in the growth of nations worldwide.

We use cross-sectional data for 101 countries with a wide range of rich and poor countries. Their income gap is found to be large, and so is the difference in school enrollment rates. The baseline regression results indicate that education, in general, plays a significant role in economic growth. For the robustness of the results, several sensitivity tests were conducted, using alternative measures of education as well as a dummy variable to isolate an East Asian growth effect. One striking result we have found is that the effect of the quality measure of education on economic growth mitigates and becomes insignificant when East Asian economies are segregated from the regression. In contrast, the growth effect of the quantity measure of schooling remains significant. The two contrasting results suggest that the significant growth effect of educational quality found in the literature could have been over-emphasized in recent decades. The excessive growth effect is due to the East Asian growth effect largely attributed to the enthusiasm for education in East Asia.

The following section specifies an empirical model and explains the dataset we have used. Section 3 discusses baseline regression results. Section 4 confirms the robustness of the results through several sensitivity tests. Section 5 investigates the role of East Asian economies in the growth effects of both quantity and quality measures of education. Section 6 concludes with policy implications.

2. Model specification and the data set

A structural model has been specified based on the crucial variables used in Barro (1991) and Hanushek and Kimko (2000). The model first includes the initial level of income to examine the convergence hypothesis across countries (Barro, 1991; Hanushek and Kimko, 2000). Openness is also included as a control variable since economies will grow faster than others if these economies are more open to the world (Grossman and Helpman, 1991; Young, 1991). Education, the key variable in this analysis, has broadly two types of measurements in the literature: one is the quantity measure of schooling (Barro, 1991) and another is the quality measure of secondary education (Hanushek and Kimko, 2000). That is,

$$\text{GRGDP8015}_i = \beta_1 + \beta_2 \ln \text{GDP80}_i + \beta_3 \text{OPEN80}_i + \beta_4 \text{EDU80}_i + \varepsilon_i \quad (1)$$

where GRGDP8015 is the average annual growth rate (%) of real per capita GDP (in 2010 U.S. dollars) over the period 1980–2015; $\ln \text{GDP80}$ is the natural logarithm of the initial level of real per capita GDP in 1980;² OPEN80 is a trade/GDP ratio (%) as a proxy for the degree of openness in 1980; EDU80 is a secondary school enrollment rate (%) in the initial year 1980 (see Data Appendix for more detailed variable definitions and data sources).

The relevant data for 101 countries were obtained from World Development Indicators (WDI, produced by World Bank) over the period 1980–2015.³ In our dataset, we intended to include all G8 countries, but Germany and Russia were excluded from our sample because of the lack of the 1980s school enrollment rate. In particular, West and East Germany were not officially unified until 1990 when the Berlin Wall fell. This means that the data for German education before 1990 were divided into two nations, the West and the East, while the education data after 1990 were measured for one Germany after unification. This caused a lack of consistency of German education data. In addition, the collapse of the Soviet Union occurred in 1991, establishing the current Russian Federation. The data for the Russian Federation before 1991 were not separately available in WDI, and thus Russia was excluded from our sample. Furthermore, there were inconsistent data for some countries, such as Australia, Brazil, Liechtenstein, Singapore, and Taiwan; therefore, we excluded them from our sample. Several underdeveloped countries were also excluded as they provided insufficient quality data.

Table 1 shows summary statistics for the variables used. The average annual GDP growth rate appears to be 1.72%, and a high standard deviation further indicates that the growth rate fluctuates a lot across countries: the lowest performer was identified as Brunei Darussalam (-1.88%) and the highest performer was Equatorial Guinea (12.19%). It is also interesting to find that the initial per capita income in 1980 was, in fact, quite different between rich and poor countries, but their fluctuations were relatively small because of the logarithmic transformation that reduces the measurement scale. The initial enrollment rate of secondary education in 1980 was approximately 47% on average, which suggests that about half of the labor force was high school graduates or

Table 1
Summary statistics for model variables.

Model Variables	Median	Mean	Standard deviation	Minimum	Maximum
GRGDP8015 (%)	1.54	1.72	1.93	-1.88	12.19
$\ln \text{GDP80}$	3.49	3.52	0.65	2.27	4.77
EDU80 (%)	46.95	47.17	29.43	2.48	102.30
OPEN80 (%)	66.30	79.41	50.01	11.54	333.58

Data Sources: World Development Indicators, World Bank.

Notes: The sample includes 101 countries over the period 1980–2015. GRGDP8015 is the average annual growth rate of real per capita GDP (in 2010 U.S. dollars) over the period 1980–2015; $\ln \text{GDP80}$ is the natural log of the initial level of real per capita GDP in 1980 (2010 U.S. dollars); EDU80 is the secondary school enrollment rate in 1980 as a proxy for the initial-year schooling; OPEN80 is a trade/GDP ratio in 1980 as a proxy for the initial-year degree of openness (See Data Appendix for more detailed variable definitions and a bird's-eye view of the raw data).

² To be consistent with the measurement scale of other variables in percentage (%), GDP80 in US dollars is converted to its natural log, which reduces its measurement scale as well.

³ Our paper initially included the full list of 217 countries available in our data source WDI. But the number of countries included in our sample was cut down one by one according to the availability of the data in the following order: OPEN80, Edu80, Edu8015, and GDP80. This paper finally includes 101 countries in which relevant data are available for all model variables.

above and another half was primary school graduates. On the other hand, the degree of trade openness in 1980 was relatively high (approx. 79%) on average, which indicates that international trade played an important role in the growth of nations. A high standard deviation further indicates that some economies like Equatorial Guinea were highly open to world trade (334%), while many others were rather protected and less open economies at the time.

3. Baseline regression results

Table 2 shows the baseline regression results. Model (1) depicts that $\ln\text{GDP80}$, the initial level of income in 1980, has a negative and significant effect on economic growth. The negative growth effect supports the convergence hypothesis, in which poor countries' per capita income grows faster than rich countries, and thus their initial differences in income will converge over time (Barro, 1991; Mankiw et al., 1992; Hanushek and Kimko, 2000, among others). In addition, our openness measure OPEN80 shows a positive and significant effect on GDP growth. The positive growth effect is, in general, consistent with the proposition that gains from trade are always positive and thus economies perform better if engaged in international trade. This also underscores empirical findings that openness has a significant effect on economic growth (Frankel and Romer, 1999; Rodriguez and Rodrik, 2000; Wacziarg and Welch, 2008).⁴

After allowing the initial level of income and trade openness measures to explain changes in economic growth, Model (1) further finds that the initial level of educational attainment EDU80 has a positive and significant effect on subsequent GDP growth. The positive growth effect suggests that GDP growth rates will be higher if countries are initially equipped with a highly educated labor force. The logic behind this finding is that only educated workers are capable of learning foreign skills embedded in imported products (Amiti and Konings, 2007, among others); talented workers also contribute to the development of frontier technologies (Vandenbussche et al., 2006; Aghion et al., 2009). In either case, domestic technology improves so that those economies will grow faster than others. The results are, in general, consistent with the widely recognized and acknowledged findings of Barro (1991) that schooling was important for economic growth in earlier decades.

Model (2) includes an alternative education measure that uses the average annual enrollment rates of secondary education, EDU8015 , over the period 1980–2015 (e.g. Mankiw et al., 1992). The parameter

Table 2
Baseline regression results.

Model: Dependent Variable:	(1) GRGDP8015	(2) GRGDP8015
Constant	5.296 (1.302)	6.933 (1.203)
$\ln\text{GDP80}$	-1.768 (0.479)**	-2.838 (0.494)**
OPEN80	0.013 (0.004)**	0.013 (0.003)**
EDU80	0.035 (0.011)**	
EDU8015		0.059 (0.011)**
No. Obs.	101	101
Adj. R^2	0.164	0.317
S.E.	1.765	1.620

Notes: For variable names and definitions, see Table 1. Standard errors are in parentheses.

** indicates significance at the 1% level,

* indicates significance at the 5% level.

⁴ In particular, Frankel and Romer (1999) took an alternative approach to test the significance of international trade. They included the distance between countries, as well as the physical size of each country. Controlling for these variables, they also found that openness is strongly associated with the growth rate of GDP per capita.

estimate appears to be positive and significant, and the positive growth effect has increased substantially, compared to the one in Model (1). Fig. 1 further shows graphically the positive growth effects of education. Holding other explanatory variables constant, the partial association between economic growth and schooling was computed. The difference in slopes well reflects the different sizes of parameter estimates we have found in the two regressions above. The results are, in general, consistent with the findings of Barro (1991) and Mankiw et al. (1992), respectively, even without an inclusion of other socio-economic control variables in the analysis.

4. Robustness checks

4.1. Homoscedasticity

The baseline regression results employed the OLS estimation method that assumes a constant variance of residuals, i.e. homoscedasticity. But in reality, it is possible to observe the cases where as countries become richer, more people get educated; and if countries are more open to global trade, economic growth may slow down. In those cases, the regression model potentially confronts a heteroscedasticity problem in which residuals are gradually smaller as the data move from developing to developed countries (Levine and Renelt, 1992). However, computed residuals are found to move rather randomly and do not show a systematic pattern, and thus we roughly conclude here that the heteroscedasticity problem may not be serious in our baseline regression model.

To check further for the potential heteroscedasticity problem, Model (1) in Table 3 uses the weighted least squares estimation method. In this case, we initially presume that our baseline regression model may have a heteroscedasticity problem such that the variance of residuals can be inversely related to the initial level of income ($\ln\text{GDP80}$). In other words, the fluctuation of residuals may gradually decrease as the income level rises. To correct for such variances of residuals, we multiply both sides of the model by the square root of $\ln\text{GDP80}$ as a weight (e.g. Barro and Sala-i-Martin, 1995). The parameter estimates are, however, changed little. In particular, education is still positively associated with the GDP growth, and the positive growth effect is statistically significant at the 1% level. Both $\ln\text{GDP80}$ and OPEN80 also have significant effects on economic growth. The results are, in general, consistent with the findings of Barro (1991) although his dataset began in 1960, two decades earlier than ours.

4.2. The notion of causality

So far, we have seen the contemporaneous association of two model variables. In that case, the causal direction from education to growth is not necessarily guaranteed because potential reverse causality cannot be avoided (Bils and Klenow, 2000). The notion of causality suggests that a causal variable should occur earlier than a caused variable (Granger, 1969, 1988). Suppose domestic workers are educated earlier, and the economy begins to rise later. In this case, education is said to Granger-cause economic growth, but not the other way around. Educated workers cause/contribute to the development of an economy since changes in education occur earlier than the growth of nations. Accordingly, Model (2) replaces the dependent variable with GRGDP9015 , ten years lagged, compared to the causal variable. This type of model is designed to demonstrate the causal influence of current education on subsequent economic growth in ten years. The significant growth effect of education indicates that education in 1980 has a causal effect on subsequent economic growth in the 1990s and afterwards.

For the robustness of the result, Model (3) has a slightly different trial, shifting the initial year of education backward to 1970 to examine its causal effect on subsequent economic growth in the 1980s and afterwards. Notice, however, that the size of the sample dramatically drops to 29 countries due to the lack of data for secondary school

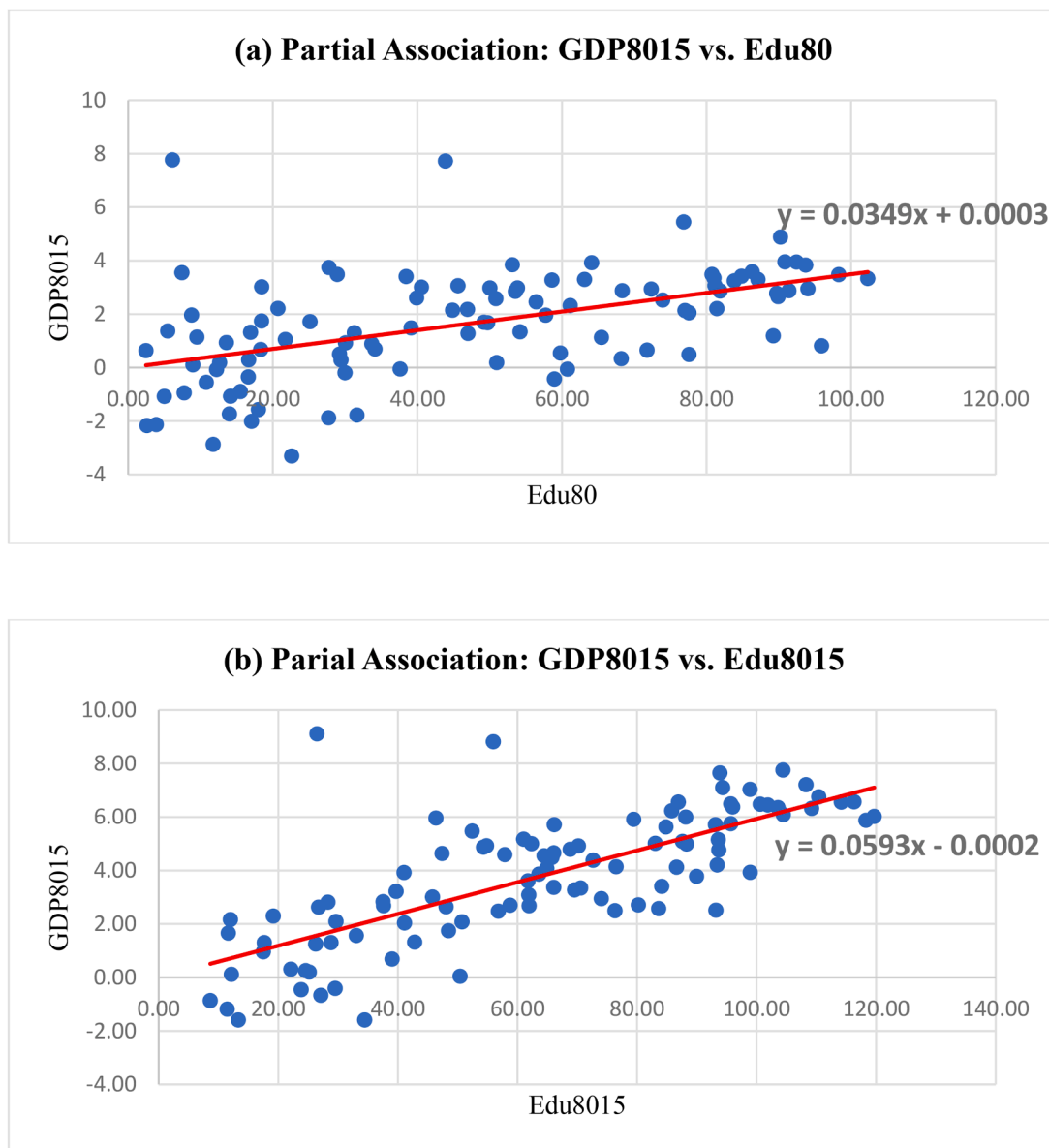


Fig. 1. Partial association of economic growth with alternative education measures.

Notes: See Table 1 for the definition of variables. Panel (a) uses the initial-year enrollment rate in 1980 (EDU80). Panel (b) uses the average annual enrollment rate over the period 1980–2015 (EDU8015).

enrollment rates in 1970. As a result, only 29 wealthy nations are included. Nevertheless, the result depicts that the causal effect of education on the subsequent growth of nations remains significant at the 5% level. The results are, in general, consistent with the findings of Barro (1991) although our sample has been updated in twenty years.

4.3. Wealthy nations

It is widely understood that poor countries lack sufficient infrastructure even for primary education, which means our baseline regression results could have been overstated. In particular, less developed countries (LDCs) in our sample had lower enrollment rates of schooling relative to developed countries, which caused the range of schooling was found wider in our sample. The income gap across countries was also bigger at the time.

To address this potential problem, we limited the number of sample countries in which per capita GDP was greater than \$3000 in 1980. This income restriction resulted in reducing the size of our sample to 52

countries, which contained relatively richer countries only. We thus focus more on higher-income countries in which the variations in both schooling and income are relatively small. Model (4), however, identifies that the growth effect of education is still significant even after the exclusion of many low-income countries. Thus, we can refute the presumption that the inclusion of many poor countries in our sample could have overstated our baseline regression results. This finding is, in general, consistent with the result of Barro (1991) in which \$1000 was used as a cutoff income in 1960, twenty years earlier than ours.

Notice, however, that the growth effect of trade openness appears to be insignificant in Model (4). The insignificant growth effect of openness was also found in Model (3) where 29 high-income countries were included in the sample. Both results suggest that the economic growth of high-income countries relies less on international trade. Industrialized countries most likely grow with the development of high-tech industries, so many developed countries may use frontier technologies that are typically developed with an increase in domestic R&D spending. In other words, the importance of international trade may diminish for the

Table 3
Sensitivity tests.

Model: Dep Var:	(1) GRGDP 8015	(2) GRGDP 9015	(3) GRGDP 8015	(4) GRGDP 8015	(5) GRGDP 8015	(6) GRGDP 8015
Weight:	$\sqrt{\ln \text{GDP80}}$			GDP > \$3000		
Constant	6.356 (1.544)	6.068 (1.412)	7.773 (2.581)	7.203 (1.619)	6.245 (1.365)	6.600 (1.355)
lnGDP80	-1.173 (0.340)**	-1.848 (0.520)**	-2.182 (0.845)**	-1.773 (0.450)**	-2.488 (0.551)**	-2.666 (0.565)**
OPEN80	0.011 (0.003)**	0.013 (0.004)**	0.003 (0.008)	0.003 (0.003)	0.0028 (0.0035)	0.0028 (0.0036)
EDU80	0.033 (0.010)**	0.028 (0.011)*		0.021 (0.008)**		
EDU70			0.055 (0.025)*			
EDU8015					0.032 (0.014)*	0.043 (0.014)**
QL1*					0.054 (0.020)**	
QL2*						0.041 (0.017)*
No. Obs.	101	101	29	52	65	67
Adj. R ²	0.171	0.153	0.142	0.207	0.270	0.262
S.E.	3.121	1.915	1.931	1.089	1.287	1.330

Notes: For variable names and definitions, see Table 1. QL1* and QL2* are the quality measures of secondary education obtained from Hanushek and Kimko (2000). Standard errors are in parentheses.

** indicates significance at the 1% level, and.

* indicates significance at the 5% level.

growth of wealthy nations, and thus trade openness no longer appears to be significant.

4.4. Quality measures of secondary education

Innovations and inventions are often led by talented scientists and engineers who have received better education in high school, so Hanushek and Kimko (2000) employed the quality measure of education that was obtained from high school students' test scores in international math and science competitions. Appendix C (labor-force quality data) in Hanushek and Kimko (2000) provides the data for two quality measures, QL1* and QL2*. The measurement of QL1* is based on 'world average scores of 50 for all six tests' and contains 65 countries for our analysis, while the measurement of QL2* is benchmarked to the 'U.S. performance on the National Assessment of Educational Progress (NAEP)' and contains 67 countries for our analysis.

Models (5) and (6) include QL1* and QL2*, respectively, and find that both quality measures of education have significant effects on economic growth. The result indicates that educational quality is important particularly for the development of higher technology in industrialized countries. At the same time, the quantity measure of schooling (EDU8015) also has significant effects on economic growth. The significant growth effects of both quality and quantity measures of education appear to be at odds with the findings of Hanushek and Kimko (2000) and Hanushek and Woessmann (2016), in which the quality measures were dominant for economic growth. Our results are, however, consistent with the findings of Jin and Jin (2013) although their quality measure differs from the ones used here.⁵

5. The role of East Asian growth effect

Table 4 includes a dummy variable DUM_{EA} to isolate the growth effect of East Asian economies (China, Hong Kong, Japan, South Korea).⁶ As noted earlier, these four economies had fast economic growth in the past decades, and their 'cognitive' skills were relatively high (Hanushek and Kimko, 2000; Hanushek and Woessmann, 2016).

⁵ One exception was the case where the size of our sample was restricted to 29 'observed' countries that had actually participated more than once in international math and science competitions. In that case, the significant growth effect of quality measures dominated, and hence the growth effect of schooling shrank and became insignificant, as in Hanushek and Kimko (2000). The results are not reported here but are available upon request.

⁶ Taiwan and Singapore were not included in the sample because relevant data were not available in our data source.

One striking result we have found here is that the significant growth effects of the two quality measures QL1* and QL2* shrink substantially, by more than half, and become insignificant when the East Asian dummy variable is included. The result is in stark contrast to the findings of Hanushek and Kimko (2000) and Hanushek and Woessmann (2016), in which educational quality rather than quantity matters for the growth of nations.⁷

In this regard, the validity of model specifications in (1) and (2) may be suspected due to the potential collinearity problem in which the two measures of educational quantity and quality are likely to be related to each other. For example, a nation would find a larger pool of talented scientists if more citizens were educated. This is because more creative scientists come from a larger number of educated students. That is, schooling quantity tends to be closely related to the quality measures of education. Their correlation with schooling is, indeed, relatively high ($r = 0.64$ and 0.63 with QL1* and QL2*, respectively). To avoid any potential problem of collinearity among these two explanatory variables, the quantity and quality measures have been included separately in each model one by one. To isolate the growth effect of East Asian economies, their dummy variable DUM_{EA} is kept included.

Models (3) – (6) show the estimation results of four separate models. Model (3) includes the quantity measure of schooling without the inclusion of quality measures. We find that the growth effect of schooling remains strong and significant even with the inclusion of the East Asian dummy. In Model (4), the quantity measure is replaced by the first type of Hanushek and Kimko (2000) quality measure (QL1*), together with the East Asian dummy. The independent growth effect of educational quality is substantially reduced and insignificant when the East Asian effect is segregated. A similar pattern is observed in Models (5) and (6), in which the growth effect is significant with the quantity measure of schooling (EDU8015) but insignificant with the quality measure of education (QL2*). The results are in stark contrast to the findings of Hanushek and Kimko (2000).⁸

⁷ Hanushek and Kimko (2000) identified the role of the East Asian effect by estimating a model with and without the inclusion of East Asian economies. Alternatively, we have included a dummy variable that isolates the effect of East Asian economies. Logically, these two approaches have the same effect.

⁸ For the robustness of the results, we expanded the number of Asian countries by including four more countries: India, Malaysia, the Philippines, and Thailand. The two quality measures of education were again found to have insignificant effects on economic growth, while the quantity measure of schooling remained significant. To better understand the difference, we further attempted to replicate the relevant tables in Hanushek and Kimko (2000) using the dataset of our present study. Our key findings remained unchanged. All these results are not reported here but are available upon request.

Table 4

The role of East Asian effect dependent variable: GRGDP8015.

Model:	(1)	(2)	(3)	(4)	(5)	(6)
Constant	6.081 (1.279)	6.190 (1.278)	6.417 (1.236)	4.113 (1.001)	6.343 (1.264)	3.567 (1.020)
lnGDP80	-2.069 (0.530) **	-2.240 (0.548)**	-2.007 (0.527)**	-1.085 (0.336)**	-2.160 (0.539)**	-0.880 (0.348) **
OPEN80	0.0030 (0.0033)	0.0032 (0.0033)	0.003 (0.003)	0.002 (0.003)	0.003 (0.003)	0.002 (0.003)
EDU8015	0.031 (0.013)*	0.040 (0.013)**	0.036 (0.013)**		0.043 (0.013)**	
QL1*	0.022 (0.022)			0.038 (0.021)		
QL2*		0.015 (0.017)				0.029 (0.018)
DUM _{EA}	2.255 (0.729)**	2.294 (0.747)**	2.620 (0.637)**	2.284 (0.756)**	2.603 (0.658)**	2.443 (0.795)**
No. Obs.	65	67	65	65	67	67
Adj. R ²	0.361	0.350	0.361	0.313	0.352	0.260
S.E.	1.204	1.248	1.205	1.249	1.245	1.331

Notes: For variable names and definitions, see Table 1. QL1* and QL2* are the quality measures of secondary education obtained from Hanushek and Kimko (2000). DUM_{EA} is a dummy variable for four East Asian economies (China, Hong Kong, Japan, and South Korea). Standard errors are in parentheses.

** indicates significance at the 1% level, and.

* indicates significance at the 5% level.

Our findings thus far suggest that the growth effect of the quality measure of education may be sensitive to the sample period used (starting from 1960 vs. 1980). The results also differ depending on the number of countries included. However, when we look back 20 years, it is difficult to avoid our proposition that the growth effect of educational quality found in Hanushek and Kimko (2000) has been overstated due to the growth effect of East Asian economies.

6. Concluding remarks

This paper has used standard growth regressions to investigate the role of education in the growth of nations. The sample includes 101 countries over the period 1980–2015. We found that education, in general, has significant effects on economic growth. For the robustness of the results, several sensitivity tests were conducted using alternative education measures. The results were generally robust in that the growth effect of education was significant. However, the growth effect of quality measures of education was substantially mitigated and became insignificant when the East Asian dummy variable was included in the model. Nonetheless, the quantity measure of schooling remained significant even with the inclusion of the East Asian dummy. The two contrasting results suggest that the significant growth effects of educational quality found in the literature have been overstated because of the East Asian growth effect, which was largely attributed to the education fever in East Asia.

Our empirical findings give a big picture of the fundamental framework for better economic growth. For nations to grow, policy-makers need to focus and contribute more to education. Especially, underdeveloped countries can make secondary education compulsory and should recruit more quality teachers for better education. With such investments in education, their economies will likely improve through the enhancement of domestic technologies that can be learned from overseas by educated workers. For industrialized countries, however, higher education rather than secondary education may play a more important role in economic growth since such developed countries are most likely to grow with the development of high-tech industries, which are normally developed by an increase in R&D spending.

Finally, it should be noted that there are some limitations in this paper. First, our measure of education is limited to secondary education and does not reflect post-graduate education such as the quality of Ph.D. programs (e.g. Valero and Reenen, 2019). In particular, the graduate programs in ‘highbrow’ universities are believed to play a more important role in the development of frontier technologies and innovations for the growth of industrialized countries (e.g. Vandenbussche et al., 2006; Agion et al., 2009). In addition, our education measures count for students’ quality, but they fail to reflect faculty quality that directly affects the future labor force (e.g. Jin and Jin, 2013; Yu and Jin, 2022, 2024). These limitations are beyond the scope of this paper and

are left for further research.

IRB disclosure statement

IRB approval is not required because the paper does not involve the collection of data on human subjects.

Data availability statement

Our publication data generated and analyzed during the current study are not publicly available due to the fact that they constitute an excerpt of research in progress, but they are available from the authors on reasonable request.

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CRediT authorship contribution statement

Jang C. Jin: Writing – review & editing, Visualization, Validation, Supervision, Formal analysis, Conceptualization. **Dan-A Kim:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

Authors declare that they have no relevant or financial interests that relate to the research described in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jge.2024.100121](https://doi.org/10.1016/j.jge.2024.100121).

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