

Short- and Long-Run Effects of Education on Economic Growth: A Panel Error Correction Analysis

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ABSTRACT

This study analyzes the effects of education on economic growth in different countries grouped by income level. The key variables are cointegrated and integrated of order one. Hence, we employ the panel error correction model (PECM) to estimate the short-run and the long-run relationships. Results show differences in the impact of education across income levels. Primary education has been shown to be beneficial in the short and long run. Surprisingly, tertiary education had a negative effect on economic growth for all except the low-income group. Granger causality also suggests the direction of causation is that of education on economic growth and not vice versa.

Keywords: Human capital, educational impact, economic growth, economic development

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1. Introduction

Improvements in human capital are considered to contribute substantially to the economic growth of a nation. Several studies argue that human capital has significantly influenced economic development and growth more than nearly every other economic driver. (Barro and Lee, 2001; Gylfason, 2001; Jose, n.d.). The value of human capital and education was emphasized in the endogenous growth models and later in the expanded neoclassical growth model as proposed by Mankiw, Romer, and Weil (Gyimah-Brempong et al., 2006). In a related topic, the primary source of differences in living standards among nations has been attributed to differences in human capital (Lucas, 1993).

The expanded neoclassical growth theories posit that countries experiencing faster education growth rates show faster transition growth rates and higher incomes owing to human capital as an added input. (Mankiw et al., 1992) According to the endogenous growth theory, this faster growth in transition and income is attributed to education because it promotes innovation, knowledge, and technology (Lucas, 1988; Romer, 1990). This theory also postulates that education drives growth in three ways. First, the endogenous model sees education as a process that aids changes in production technology by creating or enhancing products, processes, or knowledge. (Aghion, 1998; Nelson and Phelps, 1966; Romer, 1990). Second, it makes it easier to adapt to new and foreign technology (Barro, 1996; Barro and Sala-I-Martin, Xavier, 1995; Hall and Jones, 1999; Sala-i-Martin, 1997). Lastly, it facilitates the transfer of resources of knowledge and information to the technologically dynamic sector of the economy (Kim and Kim, 2000; Schiff and Wang, 2004).

Empirical evidence generally favors the result that human capital positively affects the per capita income growth rate (Temple, 1999) (See Temple). However, little research exists on the relationship between education levels and economic growth rate. Some researchers have emphasized the crucial role of higher education in research and development that, further serves as a source of growth (Hall and Jones, 1999; Nelson and Phelps, 1966; Romer, 1990). Other researchers stress that primary education is the primary source of economic growth in lower-income countries (McMahon, 1999; Petrakis and Stamatakis, 2002).

Education can directly impact economic growth. Higher educational attainment implies the availability of higher-skilled and a more productive labor force, which contributes to economic growth (Barro and Lee, 2001). A larger pool of educated population allows companies to invest in and exploit new economic opportunities, leading to improved business performance. Economic growth increases wealth, available resources, and educational opportunities (Earle, 2010). Education is also associated with long-term improvements in economic growth. The more a country invests in its education systems, the better its overall economic performance. Research also suggests that countries with higher rates of school attendance experience faster economic growth compared to those with fewer educated workers (for example, Romer, 1990). According to the Global Partnership for Education (GPE), "Education is a powerful agent of change, and improves health and livelihoods, contributes to social stability and drives long-term economic growth." Some countries invest heavily in education. Alderman et al. (Alderman et al., 1996) argue that high-income countries invest over \$100 billion annually in human capital, particularly education.

There are numerous reasons why education levels are essential. Generally, education enhances the effectiveness of every worker and helps the economy move up the chain value beyond simple production processes or manual tasks. Education affects the productivity of a country via three channels (Alesina and Giuliano, 2011). Primary education enhances the collective capability of the labor force to accomplish current work more efficiently. Secondary and tertiary education facilitates the transfer of knowledge of new technologies, products, and information developed by others, and enhances creativity which boosts the capacity of a nation to create new technologies, products, and knowledge (Grant, 2017). Education is considered the leading determinant of employment, earnings, and economic growth.

If educational attainment in countries increases with income, higher education will become more critical at the later stages of income growth. Higher-income countries would then have achieved universal primary education, while lower-income countries would see rising attainment of higher and lower levels of education. We follow World Bank's classification of countries based on income levels.

Our thesis is that a country's income and education levels go hand in hand. That is, countries with higher levels of income and economic growth would have a higher proportion of the population with advanced education. In contrast, low-income countries will have a higher proportion of the population with primary education. This study considers primary, secondary, and tertiary education levels. We hypothesize a rising gradient of the effect sizes of the levels of education on income levels. In other words, higher-income countries would have a larger proportion of the population with tertiary education. Similarly, low-income countries will have a larger proportion of the population with primary education.

Results from this study have policy implications since the education levels are easily identifiable and can be affected using policy measures/options. Estimating the magnitudes would also help us determine the cost and benefits of investing in higher education by governments or external agencies.

This study aims to analyze the role of education levels on economic growth conditional on the income levels of countries during the period 1970 - 2020. It is well documented that education as a human capital component is essential in driving long-run growth (Lucas, 1988). Research work on the impact of the levels of education on growth is essential to understand the differential effects of education levels on growth (Keller, 2006). Primary education, for example, may be sufficient to follow and perform work efficiently; secondary education would be essential for tech-related work, such as computers, and higher education would promote or support technological innovations.

In addition, most studies on the causal nexus between education and economic growth have focused on low-income and less-developed countries. There is a lack of studies focusing on different income levels. This study's objectives are as follows. First, it examines the differential effects of education levels (primary, secondary, or tertiary) on economic growth. Second, it investigates the causal link between education levels and economic growth. Finally, it attempts to fill the gap in previous studies by dividing the sample into countries with different income levels and using a reduced sample of the selected European countries.

The rest of the paper is organized as follows: Section 2 briefly discusses previous studies pertinent to this paper. Section 3 lays out the methodology, and Section 4 describes data sources. Empirical results are presented in Section 5, followed by conclusions and implications in Section 6.

2. Literature Review

Development economists have always emphasized the crucial role played by education in the development process; however, the growth theory has only recently incorporated education into its analyses (Gyimah-Brempong et al., 2006). Lucas (1988) developed an endogenous growth model that integrates human capital, proxied by education, as one of the main contributors to economic growth. Mankiw et al. (Mankiw et al., 1992) also showed that human capital is key to economic growth. Evidence shows that education should positively affect the income growth rate in either the endogenous or expanded neoclassical growth model. However, a minimum level of education may be required for any measurable growth impact (Azariadis and Drazen, 1990; Rebelo, 1992).

Several studies have evaluated the relationship between education and economic growth across developing and developed countries. De Meulemeester and Rochat (De Meulemeester and Rochat, 1995) examine the causal effect of higher education on economic growth for six developed countries using co-integration and Granger causality tests. Their study shows evidence of a significant causality of higher education on economic development in four countries, namely Sweden, the United Kingdom, Japan, and France. Using data before the Second World War, Jaoul (Jaoul *, 2004) found higher education influenced GDP in France, while economic growth in Germany increased the number of students enrolled in higher education. Analyzing recent data from 1997 to 2016 using the Granger causality technique, Dudzevičiūtė and Šimelytė (Dudzevičiūtė and Šimelytė, 2018) showed a significant interrelationship between education and economic growth in most European Union (EU) countries.

Petrakis and Stamatakis (Petrakis and Stamatakis, 2002) examined the effect of human capital on growth for the Organization for Economic Co-operation and Development (OECD) countries, developed market economies, and developing countries. Their results revealed the influence of national income on the relationship between education and economic growth. Primary and secondary education were more critical to economic growth in less developed countries (LDC), whereas economic growth in OECD countries mainly depended on higher

education. A study by Keller (Keller, 2006) examined the effects of primary, secondary, and higher education on per capita growth for LDCs and DCs from 1971 to 2000. These analyses support the finding that secondary and higher education enrollment rates play a significant role in developed countries. Besides that, more expenditure on primary education in general and per student in the primary education stage have contributed significantly to economic growth. In contrast, spending on higher stages of education was not efficient. In African countries during 1960–2000, however, expenditures in all levels of education, including higher education, significantly impact the rate of per capita income growth (Gyimah-Brempong et al., 2006).

Human capital encompasses more factors than education. Human capital achieved through education has been found to have the greatest impact on economic growth or economic progress in general (Barro and Lee, 2001). Furthermore, Barro (Barro, 2001, 2013) reveal that education positively impacts economic growth across countries and that the causal relationship runs directly from education measured by schooling rates to economic growth.

Existing studies that report a positive effect of human capital on economic growth find increasing worker productivity owing to human capital accumulation to be an important reason (Coulibaly and Asirvatham, 2021). According to Hanushek (Hanushek, 2016), countries have been pushing to expand tertiary education. Many developing and developed countries have made significant investments in education with the belief that education would improve economic growth, as is supported by various studies. Governments work with the assumption that improving people's skills will promote economic performance and, thus, economic growth. (Holland et al., 2013). Mehrara and Musai (Mehrara and Musai, 2013) found strong causal linkages between investment in education and economic growth in developing countries from 1970-2010. However, they observed a nonlinear relationship in countries where the education system is not very market-oriented; after a certain enrollment number, further enrollment increases only decrease the quality of education. As a result, larger investments in education in these developing countries do not produce higher economic performance.

3. Empirical Methods

This paper focuses on the effect of education level on economic growth. Following earlier researchers, we specify the following reduced-growth equation.

$$GGDP_{it} = \beta_{0t} + \beta_{1t}P_{it} + \beta_{2t}S_{it} + \beta_{3t}T_{it} + \varepsilon_{it} \quad (1)$$

Where $GGDP$ is the growth rate of real GDP per capita, a measure of economic growth; P is the enrollment in primary education; S is the enrollment in secondary education; and T is the enrollment in tertiary education.¹ Education levels are proxies for human capital, which is a standard practice.

In studies estimating growth regressions on cross-section data, employing panel data and fixed effect OLS estimates have been used to address the problem of biased estimates due to omitted variable bias (Chavula, 2016). According to Islam (Islam, 1995), using cross-section data from many countries and long-term growth averages can result in biased estimates. However, fixed effects OLS or pooled OLS estimators cannot be employed on growth regressions with lagged dependent variables, where the coefficient is biased but consistent over more extended periods

¹ The variables used in this study and their descriptive statistics are shown in Table 1.

(Simões, 2011). This led to a spur in using dynamic fixed effects (DFE) estimators in the empirical growth literature.

In a DFE model, pooled estimates are not uniform, which leads to biased estimates, even though the parameter estimates are consistent in coefficient heterogeneity (Chavula, 2016). Consequently, the DFE models may yield unstable and, possibly, misleading estimates, particularly if the slope coefficients are identical (M. H. Pesaran et al., 1999). In such instances, the econometric literature presents two options that relax the assumption of homogenous slope coefficients. Pesaran and Smith (M. Pesaran and Smith, 1995) suggested the mean-group (MG) estimator, and Pesaran et al. (M. H. Pesaran et al., 1999) suggested the pooled mean-group (PMG) estimator, allowing a higher degree of parameter heterogeneity in growth regressions. The MG estimator allows heterogeneous coefficients and intercepts for each country. The coefficient for the entire analytic sample is calculated by taking the unweighted average of the country-level coefficients (Blackburne and Frank, 2007). The PMG estimator considers a lower degree of heterogeneity and relies on pooling and averaging the coefficients by enabling heterogeneity in short-run coefficients and error variance while allowing homogeneity in long-run coefficients (Blackburne and Frank, 2007; M. H. Pesaran et al., 1999).

We estimate equation (1) on panel data of countries. We use the panel error correction model (PECM) with the three estimation methodologies to examine education levels' short-run and long-run effects on economic growth. The PMG estimator modifies the cointegration structure of the simple autoregressive distributed lag (ARDL) model for panel data, which produces intercepts, short-run coefficients, speed of adjustment, and error variances across groups. Since the PMG estimator pools and averages the DFE and MG estimators, the long-run coefficients are constrained between those estimates (M. H. Pesaran et al., 1999). We use the Hausman test to assess the consistency and efficiency of the PMG and MG estimators, which helps determine the more suitable estimator.

PECM is appropriate when economic variables share long-term and short-term relationships since it permits an analysis of the long-run relationship among the variables along with the short-term adjustment gravitating towards the long-run equilibrium (Asteriou and Hall, 2011; Hill et al., 2018; Wooldridge, 2012). PECM, however, requires that the series be integrated in the same order and cointegrated. Therefore, we first assess the stationarity of the time series. If the variables are not stationary, check whether a cointegration relationship characterizes them, and finally, in case cointegration holds, estimate the PECM.

Following Lee et al., Shin et al., and Blackburne and Frank (41,45,46), if the maximum fixed lag of every variable is one, then the autoregressive distributed lag, ARDL (1,1,1) model can be written as:

$$GGDP_{it} = \mu_{it} + \lambda_i GGDP_{i,t-1} + \alpha_{10i} P_{it} + \alpha_{11i} P_{i,t-1} + \alpha_{20i} S_{it} + \alpha_{21i} S_{i,t-1} + \alpha_{30i} T_{it} + \alpha_{31i} T_{i,t-1} + \varepsilon_{it} \quad (2)$$

where, for consistency, all the variables are as defined in previous equations with t as the time trend and ε_{it} is the error term. All variables in equation (2) are assumed to be I(1) and cointegrated, which makes the error term an I(0) process for all countries, or i in the equation. Based on Pesaran, Shin, and Smith (H. Pesaran et al., 1997; M. H. Pesaran et al., 1999), the ECM representation equation can be written as follows:

$$\Delta GGDP_{it} = \varphi_i (GGDP_{i,t-1} - \theta_{0i} - \theta_{1i} P_{it} - \theta_{2i} S_{it} - \theta_{3i} T_{it}) + \alpha_{11i} \Delta P_{it} + \alpha_{21i} \Delta S_{it} + \alpha_{31i} \Delta T_{it} + \varepsilon_{it} \quad (3)$$

Where $\varphi_i = 1 - \lambda_i$; which is the adjustment coefficient; Δ is a difference operator;

$$\theta_{0i} = \frac{\mu_{it}}{1-\lambda_i}; \theta_{1i} = \frac{\alpha_{10i}+\alpha_{11i}}{1-\lambda_i}; \theta_{2i} = \frac{\alpha_{20i}+\alpha_{21i}}{1-\lambda_i} \text{ and } \theta_{3i} = \frac{\alpha_{30i}+\alpha_{31i}}{1-\lambda_i} \quad (4)$$

The parameters of interest here are the error-correction speed of the adjustment parameter φ_i , and the long-run coefficients θ_{0i} , θ_{1i} , θ_{2i} , and θ_{3i} . A negative parameter φ_i would demonstrate a return to the long-run equilibrium. Theoretically, all three parameters are expected to be positive as we expect them to impact growth positively.

4. Data and Descriptive Statistics

We use international data for 77 countries from 1970 to 2020 to investigate the short-run and long-run effects of education levels on economic growth.² The data are obtained from World Bank and provided by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). The dependent variable in our model is the economic growth rate (*GDP*), which is measured as the annual growth rate of real GDP per capita in a constant 2015 US\$. The explanatory variable is the gross school enrolment ratio at primary (*P*), secondary (*S*), and tertiary (*T*) levels, which is measured as a proxy for human capital. Studies in empirical growth literature use different approaches to measure education. For example, some researchers use enrolment ratios (Barro and Lee, 1996, 1994; Petrakis and Stamatakis, 2002). Enrolment ratios have the advantage of being comparable across countries and available.

Table 1 summarizes the series in log form. Means for these variables and their associated standard errors are presented from 1970 to 2020. The average annual per capita GDP growth rate was very low during the sample period, with a 1.01 variation. The average enrolment rate is between 4.54 and 2.51 for tertiary education (*T*). The variances are between 1.45 for *T*, which shows the most fluctuation, and 0.32 for *P*.

Table 1.

Descriptive Statistic

Variables	Label	Observation	Mean	Std. Dev.	Min	Max
<i>GDP pc growth (%)</i>	<i>GGDP</i>	2,930	0.9465	1.0074	-6.2230	4.0959
<i>Primary (% gross)</i>	<i>P</i>	3,496	4.5425	0.3182	1.0296	5.1096
<i>Secondary (% gross)</i>	<i>S</i>	3,154	3.9254	0.8387	-1.6094	5.0993
<i>Tertiary (% gross)</i>	<i>T</i>	2,945	2.5109	1.4494	-2.3026	5.0166

5. Empirical Results

5.1. Panel Unit Root Test

The first step is to test for stationarity using the unit root tests before establishing the order of integration. Table 2a shows the results of unit root tests of Im–Pesaran–Shin (IPS), Augmented Dickey–Fuller (ADF), and Philips–Perron (PP) for the variables in the system. All three unit-root tests reject the hypothesis at 1% significance level that all panels possess a unit root. Thus, indicating that the panel data of some countries in the analytic sample follow a stationary process in levels. Despite *Tertiary* education showing the opposite results from the IPS and ADF tests. However, it is stationary at the first difference level since the null hypothesis of non-stationarity is rejected at a 1% significance level (see Table 2b). This confirms that these variables are integrated of order one, *I*(1).

² See Appendix 1 for countries that are included in our sample.

Table 2a.

Panel Unit Root Tests (in levels)

Variables	IPS	ADF-Fisher	PP-Fisher	Level of Integration
<i>GDP pc growth</i>	-17.787 (.000)***	31.466 (.000)***	97.035 (.000)***	I(0)
<i>Primary</i>	-4.361 (.000)***	7.964 (.000)***	8.844 (.000)***	I(0)
<i>Secondary</i>	-0.021 (.000)***	9.390 (.000)***	17.575 (.000)***	I(0)
<i>Tertiary</i>	3.187 (.999)	-2.712 (.997)	7.115 (.000)***	I(1)

Note: The null hypothesis for all test is a unit root (assumes individual unit root process). A modified inverse chi-squared test statistic is reported for ADF and PP Fisher tests. In most cases, two lags are introduced to allow for serial correlation in the errors. P-values shown below test statistics. Level of significant at *** p<0.01, ** p<0.05, * p<0.1

Table 2b.

Panel Unit Root Tests (At First difference)

Variables	IPS	ADF-Fisher	PP-Fisher	Level of Integration
<i>GDP pc growth</i>	-40.351 (.000)***	114.36 (.000)***	273.67 (.000)***	I(0)
<i>Primary</i>	-16.060 (.000)***	29.692 (.000)***	108.18 (.000)***	I(0)
<i>Secondary</i>	-17.489 (.000)***	16.700 (.000)***	85.333 (.000)***	I(0)
<i>Tertiary</i>	-21.491 (.000)	21.712 (.000)	75.239 (.000)***	I(0)

Note: The null hypothesis for all test is a unit root (assumes individual unit root process). A modified inverse chi-squared test statistic is reported for ADF and PP Fisher tests. In most cases, two lags are introduced to allow for serial correlation in the errors. P-values shown below test statistics. Level of significant at *** p<0.01, ** p<0.05, * p<0.1

5.2. Panel Co-integration Tests

After identifying the stationarity order, we proceed with testing for panel cointegration. When two variables in a time series panel data are cointegrated, they are assumed to have a long-run relationship. The most commonly employed panel cointegration tests in econometric literature are the residual-based ones proposed by Pedroni; Mccoskey and Kao; Kao; Larsson et al.; and Mark and Sul (Kao, 1999; Larsson et al., 2001; Mark and Sul, 2003; McCoskey and Kao, 1998; Pedroni, 1999b, 2004). An alternative panel cointegration test based on structural rather than residual dynamics was proposed by Kao; Pedroni; and Westerlund (Kao, 1999; Pedroni, 1999a, 2004; Westerlund, 2007).

Table 3.

Panel co-integration tests

Test Statistics	Some	All
Kao (1999)	---	-14.517 (.000)***
Pedroni (2004)	---	-20.243 (.000)***
Westerlund (2007)	-8.872 (.000)***	-4.886 (.000)***

Note: The null hypothesis for all test is no cointegration in all panels, for the Westerlund test also takes no cointegration in some panel as the null. Augmented Dickey–Fuller t statistic is considered for Kao (1999) and Pedroni (2004) tests. P-values shown below test statistics. Level of significant at *** p<0.01, ** p<0.05, * p<0.1.

Table 3 reports Pedroni's (Pedroni, 1999a, 2004) and Kao's (Kao, 1999) panel cointegration tests utilizing all-panel statistics and Westerlund's (Westerlund, 2007) test employing some or all-panel statistics to evaluate the null hypothesis of no cointegration among the variables. All panel statistics perform tests on all available countries within the panel dataset, whereas some

panel statistics perform tests only on a subset of countries. The results show strong evidence of panel cointegration among the variables. All tests reject the null hypothesis at 1% significance level in the all-panel statistics. Thus, the variables in the specified growth function are cointegrated. This is observed for all the countries in the analytic sample. In the case of some panels, cointegration is present among variables for one or more countries (See Pedroni, 1999a).

5.3. Panel Vector Error Correction Model

Upon establishing that a linear combination of the variables maintains proportionality among the pooled variables in the long run, equation (3) can be estimated to obtain short- and long-run estimates. The PECM was used with the three estimation methodologies, namely PMG, MG and DFE, to assess the impact of the different levels of education on economic growth.

Table 4.

The panel vector error correction model

(Estimation of the nonstationary heterogeneous panels: Error Correction Forms)

Variables	PMG	MG	DFE
Estimates of long-run coefficients			
Primary	2.8103 (.737)***	3.9872 (5.367)	2.3453 (.874)***
Secondary	-0.4777 (.545)	3.4873 (3.977)	-1.1368 (.610)*
Tertiary	-0.9319 (.223)***	-4.6742 (1.717)***	-.2525 (.257)
Estimates of short-run coefficients			
Error-correction term	-0.7766 (.041)***	-0.8494 (.080)***	-0.7820 (.022)***
$d(\text{primary})$	14.7508 (6.627)**	4.1554 (9.257)	4.3137 (2.682)*
$d(\text{secondary})$	7.4023 (4.083)*	1.3906 (4.195)	4.1922 (1.508)***
$d(\text{tertiary})$	1.8690 (1.367)	1.8613 (1.753)	0.6483 (.808)
Constant	-5.7970 (.422)***	-21.098 (23.810)	-2.932 (2.231)
Hausman test	PMG vs MG: $\chi^2(3)=3.28$ (0.3499)		PMG vs DFE: $\chi^2(3)=1.53$ (0.676)

Note: Dependent variable is real GDP per capita growth rate. PMG is Pooled Mean Group Regression, MG is Mean Group Regression, and DFE is Dynamic Fixed Effects Regression: Estimated Error Correction Forms. The PMG estimator relies on a combination of pooling and averaging of coefficients, MG estimator relies on averaging of cross-sections, and (DFE) estimator relies on pooling of cross sections. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

The PMG and MG models are estimated in a two-equation model, the normalized cointegrating vector and the short-run dynamic coefficients. This two-equation setup produces long- and short-run estimates. PMG model allows heterogeneous short-run dynamics but uniform long-run elasticities across all countries. MG estimators, on the other hand, allow heterogeneous elasticities in the short run and the long run.

The results in Table 4 illustrate considerable discrepancies contingent upon the estimation method employed, ranging from PMG and DFE, which are more restrictive but possibly inefficient, compared to MG methods, which are less restrictive. Upon closer examination of the PMG, MG, and DFE estimates, it is evident that, despite variations in the coefficient magnitudes and their respective levels of significance across the three estimation methods, the signs of these short- and long-run coefficients remain consistent except in the MG method. The estimates of the speed of adjustment across the various models reveal distinct short-run dynamics, with values of 0.78 in the PMG model, 0.85 in the MG, and 0.78 in the DFE model.

Do note that the PMG estimator imposes pooling, where the long-run coefficients are constrained to be identical across all countries or panels. If the restrictions are valid, the PMG method results in efficient and consistent estimates. If the restriction is violated, then the PMG estimate of slope homogeneity becomes inconsistent. Nevertheless, the MG method yields consistent estimates in such cases (Blackburne and Frank, 2007). Similar to the PMG estimator, the DFE estimator imposes the condition that coefficients of the cointegrating vector are uniform across all countries or panels. The DFE method also constrains the speed of the adjustment, resulting in identical short-run coefficients.

Therefore, we perform the familiar Hausman test to test differences in these models and establish the most appropriate model between them (Blackburne and Frank, 2007). In analyzing the DFE models, the Hausman test is used to measure the degree of endogeneity since DFE models are subject to a simultaneous equation bias due to the endogeneity between the lagged dependent variable and error term (Baltagi et al., 2000). Hausman's test compared PMG and MG suggest that the null hypothesis of heterogenous slope coefficients was rejected. Therefore, the PMG model is preferred over the MG model. Hausman's test on measuring the degree of endogeneity indicates negligible simultaneous bias in PMG and DFE models; therefore, the PMG model is favored over the DFE model. Subsequent discussion, therefore, about the education levels influencing economic growth is based on the preferred PMG model estimates.

The PMG model shows significant estimates of the education variable during the sample period, thus finding both short and long-run effects of education on economic growth. In the overall all-country inclusive model shown in Table 4, long-run estimates are significant for primary and tertiary education. In contrast, primary and secondary education levels are significant in the short run. Thus, only primary education is significant in both the short- and long-run. The results are consistent with the existing literature, which finds that the levels of technical skills at the end of compulsory education matter (Holmes, 2013). Primary education contributes positively to economic growth for all countries. On the other hand, negative and significant short-run relationships are found with tertiary education, meaning that in the short-run, a 1 percent increase in tertiary education will harm economic growth by about 0.93 percent. Tertiary education is more costly than the other education levels and also takes more time to achieve, which could explain why it has negative returns in the short run. This could suggest that public spending on education aimed at building skills and technological knowledge might be unnecessary and are not required to positively contribute to economic growth, at least in the short run. The all-country estimates do not apply to countries at all income levels defined by the World Bank. Estimates in the all-country model are weighed by the number of observations in particular income categories. For example, the percentage of observations on high-income countries in the sample is 42 percent, whereas the percentage of low-income countries is only 12 percent. Hence, we separately evaluate the high income, middle income, and low-income countries.

Looking across different groups of countries by income, Table 5 shows various and some significant results. Unlike Holmes (Holmes, 2013), we find no difference across income levels

since his model suffers from endogeneity issues.³ The results show that secondary education positively and significantly affects long-run economic growth in high-income and high-middle-income countries. These findings show that secondary education significantly contributes to economic growth during the study period. To achieve sustained economic growth, nations should allocate adequate resources to the most needful education level as well as improve enrolment rates. It shows that the high/-middle-income economy moved more toward the manufacturing and service sectors. Further, tertiary education's effect on economic growth is negative and insignificant compared to primary and secondary education. However, in the short run, primary education significantly and positively impacts economic growth for both samples. So, it is crucial to address the contribution from the agriculture sector that can affect long-run economic growth since the agriculture sector, as we know, has more primary educated workers.

Table 5.

PMG short- and long-run estimates by country income

Variables	High income	High-Middle income	Low-Middle income	Low income
Estimates of long-run coefficients				
<i>Primary</i>	1.2450 (2.639)	-6.6156 (2.753)**	1.9012 (1.740)	4.1805 (1.135)***
<i>Secondary</i>	2.7353 (1.361)**	3.7463 (.775)***	-.4961 (1.060)	-4.3410 (.646)***
<i>Tertiary</i>	-2.3669 (.413)***	-2.1241 (.469)***	-.3867 (.397)	1.7292 (.453)***
Estimates of short-run coefficients				
Error-correction term	-.6789 (.052)***	-0.5942 (.219)**	-.8080 (.071)***	-1.2202 (.071)***
<i>d(primary)</i>	20.0168 (9.646)**	44.0186 (18.67)**	6.0382 (11.04)	-14.7249 (7.403)**
<i>d(secondary)</i>	10.3079 (9.629)	-3.2601 (13.59)	2.2971 (4.305)	15.2671 (4.649)***
<i>d(tertiary)</i>	1.0046 (1.926)	4.0773 (4.949)	.6173 (2.050)	-0.1607 (2.299)
Constant	-5.3546 (.445)***	13.4147 (4.476)***	-3.5896 (.369)***	-7.5972 (.977)***
Number of Obs.	903	450	547	251
Number of Groups	26	18	23	10

Note: Dependent variable is real GDP per capita growth rate.

Traditional Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Furthermore, tertiary education positively affects long-term economic growth in low-income countries. This means that a one percent increase in tertiary education will increase economic growth by 1.73 percent in the long run. The impact of tertiary education on economic growth appears to be substantial and significant, thus echoing findings in the literature. For example,

³ See Table A3 for Results Summary in Appendix.

Loening (Loening, 2005) showed that a better-educated labor force positively and significantly affected economic growth in Guatemala from 1951 to 2002. In recent decades, attaining higher education and achieving high technical skills have emerged as essential determinants of the diffusion of technological innovations. It has been observed that individuals with tertiary education reaped the benefits of policies promoting global competitiveness, such as trade liberalization and attracting foreign investment. Furthermore, increasing enrollment in tertiary education in rural and urban areas has improved worker skills and led to a greater adoption of new technology in the manufacturing and service sectors. However, the impact of primary and secondary education on economic growth is less clear. The impact of both levels shows to be opposite in the long- and short-run. In low-middle-income countries, the results show no evidence that education levels matter for long and short-run economic growth.

Next, we will use a sub-panel of selected European countries in our sample and compare the results with the rest of the countries. Table 6 presents the short- and long-run effects of education levels on economic growth in selected European countries. Although the results consist of high-income group estimates since most are European countries, other countries' coefficients become more significant regarding primary and secondary education. Gemmel (Gemmell, 1996) finds that the influence of tertiary education on economic growth is more pronounced in OECD countries. In sum, education plays a pivotal role in economic growth, particularly countries with more higher levels of formal schooling exhibit higher economic growth.

Table 6.

PMG short- and long-run estimates (Europe Area)

Variables	Europe	Others
Estimates of long-run coefficients		
<i>Primary</i>	0.6552 (2.805)	3.8369 (.787)***
<i>Secondary</i>	3.7398 (1.338)**	-1.9278 (.571)***
<i>Tertiary</i>	-2.1560 (.428)***	-0.2461 (.270)
Estimates of short-run coefficients		
Error-correction term	-0.6951 (.033)***	0-.8138 (.047)***
<i>d(primary)</i>	16.1514 (7.831)**	12.2189 (8.111)*
<i>d(secondary)</i>	10.694 (8.977)	7.4964 (4.585)*
<i>d(tertiary)</i>	1.5677 (2.178)	1.8047 (1.609)
Constant	-7.6377 (.387)***	-6.8643 (.518)***
Number of Obs.	657	1494
Number of Groups	16	61

Note: Traditional Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

5.4. The Panel ECM Granger Causality Results

Should two variables be cointegrated, it follows that Granger causality must be present in at least one direction (Pfaff, 2008). Nonetheless, it remains to be verified if Granger causality exists in both directions; hence, testing for panel Granger causality is ideal. Dumirescu and Hurlin (Dumitrescu and Hurlin, 2012) propose a simple Granger (Granger, 1969) test adapted for large but heterogeneous panel data. Table 7 reports the test results of Dumirescu and Hurlin (Dumitrescu and Hurlin, 2012). The tests are conducted on the first differenced variables. The test rejects the null hypothesis that economic growth uniformly or homogeneously influences primary education or the other way around, thus indicating a two-way causal relationship between primary education and economic growth. However, the null hypothesis that economic growth does not homogeneously cause secondary education is not rejected, and vice versa. Hence, there is no causal relationship between secondary education and economic growth.

Further, the null hypothesis that economic growth does not homogeneously cause tertiary education is not rejected; however, the null hypothesis that tertiary education does not homogeneously cause economic growth is rejected. The results show that although causality runs from tertiary education to economic growth at the 1% confidence level, there is no causality from economic growth to tertiary education.

Table 7.

Dumirescu and Hurlin (2012) panel Granger causality test

Null Hypothesis	Zbar-stat.	Prob.	Result
$D(GGDP)$ Does Not Granger Cause $D(primary)$	2.4510	0.014 ***	reject
$D(primary)$ Does Not Granger Cause $D(GGDP)$	2.2119	0.027 **	reject
$D(GGDP)$ Does Not Granger Cause $D(secondary)$	-0.1083	0.914	don't reject
$D(secondary)$ Does Not Granger Cause $D(GGDP)$	1.1290	0.259	don't reject
$D(GGDP)$ Does Not Granger Cause $D(tertiary)$	-0.2635	0.792	don't reject
$D(tertiary)$ Does Not Granger Cause $D(GGDP)$	3.8689	0.000 ***	reject

H0: dx does not (homogeneously) Granger-cause dy.

H1: dx does (homogeneously) Granger-cause dy for at least one panel

*** 1%, ** 5%, * 10% significant level.

6. Conclusion

Understanding the role of education on the economy in general and economic growth in particular is crucial for policymakers to make policy decisions and finance education. In this study, we estimate the effects of education levels on economic growth for different groups of countries. The countries are grouped based on income levels defined by the World Bank. Employing the appropriate time-series method, we estimate both the short-run and long-run effects of education on economic growth. After finding cointegration, we proceed to calculate the short-run and long-run coefficients. Hausman test favors the pooled-mean group model, which allows heterogeneity in the short-run coefficients and a degree of homogeneity in the long-run.

A general result is that primary education is beneficial in both the short run and long run. Since the number of countries is not the same in all the income categories, the estimates are weighed towards categories with a larger percentage in the sample. Running the exact specification independently for each income category revealed interesting results. A higher percentage of the population with tertiary education had a negative impact on economic growth in all income categories except the low-income group.

It is surprising to note that the percentage of the tertiary educated population had a negative impact on economic growth. The role of primary education in low income is positive, indicating the occupation surrounding primary activities, such as agriculture and resource extraction (e.g., petroleum, minerals). However, primary education does not contribute to short-run economic growth. It is important to note that no specific education gradient is observed in any country group based on income category. The Granger causality test shows that education causes economic growth, not the other way around.

This study adds to the body of literature that education plays the role of a driver rather than a passive actor.

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Appendix

Table A1.

List of the 77 Countries in the Sample (1970-2020)

<u>Code</u>	<u>Country</u>	<u>Code</u>	<u>Country</u>	<u>Code</u>	<u>Country</u>
<u>High-income</u>		<u>High-middle-income</u>		HND	Honduras
AUS	Australia	ARG	Argentina	IND	India
AUT	Austria*	BLZ	Belize	IDN	Indonesia
BHS	Bahamas, The	BWA	Botswana	IRN	Iran, Islamic Rep.
BEL	Belgium*	BRA	Brazil	KEN	Kenya
CHL	Chile	CHN	China	LSO	Lesotho
DNK	Denmark*	COL	Colombia	MAR	Morocco
FIN	Finland*	CRI	Costa Rica	MMR	Myanmar
FRA	France*	ECU	Ecuador	NPL	Nepal
GRC	Greece*	FJI	Fiji	NIC	Nicaragua
HKG	Hong Kong SAR, China	GTM	Guatemala	NGA	Nigeria
ITA	Italy*	IRQ	Iraq	PAK	Pakistan
JPN	Japan	JAM	Jamaica	PHL	Philippines
KOR	Korea, Rep.	MYS	Malaysia	LKA	Sri Lanka
LUX	Luxembourg*	MEX	Mexico	TUN	Tunisia
MLT	Malta*	PRY	Paraguay	ZWE	Zimbabwe
NLD	Netherlands*	PER	Peru		
NZL	New Zealand	THA	Thailand	<u>Low-income</u>	
NOR	Norway*	TUR	Turkiye*	BFA	Burkina Faso
OMN	Oman			BDI	Burundi
PAN	Panama	<u>Low-middle-income</u>		CAF	Central African Republic
PRT	Portugal*	DZA	Algeria	MDG	Madagascar
ESP	Spain*	BGD	Bangladesh	MWI	Malawi
SWE	Sweden*	BEN	Benin	MLI	Mali
GBR	United Kingdom*	CMR	Cameroon	NER	Niger
USA	United States	EGY	Egypt, Arab Rep.	RWA	Rwanda
URY	Uruguay	SLV	El Salvador	SEN	Senegal
		GHA	Ghana	TGO	Togo

*Europe Area.

Table A2.

Test Diagnostics for heteroscedasticity

<u>Tests</u>	<u>Chi-sq</u>	<u>Chi-sq</u>	<u>Prob.</u>
Breusch–Pagan/Cook–Weisberg	(1)	2.15	0.143
White's test	(9)	39.07	0.000

Note: Breusch–Pagan/Cook–Weisberg test for heteroscedasticity; assumption: Normal error terms, variable: Fitted values of *GGDP*, and *H0*: Constant variance. White's test; *H0*: Homoskedasticity and *Ha*: Unrestricted heteroscedasticity.

Table A3.
Results Summary

Variables	High income	High-Middle income	Low-Middle income	Low income	All countries
Long-run coefficients					
<i>Primary</i>	No effect	(-ve)	No effect	(+ve)	(+ve)
<i>Secondary</i>	(+ve)	(+ve)	No effect	(-ve)	No effect
<i>Tertiary</i>	(-ve)	(-ve)	No effect	(+ve)	(-ve)
Short-run coefficients					
<i>d(primary)</i>	(+ve)	(+ve)	No effect	(-ve)	(+ve)
<i>d(secondary)</i>	No effect	No effect	No effect	(+ve)	(+ve)
<i>d(tertiary)</i>	No effect	No effect	No effect	No effect	No effect