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The Impact of Education Quality on Economic Growth: A Panel Cointegration and Causality Analysis

Mariem Gharsallah | Salwa Trabelsi

ESSEC Tunis, DEFI, University of Tunis, Tunis, Tunisia

Correspondence: Salwa Trabelsi (salwa.trabelsi@essect.rnu.tn)

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ABSTRACT

The study investigates the dynamic relationship between education quality and economic growth in developed and developing countries for the period 2000–2020. Considering the Group Mean Fully Modified OLS (GM-FMOLS) model, the results prove the existence of long-run equilibrium relationships among observed variables and that education quality has a strong and significant positive impact on economic growth. A Panel Vector Error Correction Model (PVECM) has been adopted to show the long-run and short-run causality among the variables across the countries. The PVECM result reveals the presence of long-run and short-run bidirectional causality between education quality and economic growth.

JEL Classification: I2, O4, J2, O470

1 | Introduction

Education is largely considered a determinant of sustainable economic growth (Goode 1959; Schultz 1961; Lucas 1988; Romer 1990). This relationship is acknowledged by the endogenous growth theory in the late 1980s and early 1990s. Several empirical studies are typically interested in this relationship (Hanushek 1995; Temple 2001; Krueger and Lindahl 2001; Gemmell 1996; Benhabib and Spiegel 1994). However, there is conflicting evidence in the literature regarding the relationship between education, in its quantitative aspect, and economic growth.

Many indicators are used to measure the education quantity such as schooling enrollment ratios (Mankiw et al. 1992; Barro 1991; Levine and Renelt 1992), the average years of schooling (Easterly and Levine 1997; Hanushek and Woessmann 2007; Krueger and Lindahl 2001; Sala-i-Martin et al. 2004; De la Fuente and Doménech 2006; Cohen and Soto 2007; Sunde and Vischer 2015; Bulut and Bulut 2015), adult literacy rate (Durlauf and Johnson 1995; Romer 1990), and education spending (Becker et al. 1990; Goodspeed 2000; Gregorious and Ghosh 2007; Baldacci et al. 2008). However, many studies present controversial results where some of them find a negative relationship between education and economic growth (Ndiyo 2007; Costantini and Monni 2008; Földvári and van Leeuwen 2009; Phillips and Chen 2011; Lawal and Iyiola 2011) while others confirm the absence of any relationship (Pritchett 2001).

Many authors explain these mixed results by the limitation in the use of quantitative education measures as a proxy for human capital and the failure to take into account his essential aspect, which is the educational quality. Pritchett (2001) argues that schooling quantity indicators are unable to capture a nation's skills and knowledge in the sense that a year of schooling cannot generate the same amount of human capital across all countries. Hanushek and Woessmann (2008) highlight that such measures remain imprecise and overly simplistic, often introducing significant biases in economic growth analyses. They suggest that the major problem with these models is that they assume a uniform educational impact across all countries, without considering the crucial differences between education systems in terms of

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teacher qualifications, school resources, and the socioeconomic background of families.

Therefore, prioritizing education quality[1] is essential for accurately assessing the true impact of education on economic growth. In response, many studies have adopted a new approach, using international cognitive test performance as a more reliable proxy for human capital, reflecting the actual skills and knowledge acquired rather than just quantitative measures such as years of schooling or enrollment rate, etc. (D. W. Lee and Lee 1995; Hanushek and Kim 1995; Hanushek and Kimko 2000; Hanushek and Woessmann 2007).

These studies have also used several techniques to examine the link between education quality and growth, based on cross-sectional data method (Hanushek and Kimko 2000; Kaarsen 2014; Castelló-Climent and Hidalgo-Cabrillana 2012; Cooray 2009; Balart et al. 2015; Bobetko et al. 2017; Hanushek and Woessmann 2008; Glewwe et al. 2014; Hanushek and Woessmann 2015; Hanushek·and Woessmann 2012), or panel data (D. W. Lee and Lee 1995; Barro 2001; Eckstein et al. 2017; Appleton et al. 2008; Goczek et al. 2021). However, using the Ordinary Least Squares (OLS) method may result in bias estimation arising from the endogeneity problem. To take into consideration this issue, empirical analysis has adopted the Generalized Method of Moments (GMM) (Cooray 2009; Altinok and Aydemir 2017) but it presents also certain drawbacks such as the homogeneity of the coefficients for which the effect of a variable cannot differ from one country to another. At the same time, this approach ignores the properties of unit root cross-section dependency and cointegration in the long run[2].

To overcome all these weaknesses, certain authors have used a Fully Modified OLS (FMOLS) approach (Idrees and Siddiqi 2013; Akpolat 2014; Yardimcioğlu et al. 2014; Mallick et al. 2016; Omitogun et al. 2016; Chani et al. 2021). However, all these studies have considered the quantitative aspect of education[3] and have ignored the qualitative aspect, which is the main objective of this paper.

This paper aims to examine the long-run relationship between education quality and economic growth using the Group Mean Fully Modified OLS (GM-FMOLS) approach and the panel Granger causality test based on the Vector Error Correction Model (VECM) to investigate the dynamic causality between education quality, education quantity, and economic growth and to examine the direction of long-run and short-run causality. So, this paper contributes to the existing literature in several ways: First, and to the best of our knowledge, it is the first empirical application of panel cointegration techniques that explores the long-run relationship between education quality and economic growth. Most macroeconomic time series are nonstationary in levels and conventional panel regressions implying nonstationary variables are spurious in the absence of panel cointegration. To correct this problem, this study uses the GM-FMOLS estimation, where the estimator considers the nuisance parameters, the possible autocorrelation, and the heteroscedasticity phenomena of the residues and corrects the endogeneity of the explanatory variables.

Second, this study is also the first that investigates the direction of causality between education quality, education quantity, and economic growth in developed and developing countries where the previous studies have neglected short-term and long-term causality. Specifically, the paper aims to fill the gap and explore a new debate by examining the dynamic causal relationships in a panel trivariate setting, using the panel VECM estimation which captures both short- and long-term causality, an area that has been largely neglected in previous studies.

The remaining part of this study is organized as follows. Section 2 consists of a literature review. Section 3 defines the data and introduces the main research methods, including the panel unit root test, panel Kao cointegration test, and the FMOLS and VECM approaches. Section 4 presents the discussions of empirical findings. The last section concludes this study and concisely illuminates the main policy implication.

2 | Literature Review

The relationship between education and economic growth has been the subject of extensive research over the past several decades. The quantity of education, often measured by years of schooling or enrollment rates, was traditionally considered a key determinant of economic growth. Pritchett (2001) suggests that the average years of schooling or enrollment rates are not a good proxy of human capital where the major challenge is to find a good one. Barro (1991) was the first study highlighting the role of school quality alongside quantity in promoting economic growth. In fact, while education quantity is important, education quality has a more significant impact on economic growth which has contested the conventional idea that increasing the number of years of education can stimulate economic growth. Hanushek and Kimko (2000) have used the results of different international student achievement tests as a measure of the labor force's cognitive skills and found that its effect surpasses the educational attainment effect. D. W. Lee and Lee (1995) have also used science scores from international tests which have a positive and significant link with growth. Where Woessmann (2002, 2003) has extended this research to show that international differences in human capital significantly contribute to variations in economic growth when considering education quality.

Since then, subsequent studies have refined the methods for assessing the impact of educational quality on economic growth. Altinok (2007) has developed a new methodology that considers the educational endogeneity resulting in the qualitative indicators of the human capital for a larger sample of countries. The result indicates that the effect of education on growth is significant if its qualitative dimension is envisaged. Several studies present similar findings and highlight the importance of both educational quantity and quality in driving economic growth, depending on various factors such as country, time, and level of development (Appleton et al. 2008; Cooray 2009; Hanushek and Woessmann 2012; Castelló-Climent and Hidalgo-Cabrillana 2012; Eckstein et al. 2017; Hanushek and Woessmann 2016; Bobetko et al. 2017; Altinok and Aydemir 2017; Goczek et al. 2021).

However, most of these studies adopt cross-sectional estimation techniques, while only a certain number employ the panel or GMM data methods. Using the OLS method to estimate the long-term relationship can provide a biased estimate due to the endogeneity problem inherent in the relationship between education and economic growth which is not considered by previous analyses. To overcome this problem, a few studies have applied the GMM technique, although it presents certain drawbacks in the sense that the number and the quality of instruments in both difference and system GMM methods can affect the results (Keho 2012). In addition, this approach ignores the unit root and the cointegration properties of the series, which makes it difficult to conclude if the results provide long-run effects while economic growth is a long-run phenomenon, and it is so important to determine the long-run effects of the educational quality.

As a solution to these problems, certain studies have examined the education and growth nexus using FMOLS model where certain of them found a positive relationship (Idrees and Siddiqi 2013; Akpolat 2014; Yardimcioğlu et al. 2014; Mallick et al. 2016; Omitogun et al. 2016; Chani et al. 2021) while other studies present a negative or nonsignificant relationship (Mammadov and Gumus 2020). The empirical results on causality are also mixed. Many studies showed a unidirectional causality between education and economic growth (Al-Yousif 2008; Kreishan and Al Hawarin 2011; Mehrara and Musai 2013; Pegkas and Tsamadias 2014) where for others the causality is bidirectional (Podrecca and Carmeci 2002; Sari and Soytas 2006; Osiobe 2020; Haryanto et al. 2021) or absent (Bosupeng 2015).

In general, numerous cross-country studies have extensively explored whether education can contribute significantly to economic growth. However, they continue to produce inconsistent and controversial results across both countries and measures of education. These studies present a lack of consensus among researchers where certain authors confirm a positive impact of education on economic growth while others reported a negative or nonsignificant relationship.

Many explanations have been advanced to clarify this mixed result. Ayara (2002) has proposed three factors that can explain these findings: the educational capital has gone into privately remunerative but socially unproductive activities; the slow growth in the educated labor demand; and the failure of the education system. Jajri and Ismail (2012) suggest that a large budget allocated to education does not translate into an improvement in the workforce's quality and production process, innovation, and technological advancement. They argue that the education system must produce a more efficient workforce to increase the contribution of human capital to economic growth. In addition, Sankay et al. (2010) indicate that to contribute significantly to economic growth and development, education must be of high quality and meet the economy's skill demand, which constitutes this paper's main objective.

More precisely, this paper tries to prove that education associated with weak quality cannot enhance economic growth. The quality of education itself should not be sidelined, if it is very low, it is reasonable to expect low returns to national output consequently. This will invalidate the anticipated positive relationship between education and economic growth. To fill this gap, we have considered all the aspects above mentioned to specify a growth regression in which human capital is measured not only by education quantity but also by education quality.

3 | Methodology and Data

The objective of this paper is to analyze the effect of educational quality on economic growth by considering a model such as proposed by Hanushek and Woessmann (2012).

Based on the conventional growth literature, the model is represented by the following dynamic growth equation:

$$\mathrm{GY}_{it} = \alpha_i + \beta_1 \mathrm{QUALITY}_{it} + \beta_2 \mathrm{HC}_{it} + \beta_3 X_{it} + \varepsilon_{it} \qquad (1)$$

where GY_{it} is the average growth rate in country i at period t which is the dependent variable of the model, α_i is the unobserved heterogeneity of each country. The main independent variables of the model are the QUALITY, which represents the educational quality measured by the scores of the international student achievement tests PISA on mathematics and science (MATH and SCIENCE), and HC as a measure of the educational quantity, which is the secondary school enrollment. β is a vector of parameters and X_{it} is a vector of control variables such as the initial income per capita (GDPi), the investment rate (IY) is the gross capital formation as a percent of GDP, the trade openness (TRADE) is the sum of export and import as a ratio of GDP and ε_{it} is a noise term. In this study, a panel of 25 countries[4,5] covering the period from 2000 to 2020[6] is considered. All these data are taken from the World Bank Database (WDI).

Tables 1 and 2 report the descriptive statistics and the correlation matrix of all the variables. The bivariate relations among the dependent variable (GY) and the explanatory variables are consistent with the previous literature. However, the correlation matrix does not confirm the positive relationship between education quality and economic growth which contradicts the results of previous studies (Hanushek and Kimko 2000; Barro 2001; Altinok and Aydemir 2017; Goczek et al. 2021). The initial GDP supports Solow's convergence hypothesis with a negative correlation with economic growth. The other factors driving economic growth (investment, trade) present positive correlations with economic growth which have been widely argued in the theoretical literature.

The empirical analysis in this paper consists of testing the long-run relationship and the dynamic causal between education quality and growth following three steps: the first stage checks the order of integration of each variable by applying unit root tests. Once all variables are integrated at the first level, the cointegration test is employed to predict the presence of long-term associations between the variables. The second stage consists of estimating the cointegration relationship between education quality and growth, using the panel FMOLS (GM-FMOLS) developed by Pedroni (2001a, 2001b, 2004). Given the long-run relationship, a panel-based VECM (Pesaran et al. 1999) is estimated to perform Granger causality tests at the final stage.

The main objective of this study is to test the long-run effect of education quality on economic growth. The economic growth is a long-term phenomenon, for this reason, it is important to determine the long-run effect of educational quality by referring to the cointegration relationship.

TABLE 1 | Descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Min	Max
GY	175	0.016	0.0159	−0.060	0.063
GDPi	175	9.693	1.017	7.670	11.430
IY	175	3.106	0.179	2.645	3.616
TRADE	175	4.347	0.524	3.150	6.070
HC	175	4.584	0.153	4.024	5.021
QUALITY	175	6.130	0.120	5.745	6.324

TABLE 2 | Correlations.

	GY	GDPi	IY	TRADE	HC	QUALITY
GY	1.0000					
GDPi	−0.4204	1.0000				
IY	0.2960	−0.1666	1.0000			
TRADE	0.1140	0.0957	0.2299	1.0000		
HC	−0.3997	0.7088	−0.2144	0.0173	1.0000	
QUALITY	−0.1804	0.7851	0.0150	0.3604	0.5310	1.0000

Abbreviations: GDPi, initial GDP; GY, economic growth; HC, human capital; IY, investment (a percentage of GDP); QUALITY, education quality; TRADE, economic openness (a percentage of GDP).

Nevertheless, the panel cointegration test only provides information on the presence of the long-run equilibrium relationship between the variables, but it does not allow us to estimate the cointegration vectors. At the same time, given the existence of a cointegrating relationship, applying the standard pooled least squares method can lead to biased estimates because of serial correlation and endogeneity problems.

To correct these weaknesses, this study uses the panel GM-FMOLS developed by Pedroni (2001a, 2001b, 2004) which is an extension of time-series FMOLS advanced by Phillips and Hansen (1990). This method incorporates a semi-parametric correction to the OLS estimator which can be interpreted as long-run elasticities and eliminates the second-order bias caused by the endogeneity of the regressors. In general, the GM-FMOLS approach can be used to draw an inference about cointegration with heterogeneous dynamics (Pedroni 2000). Also, it controls for endogeneity and serial correlation by estimating the long-run covariance directly, and for the likely cross-sectional dependence via the inclusion of common time dummies in the model (Pedroni 2001a; Lee 2007). It provides consistent and efficient estimators even for small data sizes.

The third step of this study consists of estimating the Granger causality, given the assumption of a long-run relationship between education quality, education quantity, and economic growth. In fact, the cointegration involves the existence of causality between the variables[7] but does not specify the direction of the causal relationship.

At this level, the panel-based VECM of Engle and Granger (1987) is used to identify the presence and the direction of short-run and long-run dynamic relationships between the variables[8].

Given that the set of variables for the estimation is all integrated at the first level I(1) and cointegration exists, a panel-based VECM can be estimated to perform Granger causality tests.

The empirical model is represented by the following three equations:

$$\Delta \mathrm{GY}_{it} = \alpha_1 + \sum_{i=1}^{p} \beta_{11} \Delta \mathrm{GY}_{it-1} + \sum_{i=1}^{q} \beta_{12} \Delta \mathrm{HC}_{it-1} + \sum_{i=1}^{r} \beta_{13} \Delta \mathrm{QUALITY}_{it-1} + \lambda_1 \mathrm{ECT}_{it-1} + \mu_{1it} \quad (2)$$

$$\Delta \mathrm{HC}_{it} = \alpha_2 + \sum_{i=1}^{p} \beta_{21} \Delta \mathrm{HC}_{it-1} + \sum_{i=1}^{q} \beta_{22} \Delta \mathrm{GY}_{it-1} + \sum_{i=1}^{r} \beta_{23} \Delta \mathrm{QUALITY}_{it-1} + \lambda_2 \mathrm{ECT}_{it-1} + \mu_{2it} \quad (3)$$

$$\Delta \mathrm{QUALITY}_{it} = \alpha_2 + \sum_{i=1}^{p} \beta_{31} \Delta \mathrm{QUALITY}_{it-1} + \sum_{i=1}^{q} \beta_{32} \Delta \mathrm{GY}_{it-1} + \sum_{i=1}^{r} \beta_{33} \Delta \mathrm{HC}_{it-1} + \lambda_3 \mathrm{ECT}_{it-1} + \mu_{3it} \quad (4)$$

where ECT is an error correction term, with *t* is time and *i* is cross-section data, and which is expressed as follows: $\mathrm{ECT}_{it} = \mathrm{GY}_{it} - \beta_0 - \beta_{12}\mathrm{HC}_{it} - \beta_{13}\mathrm{QUALITY}_{it}$.

The causality in the VECM model above is examined in two folds: through the short-term difference lagged variables (ΔGY_{it-1}, HC_{it-1}, $\Delta QUALITYi_{t-1}$) and the long-term error correction terms (ECT_{t-1}). β_{ij} are the short-term modification of coefficients.

In the long-run equilibrium, the error correction term is equal to zero. However, if GY, HC, and QUALITY deviate from the long-run equilibrium, this error correction term will not be equal to zero and each variable adjusts to partially restore the equilibrium relation. The coefficient of ECT (λ) measures the speed of adjustment of the endogenous variable toward the equilibrium. Precisely, it represents how fast deviations from the long-run equilibrium are eliminated following changes in each variable (Mehrara 2007).

The short-run causality is also tested using the Wald test which is based on unrestricted regression. The Wald statistic measures how close the unrestricted estimates come to satisfy the restrictions under the null hypothesis. If the restrictions are true, then the unrestricted estimates should come close to assure the restrictions.

4 | Empirical Results

The objective of this paper is to analyze the relationship between educational quality and growth. To examine the cointegration relationship, it is necessary to test the stationarity of each variable at the first difference. The results of the LLC, ADF–Fisher, and PP–Fisher panel unit root tests reject the null hypothesis which means that all variables are nonstationary in levels but they become stationary in first differences I(1) (Tables 3–5).

The Kao panel cointegration test is used to check whether there is a cointegration equation among the variables (Table 6). The result rejects the null hypothesis of no cointegration between the variables which can indicate the presence of a significant relationship between all the variables in the long term.

Table 7 presents the estimation results of the two-step GMM model and GM-FMOLS method, developed by Pedroni (2000, 2001a and 2001b), to estimate the long-run relationship respectively.

The GMM regression implies that the lag of the dependent variable and the coefficient of the educational quality and quantity are negative and insignificant. The Sargan test indicates that the additional instruments associated with the two-step GMM estimator are nonvalid and reject the specification of the null hypothesis. Furthermore, although the AR(1) test is rejected, the corresponding AR(2) test is not rejected, which confirms the hypothesis that the residuals are not serially correlated in the second order.

In general, the GMM is used as an efficient method for mitigating endogeneity and measurement error. However, it fails to fully elucidate the multifaceted dynamics of the variables, which can explain the use of the GM-FMOLS method.

With the GM-FMOLS, the estimated coefficient of education quality (QUALITY) becomes positive and statistically significant

TABLE 3 | Results of panel unit root test without intercept and trend.

	Level			First difference		
Variables	**Levin, Lin, and Chu *t***	**ADF–Fisher**	**PP–Fisher**	**Levin, Lin, and Chu *t***	**ADF–Fisher**	**PP–Fisher**
GY	−8.461***	103.571***	100.059***	−18.871***	254.815***	258.105***
GDPi	17.331	1.355	0.567	−3.779***	94.872***	97.0816***
IY	0.995	28.823	41.715	−9.749***	119.217****	178.429***
TRADE	0.077	39.067	29.170	−11.278***	125.425***	156.370***
HC	4.778	8.319	7.473	−6.588***	114.975***	114.810***
QUALITY	0.213	38.725	53.555	−10.419***	169.277***	192.005***

***, ** and * = significant at alpha 1%, 5% and 10%.

TABLE 4 | Results of panel unit root test with intercept.

Variables	Level			First difference		
	Levin, Lin, and Chu *t*	ADF–Fisher	PP–Fisher	Levin, Lin, and Chu *t*	ADF–Fisher	PP–Fisher
GY	−8.310***	80.210***	92.279***	−20.518***	154.471***	204.761***
GDPi	−4.661***	33.612	57.301	−22.073***	110.623***	129.019***
IY	−4.776***	50.943	63.179*	−11.628***	80.616***	93.795***
TRADE	−5.634***	54.185	83.618***	−13.568***	98.937***	117.103***
HC	−1.899**	24.922	29.138	−11.483***	66.210*	84.463***
QUALITY	−10.103***	69.270**	92.040***	−8.437***	81.249***	101.665***

***, ** and * = significant at alpha 1%, 5% and 10 %.

TABLE 5 | Results of panel unit root test with trend and intercept.

Variables	Level			First difference		
	Levin, Lin, and Chu *t*	ADF–Fisher	PP–Fisher	Levin, Lin, and Chu *t*	ADF–Fisher	PP–Fisher
GY	−18.600***	96.742***	165.618***	−34.785***	103.630***	169.472***
GDPi	−19.484***	57.761	87.895***	−25.566***	86.234***	151.277***
IY	−7.872***	32.186	50.826	−20.230***	67.432**	127.616***
TRADE	−8.890***	50.244	82.666***	−41.432***	104.766***	163.294***
HC	−11.929***	38.522	63.671*	−10.444***	39.625	63.187*
QUALITY	−7.853***	46.537	84.214***	−9.959***	47.020	80.845***

Note: The optimal lag lengths were chosen automatically based on Akaike information criterion (AIC).
Abbreviations: ADF–Fisher, Augmented Dickey–Fuller–Fisher; PP–Fisher, Philips–Perron–Fisher.
***, **, and * = significant at alpha 1%, 5%, and 10%.

TABLE 6 | Kao cointegration result.

Method	*t*-statistic	Prob.
ADF	−11.9215	0.0000
Residual variance	0.000237	
HAC variance	0.000172	

TABLE 7 | Two-step GMM and long-run elasticity coefficient of GM-FMOLS results.

	Two-step GMM	GM-FMOLS
L.GY	0.1467 (0.1023)	—
GDPi	−0.0705*** (−0.0705)	−0.0737*** (0.0191)
IY	0.0526*** (0.0167)	0.0192 (0.0263)
TRADE	0.0341* (0.0182)	0.0411* (0.0411)
HC	0.0025 (0.0261)	0.1706** (0.0656)
QUALITY	−0.0502 (0.0840)	0.2030*** (0.0678)
Observation	**125**	**175**
AR(1) (*p* value)	0.021	
AR(2) (*p* value)	0.662	
Sargan test (*p* value)	0.001	

***, **, and * indicate the level of significance at the 1%, 5%, and 10%, respectively.

at a 1% level. This result is consistent with the findings of many authors for which economies with better education quality grow faster (Hanushek and Kimko 2000; Barro 2001; Woessmann 2003 Hanushek and Woessmann 2008, 2015a, 2016, 2020; Altinok and Aydemir 2017; Goczek et al. 2021). In fact, high-quality education systems develop critical thinking and pertinent skills, help problem-solving which can improve the productivity and the innovative potential of the workforce, and in turn, contribute to economic growth by fostering technological progress, improving efficiency, and driving productivity gains. So, the country's economic performance differs depending on the evolution of its educational quantity and hence, on its educational quality. To maximize economic benefits, it is essential that each economy gives priority to its educational quality.

In the long run, the coefficient of the initial GDP per capita (GDPi) presents a negative sign and is statistically significant at a 1% level which confirms the convergence hypothesis of Solow, where low-income countries tend to grow faster than high-income ones (Mankiw et al. 1992). The educational quantity measured by secondary school enrollment (HC) exerts a positive and significant effect at the 1% level on economic growth in the long run. The positive relationship is explained by the improvement of the individual's productivity, the externalities generated, and the transfer of knowledge between generations (Mankiw et al. 1992; Barro 1991; Psacharopoulos and Patrinos 2004; Barro and Lee 2010). More precisely, it improves the country's capacity to create new knowledge, products, and technologies (Grant 2017).

The investment as a percentage of GDP (IY) is statistically insignificant. The literature proves that the relationship between investment and economic growth can vary across countries and regions due to the differences in economic, institutional, and policy contexts (Warner 2014). The estimated coefficient of trade openness (TRADE) is positive and statistically significant at a 10% level. This result confirms the crucial role of trade openness in boosting economic growth (Dollar 1992; Sachs et al. 1995; Chang et al. 2009; Kim 2011; Jouini 2015). In general, open economies, which are more involved in international trade, grow faster than closed ones (Grossman and Helpman 1991; Edwards 1993).

The results of the panel VECM model concern the long-term and the short-term causality between education quantity (HC), education quality (QUALITY), and economic growth (GY) (Table 8). The ECT coefficient is negative and statistically significant at the 1% level (Equations 2 and 4). It shows the speed of adjustment or the process of correction from the short-run to the long-run equilibrium of the quality and the quantity of education to the economic growth (Equation 2) and the economic growth and the education quantity to the education quality (Equation 4). This means that in the long run, the results imply a bidirectional causality between educational quality and economic growth (Equations 2 and 4) and a causality in one direction from educational quantity to economic growth (Equation 2).

The Wald test used to check for a short-run causality fails to reject the null hypothesis and does not support the short-run causality running from education quantity to economic growth, but it shows a significant short-run bidirectional linkage between education quality and economic growth.

The long-run causality between education quality, education quantity, and economic growth suggests that education quality is as important as the quantitative aspect of education for the economic growth. In fact, countries with good economies present good school systems which let them grow faster. The result is supported by Hanushek and Kimko (2000), Barro and Lee (2000), and Hanushek and Woessmann (2020) who confirm that it is not only the quantity of education measured by financial loadings or average years of schooling that matters for the economic growth but also—or even mostly—is the education quality. The reverse causality implies that higher economic growth enables countries to develop better education systems which can yield higher test performance and a higher education quality (Barro and Lee 2000; Hanushek and Kimko 2000).

More precisely, economic growth leads to increase public revenues that can be allocated to education specifically to improve the educational quality including teacher training programs, curriculum development, educational technologies, and learning resources. Adequate financial resources can help to

TABLE 8 | Panel VECM results.

Dependent variable	Panel VECM			
	Short run			Long run
	ΔGY	ΔHC	ΔQUALITY	ECT
ΔGY		2.0566 (0.3576)	10.2984*** (0.0058)	−0.8591*** (0.0000)
ΔHC	0.1658 (0.9204)		2.5931 (0.2735)	0.0202 (0.3936)
ΔQUALITY	18.0087*** (0.0001)	1.5893 (0.4517)		−0.0312*** (0.00001)

***, **, and * indicate the level of significance at the 1%, 5%, and 10%, respectively.

fill infrastructure gaps, reduce class sizes, and increase teaching and learning materials, which can help to ameliorate the quality of education (Hanushek and Woessmann 2007, 2012). At the same time, a high-quality education contributes to economic growth by promoting technological progress, improving efficiency, and driving productivity gains.

5 | Conclusion

This paper studies the long-run and the causal relationships between education quality and economic growth using the GM-FMOLS method and the panel VECM techniques, during the period 2000–2020.

The empirical results indicate that education quality has a positive and significant effect on economic growth. In this case, the panel cointegration test confirms the long-run cointegration relationship between education quality and economic growth. So, countries with the highest quality education systems can improve their economic growth rates than others. The causality analysis indicates the existence of a bidirectional causality between education quality and economic growth where the variables are related and mutually strengthened in the long term and short term. This finding implies that education quality is essential to increase the country's economic growth, but also an increase in the level of economic growth in the short term contributes to enhance the quality of education. In fact, economic growth can lead to better quality education, through the provision of resources to install the infrastructure for education, but also to finance teacher training programs, curriculum development, educational technologies, and learning resources which can reduce absenteeism, and dropping out of school, raise standards for teachers, and attenuate crowded classrooms. This improvement can help students and teachers feel decreased stress, and gain interest which can improve the performance of the education system and its quality.

The results of this paper suggest that the quality of education is also as important as its quantity, and it matters for economic growth. So, researchers and policymakers have to focus on the qualitative aspects of education, specifically in countries where it is relatively low, to improve their economic growth. The debate has to be around how to improve the education system, its quality, and precisely how to improve outcomes for students and to equip them with knowledge and skills.

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Endnotes

[1] Educational quality is a multidimensional concept that cannot be reduced to a single definition or measure. It reflects the complex interaction of various factors within education systems and involves not only academic achievement, but also factors such as equity, student well-being, holistic development, and the social and cultural context of education (Skedsmo and Huber 2021).

[2] In the long term, the presence of a unit root in a time series indicates a stochastic or unpredictable component dominating the variable, preventing it from converging to a stable mean and posing modeling and forecasting problems. Cross-sectional dependence refers to the correlation of errors between entities in a panel data set, and is crucial in long-term analyses, where ignoring it leads to biased estimates. Cointegration, which indicates a long-term relationship between nonstationary variables, becomes significant in the long term, revealing that the variables evolve together, with a common trend, and correcting short-term deviations, contributing to a more accurate understanding of equilibrium relationships in the economy. Various tests are used to address these concepts, ensuring robust analyses and reliable information on economic behavior over long periods.

[3] School enrollment and education expenditure.

[4] Albania, Argentina, Bulgaria, Chile, Czech Republic, Denmark, Hong Kong, Hungary, Iceland, Indonesia, Israel, Korea, Mexico, New Zealand, North Macedonia, Norway, Peru, Poland, Romania, Russia, Sweden, Switzerland, Thailand, United Kingdom, United States.

[5] The number of observations is limited by the availability of data. The method of estimation requires balanced data.

[6] The analysis period is limited to 2000–2020 since the first PISA cycle occurred in 2000 for 41 countries and the last test was in 2018 for 82 countries. This test is realized every 3 years. So, to mitigate the impact of potential measurement errors and address issues with missing data in individual years, this analysis considers 8 subperiods of 3-year averages.

[7] Evidence of cointegration between variables implies that there exists causality in at least one direction (Granger 1969).

[8] Engle and Granger (1987) demonstrated that if nonstationary variables are cointegrated, a vector autoregression (VAR) in the first differences will be mis-specified, because of the removed long-run information in the first differencing, but a VECM can avoid this shortcoming.

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