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Education Spending and Economic Growth: Short and Long-Term Effects*

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Abstract

This paper examines the short- and long-term effects of education expenditure on economic growth using a global panel of 107 countries from 1970 to 2019. Employing a CS-ARDL model with an error correction framework, we estimate dynamic responses to both aggregate and disaggregated real education spending across primary, secondary, and tertiary levels. The results show that public investment in education has a statistically significant and positive impact on real GDP per capita, both in the short and long run. The long-run elasticity is highest for aggregate expenditure and comparable across primary and secondary education, while it is lower for tertiary education. We further explore heterogeneity in long-run effects and find that higher educational achievement, proxied by PISA scores, amplifies the growth impact of education spending. Simulations confirm that countries with higher PISA scores experience faster and stronger returns on investment. These findings underscore the role of education quality in enhancing the productivity of public education spending and support targeted policy efforts to improve both the quantity and quality of educational investment.

Keywords: educational expenditure, economic growth, error correction model

JEL Classification: H52 , I25 , O10

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1 Introduction

Investment in education is widely recognized for its long-term direct effects on economic growth and productivity. The primary mechanism is through enhancing the quality of the labor force. Through the development of human capital, education provides individuals with the skills and knowledge needed to become more productive and innovative. This, in turn, fosters an environment conducive to entrepreneurship and the adoption of new technologies, both of which are key drivers of economic development.[1]

Beyond its direct impact on productivity, education generates several indirect benefits contributing to economic stability and growth. Educated individuals are more likely to participate in the labor force and secure higher-paying jobs, which leads to increased income and reduced poverty levels. Additionally, a more educated workforce tends to experience lower job turnover and unemployment rates, as individuals possess the skills needed to adapt to changing job market demands. This eases the strain on state welfare programs and social safety nets.[2]

Recent research has further expanded the scope of benefits associated with increased investment in education. Beyond economic indicators, education contributes to social well-being by reducing crime rates and providing greater opportunities for women to participate in the workforce. Educated women are more likely to delay childbirth and pursue careers, leading to lower rates of teenage pregnancies and improved outcomes for children. Lochner and Moretti (2004) found that higher levels of education are associated with significant reductions in crime rates, suggesting that education plays a crucial role in promoting social stability. Moreover, Psacharopoulos and Patrinos (2018) provide evidence that education leads to better health outcomes, including lower fertility rates and a reduced incidence of teenage pregnancies.

Although the benefits of education investment are well-documented, they often take time to fully materialize. Human capital development and its subsequent economic impact is a gradual process. However, the scale of education investment also implies that certain short-term economic effects can be observed. Increased educational spending can stimulate economic activity by creating jobs, boosting demand for educational materials and services, and enhancing infrastructure. The multiplier effect of such spending can lead to immediate boosts in economic activity, even as the long-term benefits continue to unfold.[3]

This paper examines whether increases in education expenditure generate measurable effects on the economic growth of countries, both in the short and long run. Using a dynamic panel approach that distinguishes between immediate and long-term responses, we estimate the average returns on education investment globally and across

[1] For instance, Hanushek and Woessmann (2010) show a strong link between educational attainment and economic growth, indicating that countries with higher levels of education tend to experience faster economic growth.

[2] See, for example, Oreopoulos and Salvanes (2011), who highlight that education significantly improves labor market outcomes, including employment prospects and earnings.

[3] Using data for the United States De Ridder et al (2020) and Angelopoulos et al (2008), show that local governments prioritizing education spending often see immediate and sustained economic benefits.

disaggregated educational levels—primary, secondary, and tertiary. Rather than comparing regional aggregates, we focus on identifying sources of heterogeneity in the growth impact of education spending. In particular, we emphasize how country-specific characteristics, possibly linked to the quality of expenditure, especially education results as proxied by standardized learning outcomes (e.g., PISA scores), can amplify these effects.

To conduct this analysis, we use the flexibility of ARDL/ECM models. An Autoregressive Distributed Lag model (ARDL) is an econometric model that allows for the analysis of a potential long-term relationship between sets of variables, not necessarily all integrated of order 1. This was initially developed in Pesaran et al (1995, 2001). One of the main features of the ARDL model is that it combines both autoregressive terms and distributed lags. In this paper, we exploit its error correction (ECM) representation, which captures both short-term and long-term dynamics in a single model specification.

This methodology has been extensively used in growth-related literature to understand the relationship with variables that are closely closely aligned with with GDP over time. Broadly, several papers have studied the relationship between various measures of human capital and economic growth (e.g., Afzal et al (2010); Adeyemi and Ogunsola (2016); Mabrouki (2023); Gebrehiwo (2016)).

Other research more closely aligned with our paper specifically examines the role of public spending on education and its relationship with GDP in various regions of the world (e.g., Coman et al (2023); Ramli et al (2022); Mohamed et al (2021); Ifa and Guetat (2018); Kiran (2014); Mallick et al (2016)). Regarding the relationship between education spending and growth in Latin America and the Caribbean, Kiran (2014) studied the effect of education expenditure on economic growth for 18 countries in the region from 1970 to 2009. This study uses a VECM methodology that identifies structural breaks to capture the potential impact of educational policies that modify the co-integration relationship for each country. The findings reveal co-integration between education spending and economic growth for the countries in Latin America and the Caribbean, with the exception of Chile, Guyana, Jamaica, Nicaragua, Paraguay, Peru, and Uruguay. Another study closely related to our research question was conducted by Mallick et al (2016). It examines the relationship between GDP and education spending across 14 Asian countries over the period of 1973-2012. Using a panel VECM methodology, the authors find positive and significant effects of education spending on growth. They also apply Granger causality tests to formalize the unidirectional effect of this relationship (i.e., to test whether education spending drives economic growth rather than the opposite).

We find that overall education expenditure has an average long-run elasticity of 3.1 percent. In contrast, elasticity estimates by level of education are lower, ranging between 1.3 percent and 1.9 percent. Importantly, we also observe that these elasticities vary considerably and are strongly associated with student achievement, as measured by PISA scores. Specifically, countries with higher average PISA scores tend to exhibit a greater elasticity of education expenditure with respect to output. In particular, countries with PISA scores near the average for advanced economies—approximately

30 percent higher than those of an average emerging or developing country, show long-run elasticities that are four times higher than those of countries with lower PISA scores. This suggests the presence of nonlinearities in the distribution of elasticities. While it is true that countries with higher education spending tend to exhibit higher average PISA scores, this may also reflect differences in the quality of spending. In this regard, higher PISA performance may be indicative of more effective, higher-quality expenditure, which in turn is associated with higher long-run elasticities of output with respect to per capita education spending. Finally, our results suggest that increasing education expenditure also yields short-run impacts, possibly through demand-side channels. These short-term effects appear relatively consistent across different levels of education quality. However, long-term impacts vary significantly depending on the quality of education spending.

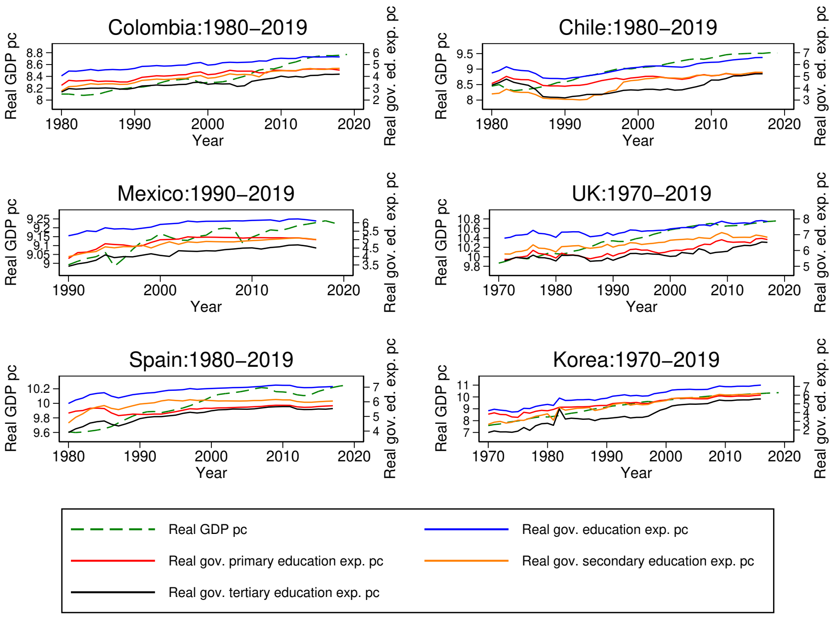
The rest of the paper is organized as follows. Section 2 describes the data and the main methodological aspects of the paper. Section 3 reports the results of estimating the CS-ARDL models using measures of expenditure disaggregated by level of education. Section 4 reports an exercise considering the impacts of different quality of education expenditure as proxied by the PISA scores of each country. Section 5 uses the estimation of the previous sections to illustrate the short and long-run adjustment dynamics of GDP per capita in response to an increase in education expenditure. Section 6 concludes.

2 Data and Methodology

To contribute to the literature on the relationship between educational expenditure and economic outputs, we analyze the short and long-term co-movements between real GDP per capita and different measures of expenditure in education. To illustrate this relationship, we first plot these data for a series of selected countries in Figure 1. This pattern, repeated across many countries, shows a potentially close relationship between the educational expenditure in real per capita terms for different educational levels and real GDP per capita.[4]

[4] See Appendix Table A1 for a description of the data and their sources.

Fig. 1: Logarithmic series of GDP, educational expenditure, primary education expenditure, secondary education expenditure, and tertiary education expenditure by country



Note: This figure plots real GDP per capita and real per capita government education expenditures by education level for a selected set of countries from 1970 to 2019. All series are shown in natural logarithms. Data are sourced from the World Bank's World Development Indicators (WDI) and UNESCO's UIS database.

An analysis of Figure 1, reveals a potentially parallel trend between aggregate output and aggregate educational expenditure. A similar pattern emerges when disaggregating expenditure by education level. Moreover, this relationship does not seem to differ when comparing developed and developing countries over a similar period.[5] Appendix Table D4 shows the pairwise correlation of the critical variables in this study. In line with the patterns observed in Figure 1 the results show a strong correlation across time and minimal differences between advanced and emerging economies.

The key question in this study is to explore the magnitude of these correlations and analyze the differences between long- and short-term co-movements. To do this, we employ a CS-ARDL(p,q) specification (cross-section ARDL generalized for panel study). The CS-ARDL(p,q) model can be summarized in the following specification

$$Y_{it} = c_i + \sum_{j=1}^{p_i} \phi Y_{i,t-j} + \sum_{j=0}^{q_i} \beta' \mathbf{x}_{i,t-j} + u_{i,t} \tag{1}$$

In this specification, for each cross-sectional unit i, $Y_{i,t}$ denotes the real GDP per capita. The term $Y_{i,t-1}$ represents the lagged level of real GDP per capita, and $\mathbf{x}_{i,t}$ is

[5]Details on the sample of countries can be found in Appendix Table B2 and basic descriptive statistics in Appendix Table C3.

a vector of real per capita government education expenditures. Let $p_i \geq 1, q_i \geq 0 \ \forall i$, and, for simplicity, we assume that the lag order q_i is the same for all variables in the vector $\mathbf{x}_{i,t}$ of dimension $K \times 1$. The selection of p_i and q_i is carried out using the Akaike information criterion. Specifically, we are interested in the error correction representation, which takes the following form:

$$\Delta Y_{i,t} = c_i + -\alpha_i \left(Y_{i,t-1} - \boldsymbol{\theta}\mathbf{x}_{i,t}\right) + \sum_{j=1}^{p_i-1} \psi_{yi} \Delta Y_{t-j} + \sum_{j=0}^{q_i-1} \psi'_{xi} \Delta \mathbf{x}_{t-j} + u_{i,t}. \tag{2}$$

In the ECM representation, the adjustment speed coefficient is given by $\alpha_i = 1 - \sum_{j=1}^{p_i} \phi_j$ and the long-term coefficients take the form $\boldsymbol{\theta} = \frac{\sum_{j=0}^{q} \beta_j}{\alpha}$. The estimation of this representation allows us to simultaneously capture the short- and long-term parameters for each country, as well as the adjustment speed. Using the methodology developed in Chudik et al (2016), we can retrieve the average of the parameters of interest (in particular the average $\boldsymbol{\theta}$) for the entire panel and draw inferences about their significance using the delta method.

A key requirement in this methodology is a sufficiently long time series combined with a broad worldwide panel, both conditions satisfied in our data. Our dataset covers 107 countries (29 advanced and 78 emerging and developing) with periods spanning from 1970 to 2019, depending on the country. This allows us to illustrate and compare countries with significantly different educational and GDP per capita trajectories.

Another critical requirement to accurately estimate a CS-ARDL model is for the variables studied to be co-integrated. In turn, a key condition to analyze co-integration is for the variables to be integrated of the same order (preferably of the first order). To test this, we implement the panel unit root test developed by Im et al (2003).[6] One of the advantages of this test is its applicability to unbalanced panels, as is the case in our study. The null hypothesis states that all panels contain a unit root. The alternative hypothesis is that some countries have stationary series. The results for the series of interest are summarized in Table 1.

[6]Other tests in this category include those developed in Levin et al (2002), Choi (2001), and Breitung and Das (2005).

Table 1: IPS Panel Unit Root Test

	Z	p-value
Whole Sample (107)		
Real GDP pc (log)	-0.63	0.26
Real gov. education exp. pc (log)	-1.45	0.07
Real gov. primary education exp. pc (log)	-2.37	0.01
Real gov. secondary education exp. pc (log)	-2.13	0.02
Real gov. tertiary education exp. pc (log)	-0.78	0.22
ΔReal GDP pc (log)	-41.80	0.00
ΔReal gov. education exp. pc (log)	-34.89	0.00
ΔReal gov. primary education exp. pc (log)	-35.55	0.00
ΔReal gov. secondary education exp. pc (log)	-36.04	0.00
ΔReal gov. tertiary education exp. pc (log)	-34.19	0.00

Note: The Im-Pesaran-Shin (IPS) test for panel unit roots relaxes the assumption of a common autoregressive coefficient across panels. The null hypothesis states that all panels contain a unit root, while the alternative allows a nonzero fraction of panels to be stationary. This approach accommodates heterogeneity in dynamics across countries or units. See Im et al (2003).

The analysis of Table 1 above, indicates that there is evidence that most variables in the dataset are integrated of the first order (I(1)), that is, they are stationary in first differences. In summary, this information allows us to conduct the desired co-integration analysis and proceed with the estimation of the CS-ARDL model.

The results summarized in Table 2 provide strong evidence of co-integration between real GDP per capita and real per capita government expenditure on education across most specifications. We observe statistically significant co-integration with total and secondary education expenditures, while the results for primary and especially tertiary education expenditures are weaker or mixed.

The panel co-integration results allow us to adequately estimate CS-ARDL models described earlier. The results of these estimations are reported in the following section.

3 Investment and Growth: A Breakdown by Type of Expenditure

This section evaluates whether increases in government education expenditure are associated with measurable impacts on economic growth in both the short and long run. The analysis focuses on disaggregated education spending by level —primary, secondary, and tertiary— to identify which types of investment are most effective at driving sustained output per capita growth.

Table 3 presents the main results estimated using a Common Correlated Effects—Autoregressive Distributed Lag (CS-ARDL) model with an error correction structure. This approach allows us to distinguish short-run dynamics from long-term relationships, while controlling for unobserved common factors. The dependent variable is the logarithm of real GDP per capita, while the independent variables are

Table 2: Kao Panel Co-integration Test Results

	Real gov. education exp. pc (log)	**Real gov. primary education exp. pc (log)**	**Real gov. secondary education exp. pc (log)**	**Real gov. tertiary education exp. pc (log)**
Modified DF t	-4.46 (0.0000)	-1.40 (0.0802)	-3.65 (0.0001)	1.06 (0.1441)
Dickey-Fuller t	-3.59 (0.0002)	-1.85 (0.0325)	-3.12 (0.0009)	1.27 (0.1012)
Augmented DF t	-3.21 (0.0007)	-1.68 (0.0469)	-3.19 (0.0007)	1.15 (0.1261)
Unadjusted modified DF t	-1.44 (0.0743)	1.10 (0.1349)	-0.50 (0.3095)	3.22 (0.0007)
Unadjusted DF t	-1.98 (0.0238)	-0.16 (0.4353)	-1.33 (0.0915)	3.15 (0.0008)

Note: We test for co-integration between real GDP per capita (Y) and education expenditure variables. Each cell reports the Kao test statistic with its p-value in parentheses. The null hypothesis is that the panels are not co-integrated. The test includes individual intercepts but no trend. Similar results are obtained using the Pedroni and Westerlund co-integration tests. Results from these alternative methodologies are available upon request.

per capita measures of real expenditure on education. All regressors are expressed in logs. The sample is restricted to countries with available disaggregated education expenditure data across all three levels: primary, secondary, and tertiary.

The results show that education investment is positively and significantly associated with output growth in both the short and long term, across all levels of education. Columns 2 through 4 in the table break down the elasticities by type of expenditure, while the first column presents the effect of aggregate education expenditure, combining spending at the primary, secondary, and tertiary levels.

The long-term coefficients reflect the elasticity of output per capita with respect to education spending. These estimates are statistically significant at conventional levels across all categories. A 1 percent increase in real per capita education expenditure leads to a 0.031 percent increase in long-run output for aggregate spending, 0.019 percent for both primary and secondary education, and 0.013 percent for tertiary education.[7] These results suggest that while all levels of education contribute to long-run economic performance, aggregate spending exhibits the highest overall elasticity. Notably, the effects for primary and secondary education are slightly higher compared with those for tertiary education, though all effects are economically significant.

The elasticities should be interpreted as follows: a sustained 10 percent increase in real per capita expenditure on primary or secondary education is associated with a 0.19 percent higher level of output in the long run. While modest in absolute terms, these effects are significant given the persistent nature of education-driven human capital accumulation and its compounding impact on growth over time.

Short-term dynamics, captured by the coefficient on the first difference of education expenditure, are also positive and statistically significant, albeit smaller in magnitude: 0.024 for aggregate expenditure, 0.014 for primary, 0.015 for secondary,

[7] It should be noted that the elasticity of aggregate expenditure growth might not be equivalent to the sum of its components (primary, secondary, and tertiary), as all variables are in logarithmic scale.

and 0.010 for tertiary education. These results are consistent with the idea that education spending does not immediately translate into productive output gains, given the time-intensive nature of learning and human capital formation. However, positive short-run effects suggest that some returns begin to materialize even in the early stages, potentially through channels such as employment effects, resource allocation, or institutional responses to investment.

The bottom panel reports the speed of adjustment to the long-run equilibrium, captured by the error correction term ($-\alpha$). All estimates are close to 0.77 and statistically significant at the 1 percent level. This implies that approximately 77 percent of the gap between current and long-run equilibrium output is corrected each period, suggesting a fast convergence speed in response to spending shocks. This serves as an important validation of the model, as it confirms that deviations from equilibrium are not persistent.

Despite the smaller long-run coefficient for tertiary education, the slightly faster adjustment speed suggests a tighter and more stable long-term relationship with output. This may reflect a higher degree of specialization and direct productivity effects associated with higher education, even if the returns take longer to accumulate or affect a narrower segment of the population.

Interestingly, while the long-term coefficient for secondary education is comparable to that of primary, its short-term effect is slightly larger. This may suggest that investment at this level may yield more immediate gains, possibly due to improved workforce readiness or reductions in dropout rates.

The R^2 values exceed 0.83 across all specifications, indicating a strong overall fit of the model to the data. This high explanatory power is observed not only in the aggregate expenditure specification but also across the decomposed models for primary, secondary, and tertiary education. Consistently high R^2 values suggest that the CS-ARDL framework captures a substantial share of the variation in real output per capita, thereby reinforcing the reliability of the estimated long- and short-term relationships.

The last rows of Table 3 report the results of the cross-sectional dependence (CD) and heterogeneous slopes (HS) tests. The CD test, based on the null hypothesis of no cross-sectional dependence, yields p-values well above conventional significance levels, indicating that the residuals are not correlated across countries. This suggests that the estimation strategy, which includes cross-sectional averages to capture unobserved common factors, is sufficient to account for any potential cross-sectional dependence. The HS test strongly rejects the null hypothesis of slope homogeneity (p-value = 0.00), indicating that the effect of education expenditure on growth varies meaningfully across countries. However, this heterogeneity is explicitly accommodated in the CS-ARDL framework through the use of country-specific coefficients and by averaging long-run effects. As a result, the estimates remain consistent and robust, without relying on potentially biased pooled estimates (Ditzen, 2021). The model's structure is therefore well-suited for this context, and the test results validate the appropriateness of the methodology chosen.

In summary, this analysis reinforces the finding that public education spending is a significant driver of economic growth, with notable effects observed across all levels of education. Both the magnitude and timing of these effects vary by educational level, suggesting that a balanced and coordinated investment strategy—targeting both foundational and higher education—may be the most effective approach to foster long-term development.

Table 3: Short- and Long-Term Coefficients of CS-ARLD(p,q) by Educational Levels

ΔReal GDP pc (log)	Aggregate	Primary	Secondary	Tertiary
Period	(1970-2019)	(1970-2019)	(1970-2019)	(1970-2019)
$(p*, q*)$‡	(1,0)§	(1,0)§	(1,0)§	(1,0)§
Long term				
Real gov. education exp. pc (log)	0.031***	0.019**	0.019**	0.013*
	(0.010)	(0.009)	(0.008)	(0.006)
Short term				
ΔReal gov. education exp. pc (log)	0.024***	0.014**	0.015**	0.010**
	(0.007)	(0.006)	(0.006)	(0.005)
ΔReal GDP pc $(\log)_{t-1}$	0.226***	0.233***	0.230***	0.222***
	(0.024)	(0.024)	(0.024)	(0.024)
Adjustment term				
$-\boldsymbol{\alpha}$	-0.774***	-0.767***	-0.770***	-0.778***
	(0.024)	(0.024)	(0.024)	(0.024)
Countries	107	107	107	107
Observations	4141	4196	4196	4208
Avg. obs. per country	40	41	41	41
R^2	0.84	0.84	0.84	0.83
Tests				
CD p-value	0.42	0.19	0.63	0.93
HS p-value	0.00	0.00	0.00	0.00

Note: ‡ Optimal lags p and q are determined for the full panel using the Akaike information criterion. § lags p and q apply to the full panel. All expenditure levels are expressed in real terms, per capita and in logarithms. The dependent variable is the logarithm of real output per capita. The estimates are based on the same set of countries that contain available data for all educational levels. Aggregate expenditure = Primary expenditure + Secondary expenditure + Tertiary expenditure.

4 Country Heterogeneity

In this section, we examine whether the elasticity of education expenditure with respect to output varies across different groups of countries. Of particular interest is the potential role of the quality of expenditure in shaping this relationship. Education quality serves as a proxy for productivity in the education sector, which may translate into improved labor market outcomes and, ultimately, higher aggregate output. This analysis seeks to explore the mechanisms that could explain cross-country variation in long-term elasticities. Specifically, we investigate whether higher educational achievements, as a proxy for quality, enhance the effectiveness of education spending. If both the expenditure and quality jointly contribute to stronger outcomes, this would provide suggestive evidence that their interaction may be central to economic development. It is important to note that we acknowledge that PISA results may be influenced by the level of per-capita expenditure itself and recognize the complexity of non-linearities present in this exercise.[8]

To implement this, we retrieve the vector of long-term coefficients for each country and conduct cross-country regressions using country-specific characteristics. To account for regional differences, we include a set of region-specific dummies in the regression. Let $\boldsymbol{\theta}$ be the vector of long-term parameters, and $\mathbf{X}$ represent a vector of country characteristics. We estimate the following specification:

$$\theta_i = \beta + \gamma \mathbf{MATH}_i + \mathbf{D}_i' \boldsymbol{\delta} + \epsilon_i, \tag{3}$$

Where Math_i represents the logarithm of the initial PISA math score for country i; $\mathbf{D}_i$ is a vector of regional dummy variables for country i; and $\boldsymbol{\delta}$ captures their associated coefficients.

The results presented in Table 4 indicate that higher average PISA math scores are associated with larger long-run elasticities of education expenditure with respect to output.[9] This suggests that, on average, countries with better education quality experience a stronger impact of public education spending on long-term economic growth. The relationship is statistically significant both in the aggregate and across all education levels (primary, secondary, and tertiary).

For instance, the coefficient of 0.320 in the aggregate expenditure regression implies that a 10 percent increase in the average historical PISA math score is associated with a 0.032 increase in the long-run elasticity of education expenditure, on average. Since the PISA score is included in the regression in logarithmic form, these estimates can be interpreted as semi-elasticities, allowing for a straightforward interpretation of proportional changes.

When comparing across educational levels, we observe that the long-run elasticity associated with primary education (0.283) is slightly higher than those for secondary (0.237) and tertiary education (0.217). However, all effects are statistically significant and economically meaningful. This pattern may reflect the broader reach and foundational role of primary education in developing basic skills that support long-term productivity. Nonetheless, the relatively strong effects at the secondary level—coupled with its sensitivity to education quality—highlight its importance as a critical stage for maximizing returns on investment, particularly in countries seeking to build a more skilled workforce.

Importantly, the relationship between PISA scores and short-term elasticities is weaker and statistically insignificant. In fact, the estimated short-term coefficients are close to zero and occasionally negative, suggesting that improvements in education quality do not yield immediate output gains, but rather accumulate their effects over time.

[8] As noted in Table C3, countries with higher PISA scores also exhibit higher per capita expenditure on education.

[9] Comparable results are obtained when using PISA Reading or Science scores rather than math. For brevity, these estimates are omitted but are available upon request.

Regional control variables reveal notable patterns. For long-term elasticities, the dummy variables for Latin America and the Caribbean, the Middle East and North Africa, and Europe and Central Asia, all load positively and significantly in most specifications, relative to the omitted reference category: East Asia and the Pacific. This indicates potential region-specific differences in the education-output relationship that may reflect variations in institutional, demographic, or policy environments.

Table 4: Returns Based on PISA Mathematics Performance

	Aggregate expenditure	Primary	Secondary	Tertiary
Period	(1970-2019)	(1970-2019)	(1970-2019)	(1970-2019)
Panel A: Long-term education expenditure				
Average PISA math score (log)	0.320**	0.283**	0.237**	0.217**
	(0.127)	(0.111)	(0.108)	(0.084)
Europe and Central Asia	0.048	0.006	0.021	0.041
	(0.038)	(0.033)	(0.032)	(0.025)
Latin America and Caribbean	0.141**	0.111**	0.078*	0.090**
	(0.054)	(0.047)	(0.046)	(0.036)
Middle East and North Africa	0.162***	0.169***	0.142***	0.081**
	(0.058)	(0.050)	(0.049)	(0.038)
Constant	-2.008**	-1.771**	-1.487**	-1.360**
	(0.786)	(0.685)	(0.666)	(0.517)
Countries	54	54	54	54
R-squared	0.18	0.22	0.17	0.18
Panel B: Short-term education expenditure				
Average PISA math score (log)	-0.021	0.008	-0.057	-0.116
	(0.547)	(0.549)	(0.542)	(0.531)
Europe and Central Asia	0.231	0.224	0.215	0.253
	(0.164)	(0.165)	(0.163)	(0.159)
Latin America and Caribbean	0.255	0.263	0.246	0.233
	(0.234)	(0.235)	(0.232)	(0.227)
Middle East and North Africa	0.102	0.088	0.102	0.140
	(0.247)	(0.248)	(0.245)	(0.240)
Constant	-0.232	-0.410	0.000	0.327
	(3.374)	(3.389)	(3.342)	(3.273)
Countries	54	54	54	54
R-squared	0.05	0.05	0.05	0.06

Note: The dependent variable is the long-term coefficient approximating the elasticity of education expenditure with respect to real output per capita for each country. The regression uses the earliest available average PISA math score as the independent variable. Countries listed in Table B2 that lack PISA data are excluded from the analysis. Full-sample estimates are performed on the same set of countries with available information for all education levels. Aggregate expenditure = Primary expenditure + Secondary expenditure + Tertiary expenditure. The East Asia and Pacific fixed effect is omitted due to colinearity.

5 Dynamics Based on Educational Achievement

This section examines how improvements in education quality—proxied by PISA math scores—affect the macroeconomic impact of public education expenditure. We simulate the dynamic response of real GDP per capita to a 1 percent *permanent* increase in real per capita government education expenditure under two scenarios: (1) a baseline scenario reflecting world average elasticities, and (2) a scenario calibrated for countries with historically 30 percent higher PISA math performance. This 30 percent differential corresponds to the observed gap in math achievement between developed and developing countries, as documented in Table C3.

Fig. 2: Simulated Response of Real GDP Per Capita (percent) to a 1 percent Permanent Increase in Real Government Education Expenditure Per Capita

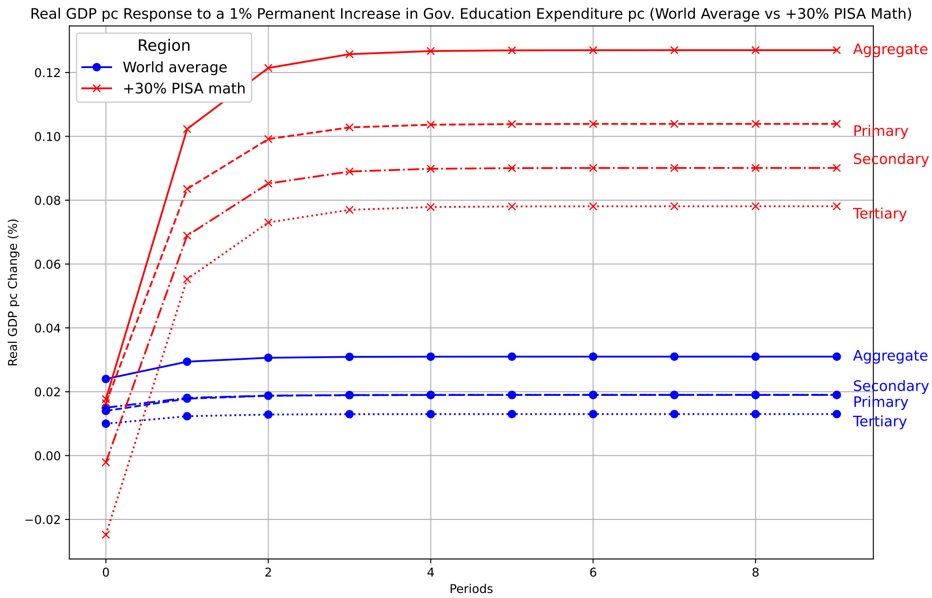


Figure 2 illustrates that higher educational achievement substantially amplifies the long-run impact of public education spending on GDP. In the aggregate case, the cumulative effect on GDP per capita nearly quadruplicates—from approximately 0.031 percent under the world average to over 0.12 percent in the high-PISA scenario. This underscores the catalytic role of education quality in enhancing the productivity of public investment.

When disaggregated by education level, primary and secondary education display particularly pronounced responses to improved achievement. Under high-PISA performance, GDP per capita increases peak at around 0.10 percent and 0.09 percent, respectively—more than four times the effects observed under average conditions

(0.018 percent and 0.019 percent). These results suggest that foundational and intermediate stages of education are especially sensitive to quality improvements, likely reflecting systemic gains in instructional delivery and student learning outcomes.

Tertiary education, while starting from a smaller baseline, shows the largest absolute gain, with GDP effects rising from roughly 0.013 percent to almost 0.08 percent—a sixfold increase. This substantial jump highlights that even advanced levels of education can yield significant macroeconomic returns when quality improves.

Across all education levels, the effects stabilize within a few periods, reflecting the time required for human capital investments to translate into productivity gains. Nevertheless, these gains are persistent, reinforcing the case for sustained quality-focused education policy.

In sum, these findings suggest that improvements in education quality—through better teaching, curricula, or student outcomes—can significantly enhance long-run macroeconomic returns on public education spending. For policymakers, this underscores the importance of complementing increased expenditure with reforms aimed at improving system effectiveness and learning quality.

6 Conclusion

This paper explores the dynamic relationship between public education expenditure and economic growth using a large global panel and a CS-ARDL framework. Our findings show that investment in education is a significant driver of real GDP per capita, providing robust evidence of both short- and long-term effects. While short-run responses are modest, long-run elasticities are positive and statistically significant across all educational levels—most notably for aggregate spending, but also for primary and secondary education individually.

Importantly, we find strong support for co-integration between education spending and output, thereby validating the use of an error correction specification. The model demonstrates rapid convergence toward the long-run equilibrium, with about 77 percent of deviations corrected each period. This finding suggests that education investment not only yields persistent effects but also contributes to macroeconomic stability.

A key contribution of this study lies in identifying heterogeneity in the effectiveness of education spending. We find that countries with higher educational achievement, as proxied by PISA math scores, experience significantly greater returns on investment. This effect is particularly notable in primary and secondary education, where quality improvements appear to most strongly enhance productivity. Conversely, short-term effects are not significantly linked to educational quality, reinforcing the notion that gains from improved education systems accumulate over time.

The simulations further illustrate how education quality acts as a multiplier: a 30 percent improvement in PISA scores can nearly quadruples the long-term impact of education expenditure on GDP per capita. This suggests that the marginal productivity of spending is not uniform across countries but is conditional on the system's performance.

In sum, these results underscore the importance of both the quantity and quality of public education investment. While increasing education budgets is beneficial, the growth dividends are substantially higher when paired with improvements in learning outcomes. Policymakers should therefore focus not only on expanding access and funding, but also on systemic reforms aimed at enhancing instructional quality, curriculum alignment, and educational accountability.

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Appendices

A Variables and Sources

Table A1: Variable Description and Sources

Variable	**Description**	**Source**
`GDP`	GDP in current US dollars (millions)	World Bank (NY.GDP.MKTP.CD)
`Y`	Real GDP in constant 2015 US dollars (millions)	World Bank (NY.GDP.MKTP.KD)
`Deflator`	GDP deflator (base year 2015), calculated as `GDP` / `Y` × 100	Constructed from World Bank (NY.GDP.MKTP.CD / NY.GDP.MKTP.KD)
`Population`	Total population by country and year	World Bank (SP.POP.TOTL)
`Real gov. education exp. pc (log)`	Log of total real government education expenditure per capita (sum of primary, secondary, and tertiary nominal expenditures deflated and divided by population)	Constructed from UIS + World Bank
`Real gov. primary education exp. pc (log)`	Log of real government primary education expenditure per capita (nominal primary expenditure deflated and divided by population)	Constructed from UIS.X.US.1.FSGOV + World Bank
`Real gov. secondary education exp. pc (log)`	Log of real government secondary education expenditure per capita (nominal secondary expenditure deflated and divided by population)	Constructed from UIS.X.US.2T3.FSGOV + World Bank
`Real gov. tertiary education exp. pc (log)`	Log of real government tertiary education expenditure per capita (nominal tertiary expenditure deflated and divided by population)	Constructed from UIS.X.US.5T8.FSGOV + World Bank
`Average PISA math score`	Average PISA mathematics score by country and year	OECD PISA Dataset

B Countries in Sample

Table B2: List of Countries Included in the Sample

Advanced (29)	*Emerging and Developing (78)*		
Australia	Albania	Algeria	Argentina
Austria	Bahrain	Bangladesh	Barbados
Belgium	Bermuda	Bhutan	Botswana
Chile	Brazil	Brunei Darussalam	Burkina Faso
Czech Republic	Burundi	Cameroon	Central African Republic
Denmark	Colombia	Comoros	Congo, Rep
Finland	Costa Rica	Cote d'Ivoire	Cyprus
France	Dominica	Dominican Republic	Ecuador
Germany	El Salvador	Eswatini	Ethiopia
Greece	Fiji	Gabon	Gambia, The
Hungary	Ghana	Guatemala	Guinea
Iceland	Guyana	Honduras	Hong Kong SAR, China
Ireland	Indonesia	Iran, Islamic Rep	Jamaica
Israel	Jordan	Kenya	Kuwait
Italy	Lao PDR	Lesotho	Liberia
Japan	Madagascar	Malawi	Malaysia
Korea, Rep	Mali	Malta	Mauritania
Luxembourg	Mauritius	Morocco	Nicaragua
Mexico	Niger	Oman	Pakistan
Netherlands	Panama	Paraguay	Peru
New Zealand	Philippines	Puerto Rico	Rwanda
Norway	Seychelles	Singapore	Sri Lanka
Portugal	St Kitts and Nevis	St Lucia	Syrian Arab Republic
Slovak Republic	Tanzania	Thailand	Togo
Slovenia	Tonga	Tunisia	Uganda
Spain	Uruguay	Zambia	Zimbabwe
Sweden			
Switzerland			
United Kingdom			

C Descriptive Statistics

Table C3: Descriptive Statistics for the Different Samples

	Mean	Std. Dev.	Min.	Max.
Whole Sample (107)				
Real GDP pc (log)	8.444	1.583	-6.057	11.795
Real gov. education exp. pc (log)	5.173	1.741	0.227	8.487
Real gov. primary education exp. pc (log)	4.264	1.603	-0.846	7.710
Real gov. secondary education exp. pc (log)	4.112	1.921	-1.777	7.627
Real gov. tertiary education exp. pc (log)	3.516	1.950	-7.380	7.429
PISA math score	447.114	75.689	292.070	563.816
Advanced (29)				
Real GDP pc (log)	10.039	0.747	6.935	11.630
Real gov. education exp. pc (log)	6.947	0.871	4.041	8.487
Real gov. primary education exp. pc (log)	5.836	0.857	2.838	7.710
Real gov. secondary education exp. pc (log)	6.060	0.962	2.651	7.627
Real gov. tertiary education exp. pc (log)	5.402	1.030	1.503	7.429
PISA math score	496.093	44.456	383.513	563.816
Emerging and Developing (78)				
Real GDP pc (log)	7.843	1.387	-6.057	11.795
Real gov. education exp. pc (log)	4.488	1.492	0.227	7.860
Real gov. primary education exp. pc (log)	3.664	1.403	-0.846	7.151
Real gov. secondary education exp. pc (log)	3.370	1.657	-1.777	7.170
Real gov. tertiary education exp. pc (log)	2.773	1.712	-7.380	6.830
PISA math score	390.290	63.808	292.070	562.019

D Correlations

Table D4: Correlation Between Variables of Interest for Different Samples

	Real GDP pc (log)	Real gov. education exp. pc (log)	Real gov. primary education exp. pc (log)	Real gov. secondary education exp. pc (log)	Real gov. tertiary education exp. pc (log)
Whole Sample (107)					
Real GDP pc (log)	1				
Real gov. education exp. pc (log)	0.961***	1			
Real gov. primary education exp. pc (log)	0.945***	0.983***	1		
Real gov. secondary education exp. pc (log)	0.946***	0.984***	0.950***	1	
Real gov. tertiary education exp. pc (log)	0.901***	0.946***	0.909***	0.915***	1
Advanced (29)					
Real GDP pc (log)	1				
Real gov. education exp. pc (log)	0.949***	1			
Real gov. primary education exp. pc (log)	0.882***	0.923***	1		
Real gov. secondary education exp. pc (log)	0.931***	0.967***	0.824***	1	
Real gov. tertiary education exp. pc (log)	0.760***	0.857***	0.709***	0.814***	1
Emerging and Developing (78)					
Real GDP pc (log)	1				
Real gov. education exp. pc (log)	0.935***	1			
Real gov. primary education exp. pc (log)	0.916***	0.981***	1		
Real gov. secondary education exp. pc (log)	0.909***	0.974***	0.933***	1	
Real gov. tertiary education exp. pc (log)	0.849***	0.921***	0.876***	0.869***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$