Investigating Education's Contribution to Economic Growth: A Panel Analysis of the OECD Nations

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Abstract

This dissertation investigates the relationship between education and economic growth with a dual focus on education input in the form of government education spending and outcomes in the form of the Human Capital Index (HCI). Analysis uses a dataset comprising of 18 OECD countries during a period of 39 years (1980-2019), with the addition of 10 control variables. A fixed effects model with country and time fixed effects is used to address unobserved heterogeneity and account for time-invariant differences across countries. Results suggest education spending exhibits a negative and significant association with growth in the short term, whilst HCI displays a positive yet often insignificant relationship. Lag structures are applied to explore the delayed effects of education and yield mixed results. Both measures of education are positively and significantly associated with growth at the 4-10 year lags yet show a negative and insignificant association at longer lags, with fluctuations throughout.

AI Statement

I acknowledge the use of generative AI in code development for this paper. However, the work reported remains my own.

Acknowledgements

I would like to express my deepest gratitude to the many wonderful colleagues I have had the pleasure of working with at the Bank of England over the past four years. I am particularly grateful to my line managers for their steadfast commitment to my academic and professional development, and to my friends, family and cats for their enduring support and encouragement throughout this journey.

Above all, I lovingly dedicate this dissertation, and any future achievements, to my beloved father. Although he is no longer with us, his inspiration and unwavering belief in me continue to guide everything I do.

Introduction

Education is considered an investment in human capital and widely acknowledged as a fundamental driver of economic growth and development.

Theoretical literature identifies three main channels through which education influences economic growth. First, education enhances human capital by improving labour productivity and efficiency, leading to higher outputs and the facilitation of transitional growth. This approach aligns with augmented neoclassical growth models (Mankiw et al., 1992). Second, education plays a vital role in fostering innovation and creative thinking. By broadening intellectual capabilities and empowering alternative thinking, education facilitates the creation of new technologies, goods and production methods, all of which contribute to long-term growth. This concept is central to exogenous growth theories (Lucas (1988), Romer (1990), Aghion and Howitt (1998)). Third, education supports the spread and advancement of existing knowledge, enabling economic agents to adopt and apply technological innovations, which in turn contributes to economic growth. This process, discussed by Nelson & Phelps (1966) and Benhabib & Spiegel (1994), highlights the broader impact of education beyond just direct innovation.

Article-26 of the Universal Declaration of Human Rights states that "everyone has a right to education", adding that education is not only a privilege but also vital for individual and societal progression (United Nations, 1948). Access to education has seen significant progress over the years with the share of the adult population to have received basic education increasing from 17% in 1820 to nearly 87% by 2020 (Our World in Data, 2023). This continued increase in education is potentially the result of a strong and continued focus on education policy across the world.

Studies often utilise pupil performance as measured through standardised testing to assess education's contributions to growth. However, positive externalities of education reach far beyond academic performance with spillovers such as better health outcomes and reduced crime (Heckman et al. 2017). Investigations into education's impact on health reveal that education contributes positively to overall wellbeing by improving social interaction and household dynamics (Feinstein et al., 2006). The impact of education on other aspects of society has also been explored by many over the years covering crime (Lochner & Moretti, 2001), societal integration (Meyer, 1977) and political participation (Milligan et al., 2003).

To better understand the many ways in which education influences an economy, a comprehensive approach extending beyond the evaluation of returns on academic performance is necessary.

Research Question

The purpose of this research question is to investigate how education as measured through i) government expenditure on education, and ii) the Human Capital Index contributes to economic growth. The following hypotheses are proposed to investigate this relationship:

H1: Education contributes positively to economic growth.
H2: Education has a positive and delayed effect on economic growth.

Both hypotheses assume a positive relationship between education and growth, as this is the notion most established in economic theory and literature. Empirical results in support of these hypotheses would reaffirm this notion, whilst discrepancies could prompt further exploration of the education-growth relationship.

Disposition

This dissertation begins by presenting the Theoretical Frameworks which establish the conceptual basis for research. The Literature Review then provides an overview of previous research covering education, human capital and economic growth theory. The Data section describes dataset used along with robustness checks to ensure the reliability of results. The empirical approach is then detailed in the Methodology section, after which Results are presented and discussed. Finally, the dissertation concludes with a summary of key findings and suggestions for future work.

Theoretical Framework

Growth Theories

Economic growth theories are broadly categorised into exogenous and endogenous models. Exogenous models emphasise savings, capital accumulation and technology, while endogenous models address their limitations by offering a more comprehensive view. Given their significant contributions, both frameworks are evaluated.

Exogenous Growth

The Harrod-Domar Model is among the earliest theories of economic growth, developed separately by Harrod (1939) and Domar (1946). Though developed independently, both theorists concluded that economic growth is driven by savings and the productivity of capital.

Harrod structures his theory around two key propositions. The first is that economic growth is contingent on the propensity to save and the capital-output ratio. The saving rate determines the availability of funds for capital accumulation, whilst the capital-output ratio governs the efficiency with which investment translates to additional output. Together, these factors jointly influence the steady-state growth rate. Harrod's second proposition is the concept of a unique equilibrium path that an economy must follow, with deviations in the form of over or under production reinforcing divergence from stability. This is known as the 'Warranted Growth Rate' (Harrod,1939). The saving rate is fundamental to this framework and is considered an exogenous variable given its determinates lie outside the scope of this model.

Domar builds upon similar principles, placing greater emphasis on the relationship between capital accumulation and labour productivity. He argues that capital investment not only expands production capacity but also generates employment, linking capital formation directly to growth. The approach and assumptions of both models are similar, thereby forming the Harrod-Domar Model (Domar, 1946).

The main limitation of the Harrod-Domar Model is its assumption of fixed production factors, limiting real-world applicability. The Solow-Swan Model addresses this by adopting a Cobb-Douglas production function with flexible inputs. Solow attributes long-term growth to exogenous technological progress rather than savings, marking a significant departure from the Harrod-Domar approach.

The role of education can be inferred through the productivity components of these models – human capital productivity in the Harrod-Domar model and labour productivity in the Solow-Swan model. While this influence is present, these models do not explicitly identify key drivers of growth beyond technological change. Addressing this limitation has been a central motivation behind the development of more modern growth theories.

Endogenous Growth

Modern growth theories argue economic growth is driven by internal factors rather than external technological progress. This perspective provides a deeper understanding of economic growth by identifying key contributors, such as innovation (Ickes, 1996).

Endogenous models first emerged in the 1980s and were influenced by earlier research challenging the neoclassical approach. A key influence was Nicholas Kaldor whose ‘stylised facts’ identified empirical regularities in growth that previous models failed to explain. Kaldor’s research pointed to factors beyond simply capital accumulation and labour productivity (Kaldor, 1957) and his ideas were further developed by many including Arrow (1962) and Uzawa (1965).

A significant figure in this movement is Paul Romer. Romer (1986) rejects neoclassical assumptions of diminishing returns**.** Instead suggesting that investment in knowledge and innovation generates positive externalities**,** leading to sustained economic growth without the need for exogenous technological change (Arrow, 1962; Romer, 1994). In contrast to the convergence hypothesis of exogenous models, which suggest economies move toward a steady-state growth rate, Romer’s framework permits ongoing divergence in growth rates across countries due to variations in knowledge accumulation and human capital investment (Schilirò,2019).

Romer’s ‘competitive equilibrium model of growth’ suggests that knowledge is a form of capital that spreads and grows through three key mechanisms:

i) Externalities: Knowledge discovered by one can benefit many, fostering cumulative innovation.
ii) Increasing returns in accumulation: Knowledge is non-rivalrous and can be accumulated indefinitely.
iii) Diminishing returns in production: Investment in research and development (R&D) may not yield proportional returns.

Extensions of Romer’s model suggest that human and physical capital, alongside innovation, play complementary roles in sustaining long-term economic growth (Nobel Prize, 2018). Lucas (1988) builds on this, showing that human capital investment enhances labour productivity and physical capital effectiveness. Lucas treats human and physical capital as one single factor, with human capital accumulation driving sustained economic growth. Unlike traditional models that assume diminishing returns to capital, Lucas argues that human capital can generate constant marginal returns, meaning continued investment in education and skills can drive ongoing growth. Similarly, the Augmented Solow Model by Mankiw, Romer and Weil (1992) emphasises human capital as a key driver of growth and cross-country income differences, suggesting continued educational investment can yield persistent economic gains.

Contributions to growth theory discussed thus far are essential for understanding its development and although many have included human capital, the factors' specific role has not been explored in depth. An economist who addresses this relationship is Robert Barro. Barro combines elements of exogenous and endogenous theories, viewing them as 'more complementary than they are competing' (Barro, 2001, 2013).
Convergence principles of neoclassical models state that economies with initially lower levels of GDP-per-capita experience higher growth rates until they converge to a steady state. A key element of Barro's framework is a shift from this narrative. Barro highlights that differences between countries can make convergence conditional, meaning that the neoclassical notion is only applicable where economies are equivalent. Additionally, Barro draws on R&D theories, such as those proposed by Grossmann and Helpman (1991), to highlight the role of innovation in fostering growth. He also emphasises how imperfect competition and knowledge spillovers can further drive economic progress (Barro, 1996). Thus providing a more comprehensive understanding of the factors driving sustained economic growth, beyond neoclassical assumptions.

Empirical Framework

The empirical framework of this dissertation follows Barro 's framework (1996) and is a derivation of the extended neo-classical growth model. This extension combines aspects of endogenous and exogenous models and is summarised by the following equation:

$$Dy = F(y, y^*)$$

where Dy is the growth rate of per capita output, y is the current level of per capita output, and $y^*$is the long-run or steady-state level of per capita output.

The steady-state level of output per capita, denoted as y^*, reflects the concept of economic convergence, where current output y moves toward a long-run equilibrium. When a country's current output lies below this steady-state, any increase in y^* leads to a rise in the growth rate Dy, while a decline in y^* slows growth. Improvements in $y^*$are typically driven by better institutional performance, more effective government policies, or favourable demographic shifts. For instance, demographic changes that increase household savings or investments in human capital can lift y^*, setting the stage for higher transitional growth.

As economies adjust toward this new steady-state, growth temporarily accelerates. However, diminishing returns eventually settle Dy at a more sustainable pace. Unlike the neoclassical model where technology is considered an external force driving long-run growth, Barro's framework positions human capital (particularly education and skill formation) as a key driver of technological advancement. This is consistent with previously discussed endogenous growth theory, where human capital not only enters directly into the production function but also facilitates innovation and knowledge spillovers.

This dissertation investigates how education influences economic growth, focusing on two complementary indicators: government education spending and the Human Capital Index (HCI). Following Barro's (2013) framework, this analysis considers both the endogenous accumulation of human capital (captured through the HCI), and the role of government policy as represented by education expenditure.

While these drivers are conceptually distinct, they often operate jointly, making their empirical separation both challenging and necessary for understanding how education contributes to growth. To isolate their respective effects, a range of control variables associated with growth are included in the empirical model. These controls capture factors such as health outcomes, trade integration and fiscal policy. The dependent variable, per capita GDP growth, is examined alongside the two key independent variables to provide a more comprehensive assessment of the financial inputs and outcomes associated with human capital development.

Literature

This section critically reviews theoretical and empirical studies on the relationship between education spending, human capital development and economic growth, providing a basis for the empirical analysis conducted in this dissertation.

Human Capital Theory

Human capital corresponds to the knowledge or characteristics of a worker which contribute to his or her productivity (Acemoglu & Autor, 2011). Human Capital Theory (HCT), pioneered by Schultz (1961) and Becker (1964), argues that investment in education and skill development boost individual productivity, ultimately driving economic growth.

Schultz emphasised the macroeconomic benefits of human capital accumulation, highlighting its role in enhancing national productivity and economic resilience. Becker then extended this by developing a microeconomic framework which quantified returns to education, distinguishing between general human capital (skills transferable across industries) and specific human capital (skills valuable only within a particular sector or firm). His work demonstrated that higher educational attainment leads to increased wages and economic mobility, reinforcing the importance of education as a long-term investment. Together, their contributions established human capital as a critical driver of both individual and national economic performance.

Education as a Mechanism for Growth

Downes (2001) identifies three fundamental roles of education in society: i) socialisation and cultural transmission, which helps integrate individuals into society through shared norms and values; (ii) human capital development, which enhances skills and competencies; and (iii) social stratification and equity, which can either reduce or reinforce economic and social divides. Of these, human capital development is particularly critical for economic growth as it promotes the development of both cognitive and non-cognitive skills. These skills enhance labour productivity, increasing innovation and overall efficiency in the economy.

Downes' model (Figure 1) illustrates the dual pathway through which education contributes to growth. Cognitive skills such as numeracy, literacy and problem-solving enhance a worker's ability to adopt new technologies and perform complex tasks (Nelson & Phelps, 1966; Hanushek & Woessmann, 2008). Whereas non-cognitive skills such as teamwork and adaptability improve workplace efficiency and innovation capacity (Heckman & Kautz, 2012). Together, these skills form the foundation of human capital, through which educational investment drives productivity and economic growth – an idea central to Human Capital Theory.

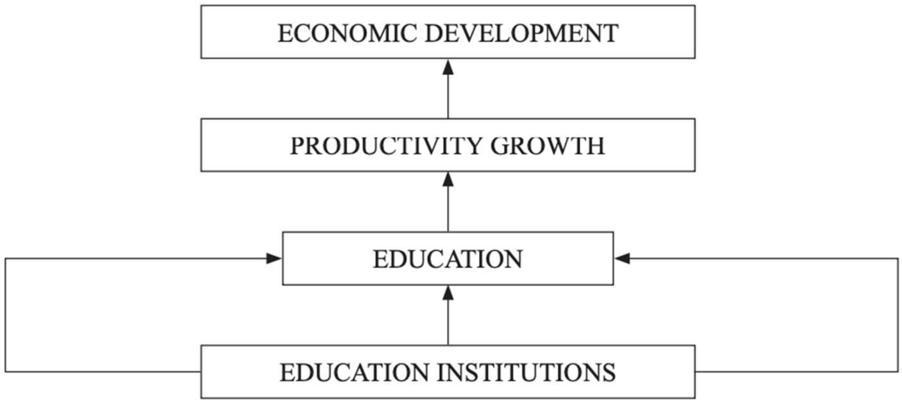


Figure 1: Education-Growth Pathway (Downes, 2001)

Rationale and Determinants of Education Spending

Public spending on education is defined as 'direct expenditure by public entities on educational institutions' (OECD,2024). Human Capital Theory frames this expenditure as an investment that enhances individual productivity and earnings. Education spending is thus viewed as a way of fostering human capital accumulation.
Theoretical justification for government investment in education stems from market failures – especially positive externalities, credit constraints and information asymmetries (Stiglitz, 1974; Arrow, 1973). Private investment in education can be suboptimal due to these market failures, making public funding necessary for broader access to schooling, particularly for disadvantaged groups (Glewwe & Muralidharan, 2016).

Additionally, the composition of education spending – specifically what resources are invested in – also plays a critical role. Targeted investments in areas such as teacher training and infrastructure yield greater returns than undifferentiated increases in total expenditure (Bold et al., 2017). This is consistent with Hanushek's (2011) findings, which find that replacing a bottom-quartile teacher with an average one can raise students' lifetime earnings by ~$250,000 per classroom.

With regards to the determinants of education spending, Castles (1989) highlights a broad range of factors including economic conditions, demographic trends and political dynamics. This aligns with other studies including Falch and Rattso (1997), which stresses the significance of macroeconomic factors, including inflation and unemployment, in determining education budgets.

A pooled time-series analysis by Busemeyer (2007) examined the determinants of education spending across 21 OECD countries (1980-2001). Consistent with prior literature, Busemeyer found that economic development and demographic factors are key drivers of education spending. GDP was positively associated with public education expenditure, suggesting wealthier nations allocate more resources to education. Demographic factors also played a role, with the proportion of young people in the population positively influencing education spending, whilst the proportion of elderly citizens had no significant effect.

A more recent study by Abdul Jabbar and Selvaratnam (2017) incorporated political factors alongside demographic influences to investigate the determinants of Malaysia's public education expenditure (1990-2015). Their results reveal that government revenue positively influences education spending, while budget deficits have a negative impact. The unemployment rate, though inversely related, had no significant effect on education spending. And demographic factors appeared to be disregarded by policymakers, with political factors having little to no influence.

Empirical Overview of Education and Growth

A multitude of research explores the role of education in driving economic growth. A seminal contribution by Barro (1991) finds that both initial levels of human capital and improvements in educational attainment are positively associated with growth. Barro and Lee (1993) refine this analysis, emphasising that higher levels of secondary and tertiary education are particularly important for long-run growth. This view is consistent with Mankiw, Romer and Weil (1992), who extend the Solow model to include human capital and find significant improvement in the model's explanatory power for cross-country differences in growth.

Numerous studies establish a positive relationship between education and growth, with foundational work by Barro (2013) highlighting that primary and secondary education levels contribute significantly to economic performance. Self and Grabowski (2004) provide evidence from India in support of this, stating that primary education plays a more significant role in driving economic development compared to higher education. Loening (2005) observes similar results in his study using time-series data from Guatemala, where primary education yields strongest returns. This suggest that returns to higher education can diminish in the absence of a strong foundation in earlier stages of schooling.

Education policies in many developing countries have thus long focused on expanding earlier stage education, especially in sub-Saharan Africa where participation in higher education remains limited. However, a growing body of literature challenges this sequencing, emphasising the critical role of tertiary education. Bloom, Canning and Chan (2006; 2014) argue that neglecting tertiary education can hinder long-term growth, with universities playing a vital role in equipping individuals with the skills needed for innovation and economic transformation.

Empirical evidence on tertiary education remains inconclusive. Aghion et al. (2009) uses a panel of US states and finds that whilst investments in four-year courses are linked to positive growth, two-year courses show no significant impact. They attribute this to a potential crowding-out mechanism whereby only certain types of education deliver measurable benefits. These insights suggest the presence of a threshold effect, emphasising the importance of directing education spending toward interventions that maximise growth outcomes.

Beyond educational attainment, scholars have increasingly emphasised the importance of education quality and cognitive skills in driving growth. Hanushek and Kimko (2000) and Hanushek and Woessmann (2012) find that international test-scores, as proxies for learning outcomes, are more strongly correlated with growth than just years of schooling. In OECD countries which are the focus of this dissertation, variations in educational effectiveness and skill acquisition are key determinants of productivity and growth. This recognition of education quality rather than solely duration or spending has led to the consideration of additional proxies for education.

Measuring Education: A shift towards Human Capital

The theoretical foundations of HCT establish education spending as a key input for economic growth. However, empirical research increasingly highlights the limitations of input-based metrics in capturing education's true impact.

Input metrics such as education spending fail to capture learning outcomes, skill acquisition, or the combined effects between education and health. This has led to refined measures of human capital, such as the Human Capital Index (HCI) developed by the World Bank, which accounts for the quality of education. This shift towards outcome-based measures has emerged from recognition of the ‘input-outcome’ paradox (Pritchett, 2013), where cross-country analyses reveal weak correlations between education spending and growth after controlling for institutional quality.

Recent research increasingly employs panel techniques to examine the education-growth relationship, allowing for the control of unobserved country-specific effects and the exploitation of both cross-sectional and time-series variation. These methods are particularly well-suited to the study of economic growth, where heterogeneity across countries can distort simpler cross-sectional or time-series models.

For instance, Angrist et al. (2021) demonstrates the empirical value of HCI using fixed-effects panel regressions covering over 150 countries from 2000-2017. Their analysis reveals that higher HCI scores are robustly and positively associated with output per worker, even after controlling for a wide set of covariates including institutional quality, initial income and demographic variables. The use of fixed-effects helps account for unobserved heterogeneity across countries which can arise from cultural attitudes towards education amongst other things. They conclude that investments which raise human capital are powerful in promoting long-term growth.

Following on from this literature review, this dissertation uses a panel dataset and fixed-effects models to control for time-invariant country characteristics. This methodological choice aims to address issues such as omitted variable bias and measurement error, thereby providing a more robust framework to examine how education influences economic growth.

Data

This dissertation draws upon data from three reputable sources: the Penn World Tables (PWT), the World Bank's Development Indicators (WDI) and Freedom House. These sources provide reliable and consistent data on macroeconomic indicators, education-related variables and institutional quality, enabling a robust empirical investigation into the education- growth relationship.

The dataset employed is panel, combining dimensions of cross-sectional and time-series data. This allows for the control of unobservable factors that are constant over time but vary across countries, as well as those that vary over time but are common across countries. The selection of countries is based largely on the availability of education spending data due to completeness issues for many OECD countries in relation to this indicator. Several countries have therefore been excluded, and a forward-filling method applied to address any remaining instances of missing data. This technique replaces missing observations with the most recent non-missing value, preserving underlying trends while avoiding the introduction of unrealistic or arbitrary values.

The panel comprises 720 observations covering 18 OECD countries from 1980-2019. As this dissertation aims to investigate the long-run relationship between education and growth, a long time series of 39-years is used. The countries evaluated in this paper are: Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Hungary, Ireland, Israel, Italy, Japan, Netherlands, Norway, Portugal, Switzerland and the United Kingdom

Independent and Dependent Variables

Analysis focuses on two key independent variables. The first independent variable of interest is government expenditure on education expressed as a percentage of GDP (GEXP) and sourced from the World Bank. This variable serves as an input measure of education, reflecting the level of resources national governments allocate to the education sector. It captures the commitment of public policy to human capital investment but does not directly measure educational outcomes or quality. The second independent variable is the Human Capital Index (HCI) from the Penn World Table. This outcome-based measure incorporates both the quantity (average years of schooling) and quality (returns to education) of education.

Both variables will be included in their original and lagged form to account for potentially delayed effects of education on growth. This allows the analysis to capture their impact not only in the short-run but also over the longer-term.

The dependent variable used in this study is GDP-per-capita growth (GDPGR), measured as the annual percentage change in real GDP-per-capita.

An initial look at the relationship between the dependent and independent variables is illustrated in Figure 2. A linear relationship cannot be identified for either GEXP (top-panel) or HCI (bottom-panel). Scatterplots show substantial clustering across all 18 countries particularly for HCI, where variation appears limited over time. Ireland and Chile display notable outliers with wider variation in both education metrics and GDP growth. Datapoints overall remain dispersed and do not point towards a clear trend.

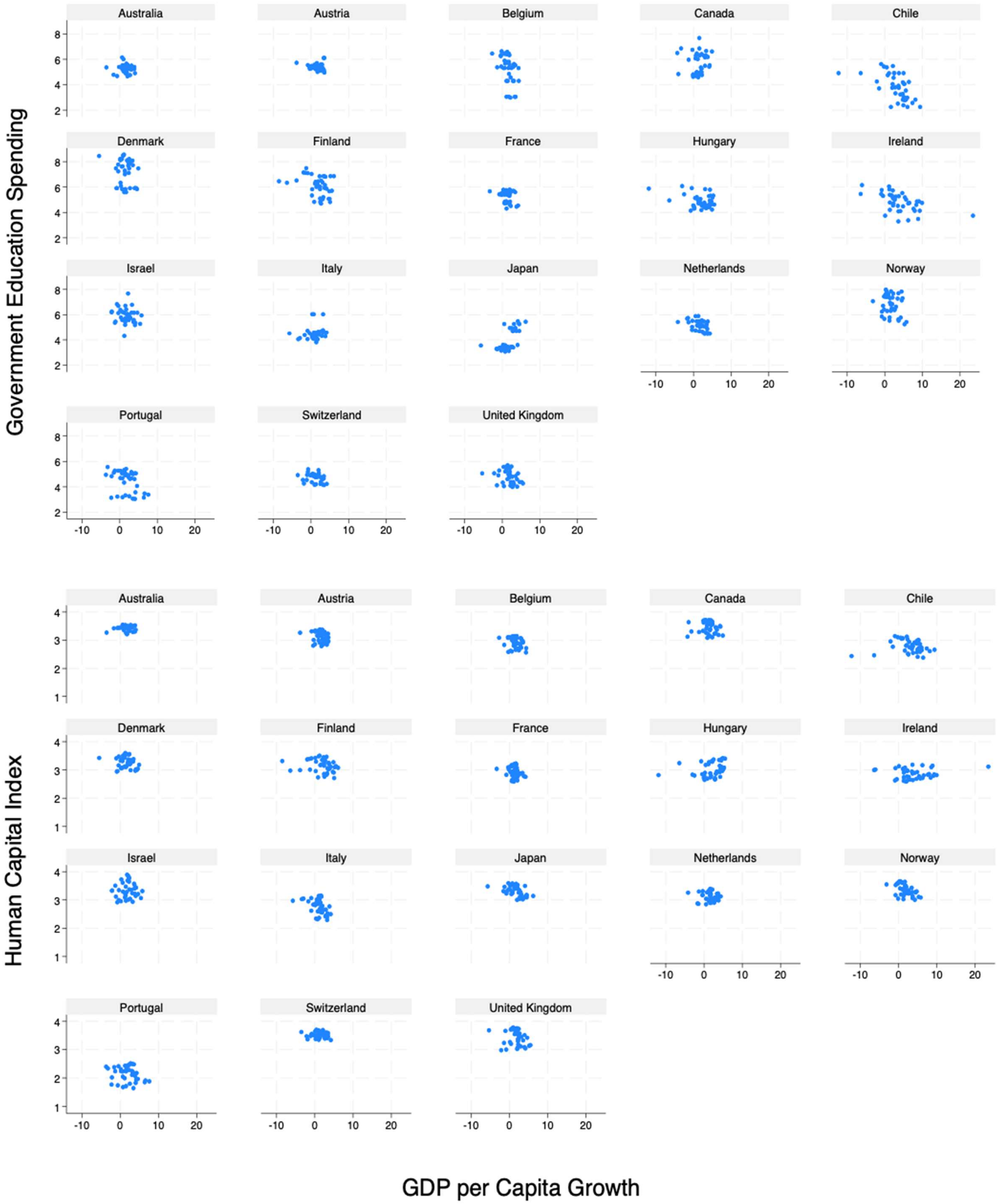


Figure 2: Scatterplots

Controls

Several control variables have been used to isolate the effects of education on economic growth, accounting for other important factors that may influence a country's growth trajectory. All controls are summarised in Table 1 below.

Table 1: Controls		
Control	**Description**	**Source**
GDP per Capita (GDPPC)	Reflects the initial economic level.	WDI
Inflation (INFL)	Reflects price increases and currency purchasing power.	
Fertility (FRTY)	Measures births per woman; proxies for health conditions and long-term labour force dynamics.	
Foreign Direct Investment (FDI)	External capital flows that may boost growth via technology/market access.	
Trade Openness (TO)	Indicates integration into the global economy.	
Population Growth (POP)	Measures the annual increase in a country's population.	
Capital per Worker (CPW)	Shows physical capital available per worker.	PWT
Total Factor Productivity (TFP)	Measures the efficiency of input (capital/labour) use in production.	
Average Annual Hours Worked (AHW)	Reflects labour input.	
Political Rights Index (PRI)	Reflects the political stability and governance of a country.	Freedom House

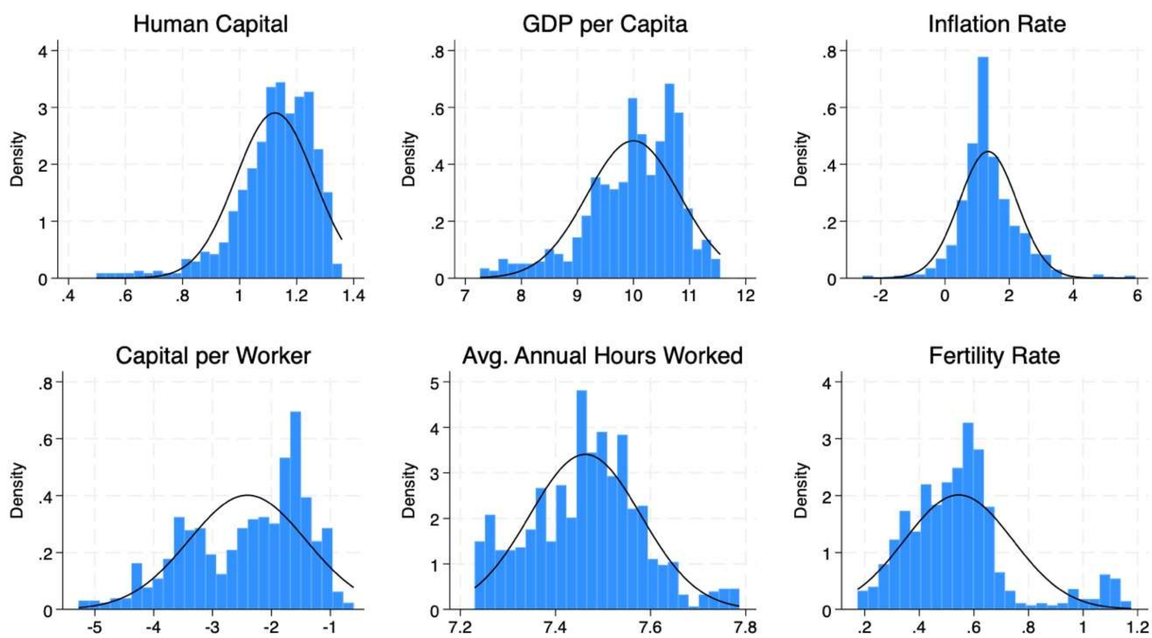
Diagnostics

Prior to proceeding with the methodology and subsequent analysis, several diagnostic tests are conducted to assess the appropriateness of the modelling approach.

Normality

Histograms visually display the distribution of residuals and assess normality. Variables exhibiting skewed distributions are log-transformed, resulting in residuals more closely resembling normality, as illustrated in Figure 3. These variables will be used in their log-transformed version here onwards.

Figure 3: Histograms of Log Transformed Variables



Note: For inflation, +1 was added before log transformation to avoid log(0), since inflation rate can be zero.

Stationarity

A stationary time-series is characterised by a constant mean and variance over time, and the absence of trends. Regressions on non-stationary data can yield spurious results that appear statistically significant despite any true relationship (Hill et al., 2008). This paper applies the Im-Pesaran-Shin (IPS) unit-root test to test stationarity.

Table 2 summarises IPS test results across all variables, both with and without a time-trend to account for linear temporal patterns.

Table 2: Im-Pesaran-Shin Unit-Root Test		
Variable	**t-statistic**	**t-statistic including trend**
GDPGR	-10.638***	-11.234**
GEXP	-1.882 *	-3.149 **
Log(HCI)	-9.425 **	4.903
Log(GDPPC)	1.824	0.279
Log(INFL)	-5.702 **	-8.677 **
Log(CPW)	-6.806 **	6.276
TFP	-0.931	-0.078
FDI	-9.571 **	-11.523 **
TO	3.376	-3.849 **
POP	-1.633	-1.35
Log(AHW)	1.198	-2.784 **
Log(FRTY)	0.744	1.848
PRI	unavailable	unavailable
ΔLog(HCI)	0.831	-2.195*
ΔLog(GDPPC)	-12.015**	-12.353**
ΔLog(CPW)	-5.694**	-8.113**
ΔTFP	-12.959**	-13.622**
ΔTO	-14.721**	-14.967**
ΔPOP	-10.488**	-10.574**
ΔAHW	-14.487**	-14.816**
ΔLog(FRTY)	-11.000**	-11.622**
H0: all panels contain unit roots H1: some panels are stationary ***significant at 1% critical value *significant at 5% critical value* *Δ denotes first difference*		

The null hypothesis can be rejected for most variables both with and without a trend, apart from GDPCC, TFP, POP and FRTY. These variables are non-stationary and should be excluded from the regression model unless found stationary when changed to their first difference form. All variables that are non-stationary either with or without a trend have been differenced and will be used in their most appropriate form for the models employed. For example, if fixed-effects with time trends are deemed appropriate, variables can be used in their original form provided they are trend-stationary. Upon differencing, most variables are significant at the 1% critical value with a time trend except for HCI which is significant at the 5% level.

The Political Rights Index does not return meaningful test results due to its ordinal and bounded nature (1–7 scale). Following political economy literature (Acemoglu et al., 2019; Boix et al., 2013), PRI is treated as stationary given institutional indices rarely exhibit stochastic trends.

Multicollinearity

Multicollinearity arises when the relationship between independent variables in a regression model are highly correlated. This complicates the identification of individual effects on the dependent and is visually inspected through a correlation matrix. Total Factor Productivity is highly correlated with GDP-per-capita with a value of 0.74, indicating strong multicollinearity. TFP will therefore be excluded from regression analysis to avoid overfitting and ensure model stability.

The variance inflation factor (VIF) results also show no evidence of harmful multicollinearity, with all VIF values significantly below conventional thresholds (maximum VIF = 1.32, mean VIF = 1.18).

Methodology

A panel dataset is used due to its multidimensional characteristics which offer many observations across both cross-sectional and temporal dimensions. This approach is widely adopted in education-growth literature with many employing panel techniques to investigate how education contributes to growth. This section outlines the empirical strategy adopted.

Initially, a Pooled OLS model is used to establish a baseline overview of the relationship between education and economic growth. This model treats the dataset as one singular cross-section, assuming homogeneity across countries and ignoring country-specific characteristics. However, if unobserved fixed-effects or time-varying confounders are present, its estimates can be biased (Hsiao, 2014). As such, this model serves as a preliminary benchmark, with fixed or random-effects models used to better account for heterogeneity.

Fixed Effects

To address this bias the analysis progresses towards Fixed Effects (FE) Models. FE estimators control for unobserved heterogeneity within countries by including country-specific fixed-effects. This is useful in controlling for factors like institutional frameworks which remain constant over time yet differ between countries. The FE specification accounting for country and time fixed-effects takes the following form:

$$y_{it} = \beta_1 \chi_{it} + \alpha_i + \delta_t + \varepsilon_{it}$$

where y_{it} represents the dependent variable for country i at time t, χ_{it} represents one of the independent variables and β_1 its associated coefficient. The term α_i captures the country-specific intercept, controlling for unobserved heterogeneity across countries. δ_t accounts for time fixed-effects, reflecting shocks or trends affecting all countries in a given period, and ε_{it} is the error term capturing idiosyncratic errors unexplained by the model. Incorporating all controls as well as both country and time fixed-effects yields the following equation:

$$y_{it} = \beta_1 \chi_{it} + \beta_2 \chi_{it} + \beta_3 \chi_{it} + \ldots . \beta_9 \chi_{it} + \alpha_i + \delta_t + \varepsilon_{it}$$

Where y_{it}represents GDP-per-capita growth (GDPGR) for country i at time t. The independent variables represented by χ_{it} include education expenditure (GEXP) and HCI as well as all other controls. The coefficients $\beta_1, \beta_2 \ldots . \beta_9$ correspond to each of the variables and reflect the direction and magnitude of the relationship between the independent and growth.

Random Effects (RE) Models are also considered to determine whether country-specific effects are uncorrelated with the regressor. RE models assume α_i is uncorrelated with the independent variables, allowing for both within-country and between-country variations to be exploited. RE models are more efficient than FE models when the assumption holds, as it uses information from both the cross-sectional and time-series dimensions of the data. However, if the assumption of no correlation between the country-specific effects and the regressors is violated, RE models can produce biased estimates. To empirically justify the choice between FE and RE, a Hausman (1978) test is conducted, which compares the consistency of the two estimators under the null hypothesis of no systematic differences. If the test rejects the null ($p < 0.05$), FE is preferred.

Time Lags

To test the second hypothesis which looks to investigate the long-run impact of education on economic growth, time lags are incorporated into the model to account for the delayed effects of education spending and human capital development. This is consistent with the theoretical framework of endogenous growth models (Lucas, 1988; Romer, 1990), which find that education investments can take years to manifest into productivity gains. The inclusion of lagged education variables can empirically be captured through the following specification:

$$y_{it} = \sum_{k=0}^{K} \beta_k \, \mathrm{EDUCATION}_{i,t-k} + \delta \mathrm{X}_{it} + \alpha_i + \gamma_{it} + \varepsilon_{it}$$

where $\mathrm{EDUCATION}_{i,t-k}$ represents GEXP or HCI lagged by k-years, and controls are represented by X_{it}. α_i and γ_{it} represent the country and time fixed-effects respectively and ε_{it} the error term.

Incorporating lags is consistent with the approach of Krueger & Lindahl (2001), Cohen & Soto (2007) and De Vries (2015) who employ lag structures to observe long-run effects and address two critical challenges. The first is the issue of delayed effects, whether it be input based in the form of education spending or outcome based in the form of improved human capital, the effects of education on growth materialise overtime. The second challenge relates to endogeneity and specifically the issue of reverse causality. Economic growth itself can influence education spending or human capital outcomes – as economies expand the demand for education rises from individuals seeking better opportunities, and industries requiring a more skilled workforce in response to structural transformation and technological advancement. Failing to account for this potential simultaneity bias can lead to bias coefficient estimates.

Separate regressions will be run for Human Capital Index and education spending with both variables investigated in relation to GDP-per-capita growth. This dual approach expands on existing research, offering a more detailed and recent overview of how education contributes to growth.

Results

This section presents the empirical results of the study, exploring how education contributes to economic growth using two primary indicators: education-related government expenditure (representing input) and the Human Capital Index (representing output). The analysis considers current and delayed effects, capturing both short and long-term trends.

Initial Effects of Education on Growth

Initial regressions are used to test Hypothesis 1 which states a positive relationship between education and growth. The coefficients of GEXP are consistently negative and significant across all models. This contradicts H1 which speculates a positive relationship between education and growth. Models using HCI as a proxy for education on the other hand output positive coefficients in support of H1. Results are summarised in Table 3.

Table 3: Initial effects of GEXP and HCI								
Independent	**Pooled OLS (Robust SEs)**		**Random Effects (RE)**		**Country Fixed Effects (FE)**		**Country and Time FE**	
GEXP	-0.337* (0.170)		-0.412*** (0.083)		-0.734*** (0.110)		-0.484*** (0.980)	
ΔLog(HCI)		88.951* (28.628)		102.596*** (30.255)		128.051*** (34.001)		37.845 (32.196)
ΔLog(GDPPC)	9.703*** (1.493)	10.049*** (1.850)	9.356*** (0.792)	9.694*** (0.794)	8.483*** (0.771)	9.024*** (0.781)	14.161*** (1.106)	14.725*** (1.120)
Log(INFL)	-0.051 (0.210)	-0.140 (0.213)	-0.080 (0.097)	-0.155 (0.101)	-0.179* (0.099)	-0.197* (0.104)	-0.432*** (0.121)	-0.423*** (0.123)
ΔLog(CPW)	-29.564 (23.839)	-47.503 (30.502)	-59.132*** (20.157)	-75.133*** (20.319)	-129.806*** (21.756)	-129.861*** (22.251)	-103.124*** (19.500)	-101.085*** (19.887)
FDI	0.026 (0.028)	0.030 (0.029)	0.025*** (0.009)	0.028*** (0.009)	0.022** (0.009)	0.023** (0.009)	0.032*** (0.008)	0.033*** (0.009)
ΔTO	0.166*** (0.016)	0.173*** (0.015)	0.166*** (0.016)	0.171*** (0.016)	0.164*** (0.158)	0.167*** (0.016)	0.138*** (0.019)	0.140*** (0.020)
ΔPOP	0.366 (0.651)	0.383 (0.689)	0.323 (0.345)	0.336 (0.348)	0.232 (0.332)	0.263 (0.340)	0.249 (0.298)	0.243 (0.303)
ΔAHW	0.021*** (0.003)	0.019 (0.003)	0.021*** (0.004)	0.019*** (0.004)	0.022*** (0.004)	0.021*** (0.004)	0.017*** (0.004)	0.015*** (0.004)
ΔLog(FRTY)	-1.180 (5.079)	-1.24 (5.211)	-0.339 (3.317)	0.371 (3.344)	-0.072 (3.262)	2.901 (3.300)	5.575* (3.153)	7.680** (3.181)
PRI	0.091 (0.192)	0.141 (0.190)	0.043 (0.120)	0.071 (0.121)	-0.062 (0.127)	-0.082 (0.130)	-0.198* (0.116)	-0.198* (0.118)

Constant	3.066*** (1.010)	0.855*** (0.202)	3.666*** (0.503)	0.997*** (0.250)	5.867*** (0.641)	1.318*** (0.272)	6.075*** (0.748)	3.246*** (0.625)
R-squared	0.323	0.312	0.319	0.309	0.272	0.285	0.476	0.482
Breusch and Pagan LM test (p-value)			0.000***	0.000***				
Hausman Test (p-value)					0.000***	0.000***	0.000***	0.020**
Dependent Variable: GDP per Capita Growth Rate | Standard Errors shown in parathesis | Δ denotes first difference ***significance at 1% critical value ** significance at 5% critical value * significance at 10% critical value								

Education Spending and Growth

Pooled OLS estimates reveal a statistically significant and negative relationship between GEXP and GDPGR (-0.337, $p<0.10$), though the reliability of this coefficient is limited by potential omitted variable bias due to unobserved country-level heterogeneity, despite the use of robust standard errors. A Random Effects (RE) specification which accounts for time-invariant cross-country differences is used to mitigate these concerns and yields an increasingly significant coefficient (-0.412, $p<0.01$) suggesting a stronger negative association. The Breusch-Pagan Lagrange Multiplier test is then employed and returns a p-value of 0.000, providing strong evidence in favour of the RE model.

However, the Hausman test which compares Random and Fixed Effects returns a highly significant p-value, indicating that RE estimates are inconsistent. This is due to correlation between the regressors and unobserved effects, thereby preferring FE.

FE estimates further increase the magnitude of the GEXP coefficient to -0.734 with significance at the 1% level. A similar result is found in the two-way fixed-effects model (controlling for both country and time effects), where the GEXP coefficient is -0.484 and remains highly significant. This persistence across models supports the robustness of an inverse relationship and directly contradicts Hypothesis 1.

The overall R-squared value is highest for the two-way FE model at 0.476 indicating that approximately 47% of the variation in GDP-per-capita growth within OECD countries can be explained by the included independent variables. Although R-squared is secondary to theoretical considerations in panel model selection, its improvement following the inclusion of time effects indicates that accounting for temporal dynamics enhances the model's explanatory power. The coefficient of GEXP in the final country and time FE model is -4.84 meaning that a 1% increase in education spending as pct GDP is associated with a 0.48% decrease in GDP-per-capita growth, ceteris paribus. The coefficients of most controls in the GEXP initial two-way FE model are highly significant except for Population Growth, Fertility and the Political Rights Index. Population Growth especially is consistently insignificant across all models.

Consistently positive and significant effects are observed for Trade Openness, FDI and Average Hours Horked (ΔAHW), aligning with expectations that trade, external capital and labour input support economic activity. Inflation and Capital per Worker on the other hand are negatively associated with growth, with INFL becoming significant only in FE models.

Human Capital and Growth

Models using HCI as a proxy for education support H1, reinforcing the idea that education plays a key role in driving economic performance.

The coefficients of ΔLog(HCI) remain positive across all models (Pooled OLS, RE and FE), increasing in magnitude as controls for unobserved heterogeneity are added. The Breusch-Pagan Lagrange Multiplier and Hausman tests are employed for HCI models and support the use of FE.

Coefficients increase from 88.951 ($p < 0.10$) in Pooled OLS to 102.596 ($p < 0.01$) under Random Effects, and further to 128.051 ($p < 0.01$) in the Fixed Effects model. This upward trend indicates that failing to account for country-level heterogeneity likely underestimates the true impact of HCI on growth. However, once both country and time fixed-effects are included, the coefficient of HCI declines sharply to 37.845 and loses statistical significance. This suggests that much of human capital's apparent effects in simpler models may reflect omitted institutional and cultural factors that simultaneously promote both skill accumulation and economic growth, as argued by Acemoglu et al. (2014).

The coefficients of all control variables except for Population Growth remain significant and consistent in both magnitude and direction with those found in the initial GEXP regressions. The overall R-squared value for the HCI model is 0.482, marginally higher than the equivalent GEXP model, indicating slightly greater explanatory power when using education outcomes as opposed to inputs.

Delayed Effects of Education on Growth

Whilst initial regressions provide insight into the immediate relationship between education and growth, returns to educational investment are widely understood to be long-term in nature. This section investigates the lagged effects of education with the aim of testing Hypothesis 2 which predicts the effects of education to be delayed.

Both education proxies (GEXP and HCI) are lagged at 5-year intervals ranging from 5 to 30-years to investigate the long-run impact of education on GDP-per-capita growth. The main results estimated using a two-way fixed-effects model controlling for both country and time effects, are summarised in Table 4. For comparative and robustness purposes, additional regressions using Pooled OLS and country-only fixed-effects models were also considered.

An initial look at the country and time FE estimates for both proxies of education reveals a changing relationship over time. The coefficient for GEXP is negative at the 5-year lag (-0.123) but becomes positive over time. HCI coefficients are more stable and positive over the lag years, except a notable dip at the 15-year lag (-14.140). The 15-year lag is a critical point for both GEXP and HCI as it marks the point at which coefficients become statistically significant and negative before recovering to positive values by the 25-year lag. All other lagged estimates remain statistically insignificant, with the exception of a positive 10-year GEXP effect (0.245).

TABLE 4: Delayed effects of GEXP and HCI

Country and Time Fixed Effects

Independent	**Government Expenditure on Education**						**Human Capital Index**					
Lag Length	5-years	10-years	15-years	20-years	25-years	30-years	5-years	10-years	15-years	20-years	25-years	30-years
Education	-0.123	0.245**	-0.204*	-0.125	0.241	0.347	30.164	113.27***	-14.140	112.728	122.521	84.592
	(0.104)	(0.110)	(0.108)	(0.128)	(0.184)	(0.345)	(33.298)	(36.142)	(41.072)	(79.520)	(103.166)	(231.251)
ΔLog(GDPPC)	14.177***	14.976***	14.464***	14.048***	14.757***	15.848***	14.181***	15.587***	13.653***	14.930***	14.167***	19.211***
	(1.242)	(1.372)	(1.458)	(1.710)	(2.212)	(2.875)	(1.255)	(1.385)	(1.502)	(1.800)	(2.427)	(3.450)
Log(INFL)	-0.305**	-0.430***	-0.419***	-0.331*	-0.356	-0.105	-0.333**	-0.417***	-0.437***	-0.364*	-0.335	-0.140
	(0.131)	(0.150)	(0.154)	(0.182)	(0.238)	(0.317)	(0.137)	(0.149)	(0.159)	(0.185)	(0.250)	(0.438)
ΔLog(CPW)	-105.617***	-102.438***	-76.505***	-61.532***	-37.697	-44.991	-106.748***	-104.972***	-70.687***	-54.060**	-46.823*	-48.759
	(19.448)	(19.605)	(20.124)	(23.397))	(27.038)	(33.422)	(19.565)	(19.550)	(21.113)	(23.742)	(28.106)	(37.018)
FDI	0.034***	0.033***	0.027***	0.031***	0.033***	0.033**	0.032***	0.028***	0.029***	0.032***	0.035***	0.036**
	(0.010)	(0.009)	(0.008)	(0.009)	(0.010)	(0.013)	(0.009)	(0.008)	(0.008)	(0.009)	(0.010)	(0.014)
ΔTO	0.143***	0.128***	0.104***	0.110***	0.117***	0.117***	0.142***	0.139***	0.106***	0.109***	0.120***	0.103**
	(0.020)	(0.020)	(0.020)	(0.022)	(0.028)	(0.038)	(0.020)	(0.020)	(0.021)	(0.024)	(0.030)	(0.043)
ΔPOP	0.187	0.061	0.961**	0.761	0.607	-0.183	0.114***	-0.101	0.870*	0.683	0.629	-0.505
	(0.300)	(0.309)	(0.481)	(0.510)	(0.580)	(0.730)	(0.303)	(0.315)	(0.490)	(0.514)	(0.605)	(0.825)
ΔAHW	0.016***	0.016***	0.013**	0.016**	0.025***	0.029**	0.016***	0.017***	0.014**	0.018**	0.030***	0.016
	(0.004)	(0.005)	(0.006)	(0.007)	(0.009)	(0.013)	(0.005)	(0.005)	(0.006)	(0.007)	(0.010)	(0.018)
ΔLog(FRTY)	8.002**	10.678***	10.432***	7.047	8.769	16.426**	7.888**	11.634***	10.745***	6.354	9.627	14.791
	(3.336)	(3.628)	(3.788)	(4.365)	(5.722)	(7.591)	(3.421)	(3.655)	(3.880)	(4.531)	(6.149)	(9.233)
PRI	-0.007	0.207	0.394	0.242	0.539	0.506	0.132	0.084	0.251	0.252	0.690	0.483
	(0.158)	(0.295)	(0.303)	(0.362)	(0.446)	(0.568)	(0.177)	(0.304)	(0.324)	(0.379)	(0.467)	(0.641)
Constant	3.633***	-0.452	2.301***	4.088***	-0.499	-1.712	0.080	0.465	2.676***	1.297	-0.374	-1.742
	(0.757)	(0.839)	(0.817)	(0.965)	(1.127)	(1.966)	(0.675)	(0.641)	(0.581)	(0.850)	(1.054)	(1.922)
R-squared	0.484	0.489	0.546	0.558	0.576	0.426	0.488	0.508	0.547	0.512	0.559	0.426

Notes to Table 4.

Dependent Variable: GDP per Capita Growth Rate.Standard Errors shown in parathesis Δ denotes first difference. ***significance at 1% critical value ** significance at 5% critical value * significance at 10% critical value. Note also that 'Education' represents either GEXP or ΔLog(HCI) as specified and is the ONLY lagged variable

To further investigate the long-run relationship between education and growth and better observe this turning point, regression coefficients controlling for both country and time fixed-effects have been plotted for GEXP and HCI (Figure 4). A lag is applied for each individual year from 1 to 30-years with separate regressions ran for each of the two independent variables.

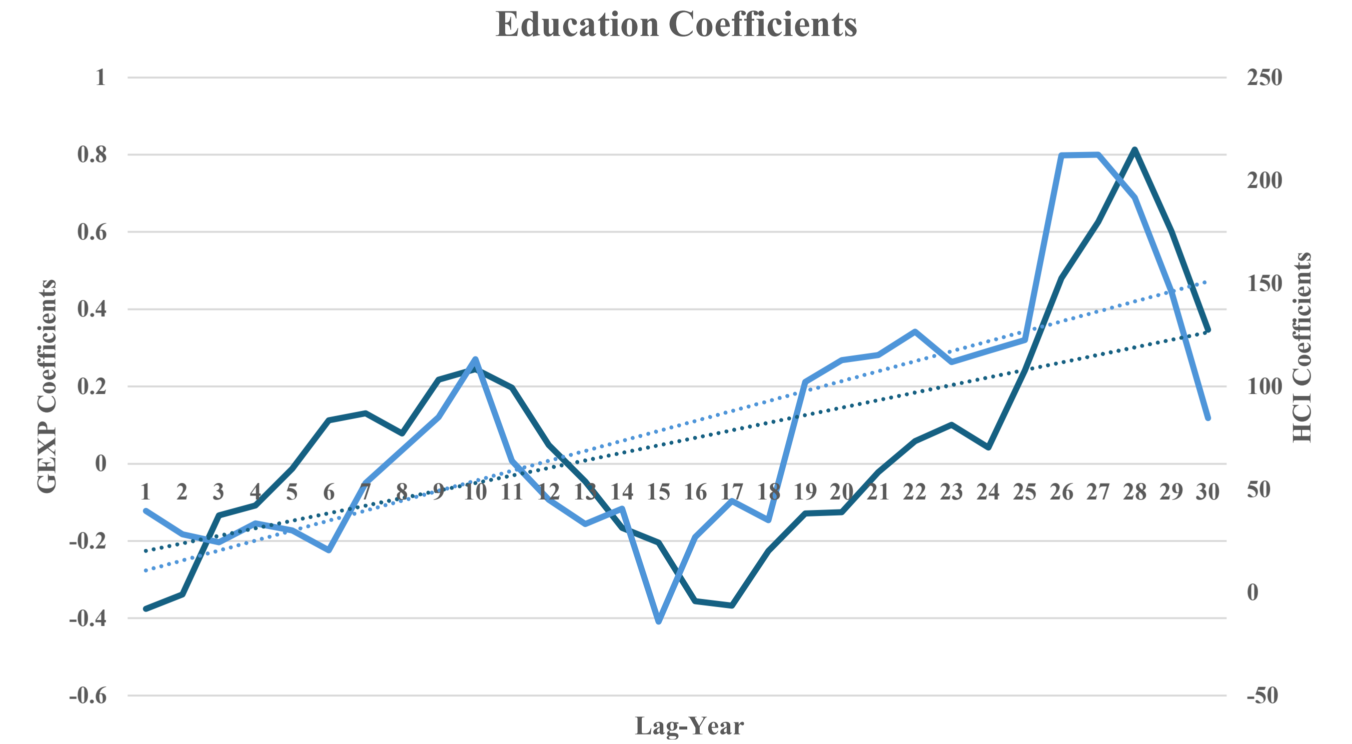


Figure 4: Lagged Coefficients

Neither of the two variables depict a generally linear trend with much variation over time, however a generally positive relationship is seen for both variables between the 4-10 and 15-28 year lags. There are also common segments during which a negative relationship is generally observed for both GEXP and HCI such as the 10-15 and 27-30 year lags. This suggest that the contributions of educational inputs and outcomes in the OECD countries covered can occur in distinct phases or episodes. Taking a theoretical approach, education exhibiting a positive relationship with growth during these distinct phases can be interpreted through consideration of the transmission mechanisms through which education contributes to growth.

Higher government spending on education can lead to better access and quality within the education system in the form of increased teacher training or the provision of learning materials and facilities. Such improvements can raise overall attainment contributing to a higher HCI, particularly for individuals completing their academic journey. Bachelor's degrees as an example tend to be 3-4year courses, highlighting a medium-term window through which education spending and human capital development can yield returns as students transition into the workforce. De Vries (2015) found similar patterns, identifying 'surges' in education spending with positive effects on growth lasting 4-5 years at the 3 and 22-year lag.

These dynamics suggest that the relationship between education and growth is not always linear or uniformly positive. Studies have addressed these non-linearities using squared terms (Hanushek & Woessmann, 2012), or interaction effects (Vandenbussche et al., 2009). While this dissertation does not explore non-linear specifications, future research could benefit from considering this.

However, the validity of these coefficients relies on their statistical significance as evaluated using 95% confidence intervals (Figure 5). GEXP shows significant negative effects in early lags shifting to positive in later periods, with some transitional ambiguity. HCI estimates are generally less precise with wide intervals often crossing zero. Some later HCI lags show strong positive estimates, though broad CIs reduce confidence in their reliability.

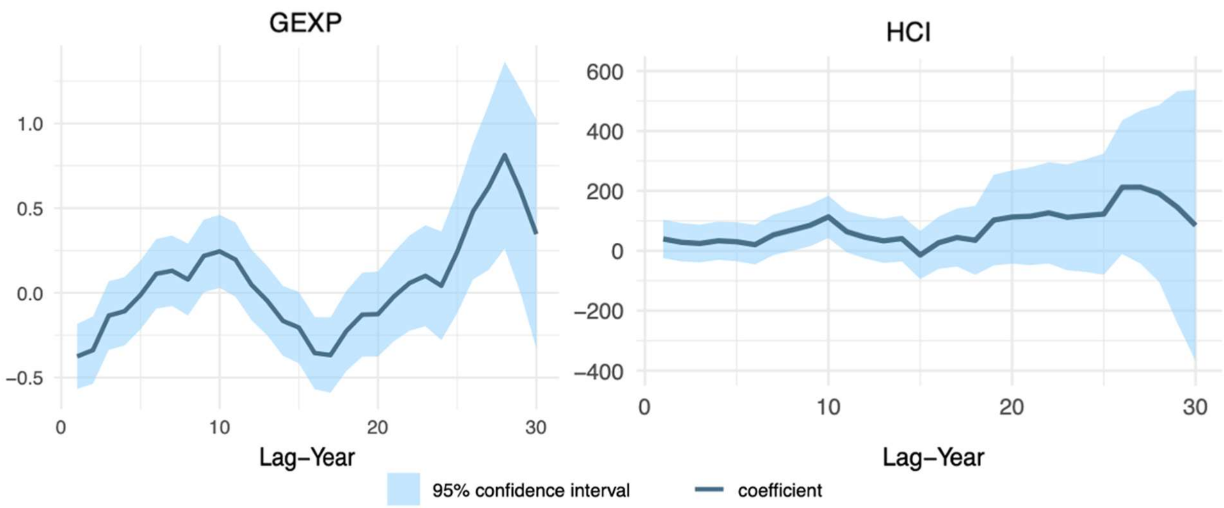


Figure 5: Confidence Intervals

Looking at the controls in Table 4, many results align closely with those of Table 3, revealing several consistent relationships. A negative and mostly significant relationship is observed for INFL and CPW, with other variables apart from PRI and POP outputting significant and positive results. Most controls exhibit a general pattern. For instance, FRTY shows a positive and increasing effect up to a 20-year lag, after which it declines before rising again. The average R-squared across all lags for both proxies of education is 0.51, suggesting that whilst the included controls capture some determinants of growth, they do not reflect the full picture.

Conclusion

This dissertation investigates the relationship between education and economic growth, with a focus not only on education input (government education spending, GEXP) but also outcome (measured through human capital development, HCI).

The effects of both GEXP and HCI are investigated in two parts, initially focusing on the immediate relationship between education and growth. GEXP portrays a negative and significant association, whereas HCI demonstrates a positive and significant relationship with the exception of a country and time fixed-effects model in which HCI loses statistical significance.

Subsequent regressions investigate the long-run and potentially delayed relationship between education and growth. Most coefficients for both education proxies are statistically insignificant, except at the 10-year lag for both GEXP and HCI, and at the 15-year lag for GEXP. Results are therefore ambiguous however GEXP displays a positive effect over time, indicating that educational investments can take years to translate into growth. The impact of HCI in contrast is mostly positive albeit insignificant apart from at the 15-year lag.

It can therefore be concluded that educations contributions to growth vary with input and outcome measures. Whilst an immediately negative relationship is observed for input measure GEXP, the coefficients of outcome measure HCI remain positive thought insignificant in the short-run. There are fluctuations in observations assessing the delayed effects of GEXP, yet HCI remains largely positive. Given the persistence of insignificant and fluctuating results, neither of the two hypotheses can be conclusively validated.

Policy Implications

Contrasting results for GEXP and HCI suggest the effectiveness of education policy depends not solely on investment, but also on its efficiency and alignment with long-term human capital development. The conversion of investment into tangible improvements in human capital is what ultimately matters most. Education policies should therefore focus on improving the institutional and delivery mechanisms that determine how effectively spending translates into long-term productivity and human capital accumulation.

Limitations

Limitations relate largely to methodological constraints. Although fixed-effects controls for time-invariant country heterogeneity, endogeneity issues remain due to potential reverse causality and omitted variable bias. Future studies could address this through use of instrumental variables (IV) to mitigate reverse causality by exploiting exogenous sources of variation in education. The bidirectional link between education investment and human capital formation also warrants further investigation, as increased spending can drive improvements in human capital, which in turn supports long-term growth. A Two-Stage Least Squares model utilising an IV in the first-stage to isolate exogenous variations in education spending could be employed to better explore this causal pathway.

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