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Education Expenditure and Economic Growth of GCC Countries: New Evidence from Panel ARDL and Wavelet Coherence Approaches

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ABSTRACT

This study investigates how government education expenditure (EDE) and research and development (R&D) spending shape economic growth in the Gulf Cooperation Council (GCC) countries. Using annual panel data for Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates over 1998–2021, the analysis applies a panel autoregressive distributed lag (ARDL) framework to separate short-run from long-run effects and to capture equilibrium dynamics through the error-correction term (ECT). To uncover time–frequency co-movement and horizon-dependent effects, the econometric evidence is complemented with wavelet coherence analysis. The panel ARDL results indicate that EDE is positive and statistically significant in both the short run and the long run, supporting the view that higher public education spending raises GDP contemporaneously and also contributes to long-term output expansion. Wavelet coherence further shows that EDE and GDP are predominantly in-phase (positively associated) in the short run, while the long-run influence of EDE on GDP is weak or not clearly sustained in the time–frequency domain, suggesting that the strongest growth payoffs from education spending may materialize over shorter horizons despite the long-run cointegrating relationship identified in the panel ARDL estimates. For R&D, the coefficient is positive and significant in the long run but insignificant in the short run, indicating that innovation expenditures support growth primarily through longer-gestation channels. Wavelet coherence reveals that R&D and GDP are in-phase across both short- and long-run horizons, consistent with the notion that innovation activity co-moves positively with output over time even when immediate short-run ARDL effects are statistically weak. The findings imply that education spending delivers more immediate growth impulses, whereas R&D spending strengthens long-term growth and diversification, supporting a balanced policy mix for GCC economies.

Keywords: Economic growth; Education expenditure; Research & development; GCC countries; Panel ARDL.

INTRODUCTION

Economic growth, commonly proxied by gross domestic product (GDP) growth, remains a central indicator of whether an economy is expanding its productive capacity, generating employment, and sustaining improvements in living standards. However, the global macro environment has become more uncertain and less supportive of rapid growth. The International Monetary Fund (IMF), for example, projected global growth to slow from 3.5% (2022) to 3.0% (2023) and 2.9% (2024), reflecting tighter financial conditions and persistent structural headwinds. This context strengthens the policy relevance of identifying which growth inputs—particularly public investments—produce durable GDP gains.

The importance of education as a driver of economic development is well established in both classical and modern growth theory. From Adam Smith's emphasis on skills and specialization to neoclassical and endogenous growth frameworks, education and innovation are consistently treated as mechanisms that raise productivity and the economy's long-run output path (Ahmad & Mokal, 2024). Solow's (1957) neoclassical growth model highlights the role of productivity in sustaining growth beyond factor accumulation, while Lucas and Romer formalize how human capital and knowledge creation can generate persistent growth effects. Consistent with these theoretical foundations, a large empirical literature has examined the education–R&D–growth nexus and its implications for output performance (Hussin et al., 2012; Mercan & Sezer, 2014).

Education represents a core component of human capital investment with clear micro-to-macro transmission channels. At the individual level, higher education and skills are associated with improved earnings prospects, stronger employability, and reduced unemployment risk; at the firm and economy levels, these improvements translate into higher productivity, better job matching, and greater capacity to adopt and generate new technologies (Mokal & Ahmad, 2023). Consequently, raising education levels—and complementing them with research and development (R&D)—is frequently viewed as an effective policy lever to address unemployment and poverty, particularly in developing and transitioning economies. In this sense, education spending is not merely a social-sector allocation but a forward-looking investment in a nation's growth potential.

This growth logic is especially salient for the Gulf Cooperation Council (GCC) economies—Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE)—which have historically relied heavily on hydrocarbon revenues and are actively pursuing diversification toward knowledge-based development. In macroeconomic terms, the GCC economies are sizeable and strategically significant: recent World Bank estimates place 2024 GDP (current US$) at approximately Saudi Arabia: 1.24 trillion, UAE: 552.3 billion, Qatar: 219.2 billion, Kuwait: 160.2 billion, Oman: 107.1 billion, and Bahrain: 47.1 billion. These magnitudes underline why the growth consequences of education and R&D spending—if empirically established—carry substantial regional and global relevance.

Recent data also indicate meaningful variation in the GCC's education and innovation effort, reinforcing the need to treat education and R&D spending as measurable growth inputs. World Bank indicators report government expenditure on education of about 5.1% of GDP for Saudi Arabia (2023) and 3.9% for the UAE (2021). On the innovation side, R&D expenditure differs sharply across the bloc, with the UAE reporting about 1.49% of GDP (2021) while Kuwait reports about 0.10% (2023). Such dispersion suggests that the GCC is not a uniform policy space in human-capital and innovation investment, creating an empirical opportunity to evaluate whether higher education and R&D intensity is systematically associated with stronger GDP growth.

The urgency of this research is heightened by the GCC's exposure to oil-market cycles and the fiscal trade-offs they create. Reuters reported that Brent crude fell about 19% over 2025, its third consecutive annual decline, reflecting oversupply concerns and broader uncertainty. At the same time, country-level macro outcomes and financing choices underscore the pressure to ensure that public spending supports resilient growth: Saudi Arabia's economy grew 1.3% in 2024, driven by stronger non-oil activity (4.3%) despite weakness in oil-related output. Regionally, the World Bank noted that while GCC economies remain resilient and diversification is advancing, softer oil prices are widening fiscal deficits and pushing debt ratios upward. In parallel, Saudi Arabia approved a 2026 borrowing plan with financing needs of about 217 billion riyals ($57.9 billion) to cover deficits and maturing debt as it continues large-scale investment under Vision 2030. Together, these developments elevate the practical question: which growth-enhancing expenditures—education and/or R&D—justify priority under tighter fiscal constraints?

Prior studies provide valuable foundations but also leave identifiable gaps. Al-Yousif (2008) examined the education–growth relationship in the six GCC economies (1977–2004) using a Granger-causality test within an error-correction framework and reported mixed results that vary by country and human-capital measure. Benlaria et al. (2023) focused on the GCC and modeled government R&D support as a moderator in the entrepreneurship–output relationship, highlighting the policy role of innovation spending but not directly estimating the joint, dynamic effects of education and R&D on GDP growth. Ahmadini (2025) investigated public education spending and GDP in Gulf countries (1980–2022) using a fixed-effects panel approach, offering updated regional evidence but with more limited treatment of long-run adjustment dynamics and without fully integrating R&D as a parallel growth input. Finally, Diakodimitriou (2025) provided broader cross-country evidence that education expenditure significantly influences income performance and identified R&D as a main channel through which education affects growth—an important mechanism that still warrants GCC-specific validation given the region's distinctive economic structure. Collectively, these studies motivate a focused contribution that jointly models education and R&D spending, distinguishes short-run from long-run effects, and updates inference for the contemporary GCC policy environment.

Against this background, the purpose of this study is to quantify how education spending and R&D spending (as shares of GDP) affect GDP growth in GCC countries over the period 1998–2021. Methodologically, the study applies a panel autoregressive distributed lag (panel ARDL) framework to estimate both short-run dynamics and long-run relationships, thereby capturing adjustment processes that static panel methods may overlook. The study's novelty lies in its combined treatment of education and R&D as joint public-investment drivers of growth within a single dynamic framework, and in its policy relevance for diversification-era fiscal choices. The expected benefit is practical: by clarifying whether (and when) education and R&D expenditures translate into measurable GDP growth gains, the findings can inform GCC governments on how to prioritize human-capital and innovation allocations to strengthen resilience, reduce oil-cycle vulnerability, and support sustainable long-run economic performance. The remaining part of the paper presents the previous literature related to the variables in the context of GCC countries. Subsequently, research methodology is presented in section 3 of the paper. Results and Conclusions and Policy Implications are presented in sections 4 and 5, respectively.

METHOD

This panel data study estimates the effect of spending on education and R&D on GDP growth in the Gulf Cooperation Council (GCC) from 1998 to 2021. The fundamental rationale for employing panel data is that it quantifies the effect on a collective rather than on individual units, hence minimising data loss. Another benefit of panel data analysis is that it eliminates heteroscedasticity (Hu et al., 2023; Sun et al., 2023) since it minimises noise from individual time series (Chen et al., 2023; Westerlund, 2007). Also, when there is a lack of data, panel data works best (Aldieri et al., 2023), which is especially true in developing nations with available short-period variables. By including subject-specific variables and dynamic changes caused by repeated cross-sectional observations, panel estimate techniques account for this variability. According to Khan et al. (2020) and Shastri et al. (2018), panel-ARDL is the name of heterogeneous panel data modelling that is the exclusive focus of this study. The generalized ARDL (p, q, q, …, q) model is specified as:

$$Y_{it}=\sum_{j=1}^{p} \delta i Y_{i,t-j} + \sum_{j=0}^{q} \beta' X_{i,t-j} + \varphi_i + \varepsilon_{it} \qquad [1]$$

Where Yit is the dependent variable, $(X'_{it})'$ is a (k X 1) vector that is allowed to be pure I (0) or I (1) or cointegrated, δ_I id the coefficient of the lagged dependent variables called scalars; β_{ij} are K x1 coefficient vector; φ_i is the unit-specific fixed effect; I, …, N; t=1, 2, 3, …, T; p, q are optimal lag orders; ε_{it} is the error term.

The re-parameterized ARDL (p, q, q, q, …, q) error correction model is specified as:

$$\Delta Y_{it} = \theta_i [Y_{it-1} - \lambda' X_{i,t}] + \sum_{j=1}^{p-1} \xi_{ij} \Delta Y_{it-j} + \sum_{j=1}^{p-1} \beta_{ij} \Delta X_{i,t-j} + \varphi_i + \varepsilon_{it} \qquad [2]$$

Where θ_i is the – (1- δi) shows the group-specific speed of adjustment coefficient (expected that $\theta_i<0$), λ'_I is the vector of long-run relationships, ECT is $[Y_{it-1} - \lambda' X_{i,t}]$ is the error correction term represents the long run information in the model, term and ξ_{it} and β'_{ij} are the short-run dynamic coefficients. Based on the above model, ***y*** is GDP dependent variable including both the lag and difference value for short-run and long-estimation. While ***x*** shows the set of independent variables education expenditure and research and development expenditure their lags and difference value. This study utilises the continuous wavelet transform (CWT) technique, as described by Aladwani (2023) and Huang et al. (2023), to identify and measure the co-movement of variables across various timescales. According to Subasi and Kiymik (2010), the CWT methods incorporate time and frequency with zero mean. One big perk of CWT is that it may be defined by pinpointing it in either time (Δ t) or frequency (Δϋ), or both. Wavelet has two properties - scaling and shifting - that can be modified to create "daughter" wavelets. The continuous wavelet transform (CWT) is defined as the integral over all time of the signal multiplied by scaled, shifted versions of the wavelet function ψ (*scale, position, time*):

$$C(scale, position) = \int_{-\infty}^{\infty} x_t \psi (scale, position, t) dt$$

Where: C is wavelet coefficient; t is time. The high and low frequencies of the signal are captured by the wavelet transform, which uses a stretched, scaled, and shifted fundamental function called the mother wavelet. Extending (or contracting, expanding) a wavelet is all that's required to scale it. To advance or defer a wavelet is to shift it. In this study, we rely on the previously mentioned adaptable strategy using wavelet coherence, which counts the sequential relationship between two time series in a bivariate model. Investments in education and R&D and their effects on GDP growth are the primary foci of this analysis. These variables' data are sourced from the World Bank and the World Development Indicator.

Description of Variables

Gross domestic product is one of the most important economic statistics. It is calculated based on the money value of all final products and services manufactured inside the territory of a country over specific durations of time, normally the equivalent of a quarter or a year. There are three different ways to calculate gems: it is possible to record how much was produced, how much money was received; how much was spent through the expense approach. Particularly, the money spent is used by consumers and businesses, governments, and net exporters. Moreover, According to Giannetti et al. (2015), gross domestic product (GDP) is an important economic statistic that determines the monetary value of all final goods and services that are produced inside the borders of a nation within a specific period of time, typically the equivalent of a quarter or a year. It is necessary to use additional metrics in addition to GDP in order to evaluate the health of an economy. This is because it is necessary to take into account income inequality, quality of life, and environmental sustainability, all of which are important considerations when comparing national economies and making decisions regarding policy (Kummu et al., 2018; Tacchella et al., 2018).

According to Ejiogu et al. (2013) government spending on education, or EDU, is the most common nomenclature for the funding source for a given government sector. This sector comprises public elementary, middle, and high schools and colleges and universities, as well as a full range of educational pursuits. 'Distribution of funds reflects a nation's commitment to invest in its human capital and future workforce through teacher compensation, school capital growth, curriculum development, support services for pupils, loan and award programs for students, and research programmes is a prime example of a nation's commitment to invest in its human capital. Governments' Education spending is the government's investment in raising the variety of educational options available to all its citizens and the quality of those options, this, in turn, increases the level and quality of human capital (Oyekan et al., 2015; Mekdad et al., 2014).

As Guo et al. (2018) argue, one excellent way to measure how serious a nation is about increasing its people's technological and scientific capacities in the future is the amount of money spent on research and development. The funding of scientific research, technological development, innovation incentives, research infrastructure, partnerships with industry and academic institutions, and programs designed to tackle capital issues like environmental conservation all fall within the purview of this investment, which necessitates a pro-active approach to it. Investment enable boosting discoveries, increasing economic growth, and keeping a monopoly status in the global economy.There is a consensus among numerous researchers, including Olaoye et al. (2021), Foray et al. (2012), and Falk (2006), that this has a cumulative impact on society and the economy as a whole.

RESULTS AND DISCUSSION

Pre-estimation Results

For empirical analysis, the study uses the panel ARDL dynamic method to investigate the impacts of education expenditure and research and development expenditure on the economic growth of GCC countries. In addition, in order to address the study hypothesis, statistical evaluations are utilised, together with a theoretical and conceptual analysis of the outcomes. The study comprised descriptive statistics of the study variables and a diagnostic test for best-fit models in addition to the empirical outcomes.

Table 1 (a) Descriptive Statistics

Variable	Variable Name	Obs.	Mean	Std. Dev.	Min	Max
GDP	GDP growth (Annual percent change) %	144	.1195023	4.015102	-17.14539	14.71064
EDE	Education expenditure	144	6.11323	4.753726	-2.32722	10.76013
R & D	Research and development expenditure	144	-.6270611	.3866406	-1.49485	.2535825

Sources: World Development Indicators (WDI)

The descriptive statistics in Table 4.1. (a) shows a comprehensive overview of three key variables. First, in the case of GDP growth (Annual percent change) %, analyzed across 144 observations, the data reveals an average annual growth rate of approximately 0.1195%, exhibiting notable variability as indicated by a standard deviation of approximately 4.0151%. The range of this variable extends from a minimum annual contraction of -17.1454% to a maximum growth rate of 14.7106%, reflecting significant economic fluctuations. Second, education expenditure, also encompassing 144 observations, demonstrates an average expenditure level of approximately 6.1132, with a standard deviation of roughly 4.7537. The expenditure on education demonstrates substantial diversity, with recorded values spanning from a minimum of -2.3272 to a maximum of 10.7601. Lastly, research and development expenditure display an average expenditure of approximately -0.6271, with a standard deviation of approximately 0.3866. This variable encompasses a range from a minimum expenditure of -1.4949 to a maximum of 0.2536.

Table 2 (b) Metrix correlation

Variables	EDE	R & D
EDE	1.0000	
R & D	0.0686	1.0000

Here is Table 4.1. (b) A Pearson correlation coefficient of 0.0686 was found in the correlation study between the variables (EDE) and (R&D) in terms of education spending and research and development spending, respectively. With this coefficient, we can infer that the two variables are somewhat positively related to one another. To rephrase, while there is a little trend towards higher spending on education and R&D simultaneously, the connection is weak, suggesting that shifts in either category are not closely linked to each other. This means that the dataset under consideration does not exhibit multicollinearity, a phenomenon in which independent variables are extremely connected with one another. That each variable contributes unique and complementary data that strengthens the subsequent regression test is supported by this.

Unit Root

The Unit Root test is a crucial tool in data analysis with significant importance in empirical research and econometrics for several reasons. It helps researchers to determine whether a given data is stationary or non-stationary, in turn, guide the selection of appropriate econometric models and prevent misinterpretation of results in economic and financial analyses.

Table 3 Unit Root

Variable	I (0)	I (1)
GDP	Stationary	Non-Stationary
EDE	Non-Stationary	Stationary
R & D	Non-stationary	Stationary

Table 4 demonstrates that the Unit Root analysis that was performed on the dataset indicates the stationarity qualities of the variables that are being considered under consideration. A stochastic trend component is not present in the Gross Domestic Product

(GDP) variable since it is determined to be stationary at the level (I (0)). This indicates that the variable does not have a unit root, and as a result, it does not have a stochastic trend component. Education Expenditure (EDE), on the other hand, exhibits non-stationarity at the level (I (1)), which indicates that there is both a unit root and a random trend. Nevertheless, it becomes stationary after one difference; hence, first-order differencing is required in order to attain the desired state of stationariness. In a similar vein, research and development spending is non-stationary at level (I (1)), which may indicate a unit root and a random trend; however, after a single difference, it becomes stationary. The level of confidence for the application of panel ARDL for estimation is determined by the outcome of the unit root test, as stated by Phillips (2023), Çelik et al. (2023), Im et al. (2003), Mokal et al. (2023), Hijazi et al. (2025), and Yamarik et al. (2016). After the unit root test, the selection of optimal lag is based on the most common lag selection for each variable. This selection is then used to represent the lags for the model, such as (1,0,0,0), in order to circumvent the issue of degree of freedom. After the ideal lag has been chosen, the Padroni's cointegration test is carried out in order to determine whether or not the variables are cointegrated over the long run. The works of Pedroni (1999, 2004). The statistical significance of the long-run coefficients and the error correction term are examined in order to determine whether or not cointegration exists.

Table 4 Cointegration

Test Stats.	Panel	Group
v	1.085	.
rho	-3.111	-2.168
t	-5.014	-5.326
adf	-2.172	-2.857

In Table 4 of our analysis, the importance of cointegration testing becomes quite clear. In this study, we carefully explore whether there are enduring relationships among the variables we have used for our estimations. We accomplish this by comparing two distinct sets of cointegration outcomes. Please take note that we rejected the null hypothesis (the idea that there are no persistent linkages) completely at the 1% level of significance for both group and panel data. This is something that you should take into consideration. It is vital to do cointegration testing in order to uncover significant and long-lasting correlations between the variables that are being investigated (Wagner et al., 2023). As a result of this discovery, which validates the connections that we discovered in the data, the findings that we derived from our research are now more trustworthy.

Post-estimation Results

Following the application of the Hausman test criteria is a crucial step that must be completed before moving on to the estimation. In order to make an informed decision between the Mean Group (MG) and Pooled Mean Group (PMG) estimating methodologies, it is essential to conduct this test since it provides assistance. The selection is made based on the likelihood value that was obtained from the test. In situations where the p-value of the Hausman test is higher than the 5% level of significance, the PMG estimate approach is the one that yields the most accurate results. The significance of this option lies in the fact that it ensures the use of the appropriate method for estimation, one that is compatible with the characteristics of the data that is being utilised. Through the methodical application of this criterion to all of the GCC nation panels of datasets, this study establishes a foundation for future research in terms of methodology, hence increasing the level of trust in the observed results.

table 5 GDP to education expenditure

D.GDP	Coef.	Std. Err	z	P>|z|
LR				
EDE	.3955276	.0420121	9.41	0.000
ECT	-.7998027	.1269137	-6.30	0.000
SR				
EDE (D1)	14.13153	5.988415	2.36	0.018
_cons	-2.484776	.8571993	-2.90	0.004
Pooled Mean Group Estimation: Error				
Number of obs. = 144				
Number of groups = 6				

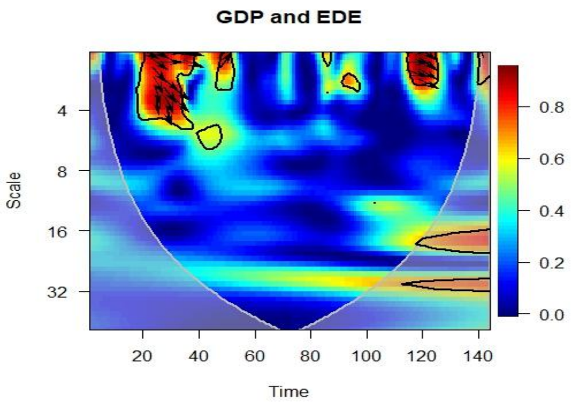

Figure 1 GDP and EDE

In the Gulf Cooperation Council (GCC) countries, the coefficient of government education expenditure (EDE) is positively significant both in the short run and in the long run. Based on this conclusion, it appears that the dataset that was selected provides support for the hypothesis that the correlation between the government education expenditure (EDE) and the GDP that is being considered is statistically significant both in the long run and in the short run. In the countries that are part of the Gulf Cooperation Council (GCC), the results of the study indicate that the government education expenditure (EDE) has a positive and statistically significant link with GDP. Essentially, it demonstrates that an increase in the amount of money spent by the government on education leads to an increase in GDP over time. This indicates that investing in education could assist in the expansion and flourishing of the economy of the region. Moreover, the discovery emphasises the shorter-term effects of governmental education policy, suggesting that shifts in education expenditure can affect short-term economic outcomes. The importance of education in the GCC nations' economic growth and stability, both in the short and long term, is highlighted by these data, which highlight the impact of government investment in education in both contexts. But the ECT coefficient is substantial, so we know that adjustments have an effect, and we know that the ECT coefficient is statistically significant, too. This suggests that there is a mechanism for adjustment at 79%, and that changes in the variable being studied are linked to changes in the country's GDP. A dynamic and interdependent link between the variables is suggested by the presence of a significant ECT, which means that any deviations from the long-run equilibrium will be adjusted over time. Zooming down on these findings using wavelet coherence analysis reveals that government education spending (EDE) has a short-run influence that is in-phase (positively associated) with GDP. In the long term, nevertheless, EDE doesn't affect GDP. Finding that government spending on education is associated with economic growth is consistent with this finding (Hussin et al., 2012). This study also demonstrated the importance of human capital, which includes education as a determinant contributing to economic growth.

Table 6 GDP to research and development

D.GDP	Coef.	Std. Err	z	P>|z|
		LR		
R & D	1.511397	.4771636	3.17	0.002
ECT	-.7803172	.1022992	-7.63	0.000
		SR		
R & D (D1)	1.745532	1.769354	0.99	0.324
_cons	.9183512	.2742591	3.35	0.001
		Mean Group Estimation: Error		
		Number of obs. = 144		
		Number of groups = 6		

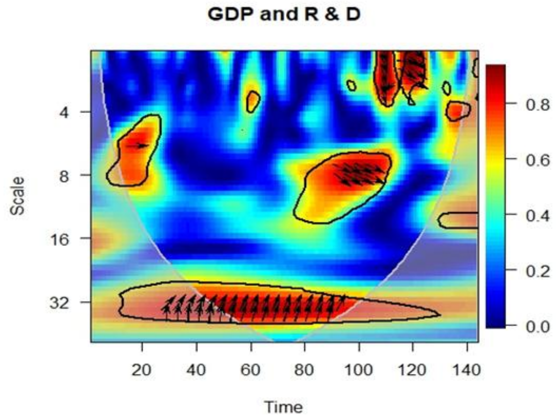

Figure 2. GDP and E&D

The research and development (R&D) coefficient in GCC nations is positively significant in the long run but is insignificant in the short run, according to Table 4.2 (b). This finding suggests that the chosen dataset only finds a statistically meaningful association between R&D and GDP over long periods of time. Investments in R&D do, in fact, correlate with GDP growth; however, it is only after looking at the data over a long enough time frame that the significance of this correlation becomes clear. This finding has long-term implications for the GCC economies, suggesting that more spending on R&D leads to better growth and development all around. This provides more evidence that policies that encourage scientific inquiry, technological progress, and innovation can benefit economies in the long run. Nevertheless, the outcome suggests that changes in R&D spending do not have rapid and statistically significant impacts on GDP in the short run. It appears that investments in research and development require some time to provide tangible and statistically significant economic advantages. Nevertheless, our findings are further enhanced by using the Error Correction Term (ECT) in the study. It is worth mentioning that the ECT coefficient is highly substantial and holds major value. It means that the relationship between the variable being studied and the country's GDP is actually adjusted, since it accounts for about 78% of the relationship. This finding is significant because it provides more evidence that changes in the examined variable are strongly associated with changes in economic production as a whole. There is a dynamic and interdependent interaction between these variables, as highlighted by the enormous significance of the ECT. In addition, the long-term equilibrium between these variables will be restored with time, validating the association's enduring character and highlighting the durability of the link, as shown by the substantial ECT. This has far-reaching consequences for the precision of policymaking and predictions, since it suggests that changes in the economy have a tendency to bring the variables under study back into equilibrium, guaranteeing a strong and long-lasting link. Investigating these findings further with wavelet coherence analysis reveals that R&D's impact on GDP is in-phase (positively associated) with time, both in the short and long run. Similar results have been found by (Aghion & Howitt, 1996).

CONCLUSION

A country's development trajectory is closely tied to the effectiveness of its education system and its capacity to generate and absorb new knowledge through research and development (R&D). Beyond their broader social returns, education and R&D strengthen competitiveness by improving workforce skills, supporting productivity gains, and enabling economies to move up the value chain. For the GCC economies, where diversification and resilience are strategic priorities, these channels are especially salient because human-capital formation and innovation are key to reducing exposure to oil-cycle volatility and sustaining long-run growth. Using panel data for GCC countries over 1998–2021 and estimating a panel ARDL framework, this study finds that government education expenditure (EDE) is positively associated with GDP in both the short run and the long run, indicating that education spending delivers contemporaneous growth support while also contributing to longer-term output expansion. The error-correction term (ECT) is negative and statistically significant, with a high speed of adjustment (around 79%), implying that short-run deviations from equilibrium are corrected relatively quickly and confirming a stable long-run relationship. Importantly, the wavelet coherence results refine this interpretation by showing that the co-movement between EDE and GDP is predominantly in-phase in the short run, whereas the long-run influence of EDE is weak or not consistently sustained in the time–frequency domain. Taken together, the evidence suggests that education spending is most visible as a growth driver over shorter horizons, even while the panel ARDL indicates an enduring equilibrium linkage. For R&D expenditure, the panel ARDL estimates reveal a positive and significant long-run effect on GDP but an insignificant short-run effect, consistent with the idea that innovation investments require time to translate into measurable output gains. The ECT is again substantial and significant (approximately 78%), indicating strong adjustment toward long-run equilibrium and reinforcing the durability of the relationship. Wavelet coherence complements these findings by indicating that R&D and GDP are generally in-phase across both short- and long-run horizons, suggesting persistent positive co-movement over time even when immediate short-run ARDL coefficients are not statistically detectable. Overall, the combined econometric and wavelet evidence points to a sequencing logic: education spending tends to support nearer-term growth dynamics, while R&D spending strengthens longer-term growth capacity. These findings have several policy implications for GCC governments. First, sustaining and improving the efficiency of education expenditure should remain a priority, with emphasis on quality-enhancing allocations (skills formation, curriculum relevance, teacher development, and higher-education–labor market alignment) to maximize the short-run growth impulse evidenced in the wavelet results and the broader equilibrium gains shown in the ARDL estimates. Second, because R&D effects materialize primarily in the long run, policymakers should treat innovation funding as a strategic, multi-year commitment rather than a short-term stabilization tool. Third, to accelerate the translation of R&D spending into output gains, GCC economies can strengthen commercialization pathways and public–private collaboration (industry–university linkages, innovation clusters, and incentives for firm-level R&D). Finally, continuous monitoring and evaluation of both education and R&D programs is essential to balance immediate growth needs with long-term sustainability, ensuring that spending composition supports resilient and diversified GDP growth over time.

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