Journal of Contemporary Macroeconomic Issues
December, 2025, Vol. 6, No.2 [75-93]
ISSN (Print) 2708-4973
ISSN (Online) 2709-0469

DOI: 10.5281/zenodo.18656751

Journal of Contemporary Macroeconomic Issues
www.scekr.org

# The Role of Energy Investment in Promoting Economic Sustainability in Developing Countries: A CS-ARDL Analysis

Aqeel Ahmad[1]; Tusawar Iftikhar Ahmad[2]; Asma Sajjad[3]; Sajjad Ali[4]
1. PhD Scholar, Department of Economics, The Islamia University of Bahawalpur, Pakistan
Email: aqeelahmed.iub18@gmail.com
2. Associate Professor, PhD (Economics), Department of Economics, The Islamia University of Bahawalpur, Pakistan
Email: tusawar.iftikhar@iub.edu.pk
3. Monitoring Officer, Ministry of National Food Security & Research (MNFSR), Islamabad, Pakistan
Email: asmasajjad2406@gmail.com
4. Lecturer of Economics, Govt. Sadiq Egerton Graduate College, Bahawalpur, Pakistan
Email: sajjadali.iub19@gmail.com

**PAPER INFO**

**Information:**
Received: 04 October, 2025
Revised: 30 December, 2025
Published: December, 2025

**Keywords:**
Economic growth, public-private partnership in energy investment, energy investment with private participation, foreign direct investment

**Corresponding Author's email:**
aqeelahmed.iub18@gmail.com

**ABSTRACT**

*Energy investment plays a pivotal role in promoting economic sustainability through a reliable energy supply to support industrial production and innovation. The current work investigates the difference in energy investment and economic sustainability between 1990 and 2022 for the 88 developing countries with an income classification. Using the Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) methodology, the research simultaneously tests the short and long run dynamics, while explicitly modeling cross section dependency. The results suggest that although labor force participation, capital formation, human capital, and foreign direct investment have positive impacts on economic sustainability across income levels, energy investment, especially when used for creating public-private partnerships, fosters economic growth in middle-income economies but has a negative correlation with low-income economies. Policy implications drawn from the findings induce that boosting investment in the energy sector, with special focus on the use of renewable technologies in low- income countries, would be an effective strategy for promoting sustainable development.*

## 1 Introduction

Achieving economic sustainability in developing countries is a critical objective of contemporary development policy. Among the key pillars supporting long-term economic growth, energy investment plays a foundational role, enabling industrial activity, public infrastructure expansion and social welfare improvements (Anarfo et al., 2021). Access to reliable and affordable energy catalyzes economic diversification and resilience, especially in economies historically constrained by energy poverty (Sadorsky, 2011). That's why energy investment is not just about powering homes, its's about giving countries the tools they need to grow and support their people (Bhattacharyya, 2013). Studies show that more energy investment often leads to more economic growth and better living conditions (Lee & Chang, 2007; Were, 2015; Wolde-Rufael, 2009).

Low-income countries show significant variability in energy investment with private participation and public-private partnership, with sharp peaks in countries like Congo and Mozambique. Lower middle-income countries exhibit more stable investment trends, though generally lower in percentage compared to low-income countries. In contrast, upper-middle-income countries display higher and more consistent investment levels, reflecting stronger and steadier involvement from both private and PPP sectors in their energy investments. But it's not just about how much money is spent. The type of energy used (clean energy like solar, or polluting energy like coal) also makes a significant difference (Zhang & Cheng, 2009). Some studies have found that energy and economic growth can affect each other in both directions: countries grow because of energy investment and then they invest more as they become richer (Narayan & Smyth, 2008). This shows the relationship is more complex than it looks.

To rigorously examine the relationship between energy investment and economic sustainability, it is essential to adopt an advanced econometric technique capable of addressing the complexities inherent in cross-country data. Earlier studies have largely relied on first-generation models such as ARDL, OLS and GMM. While these models have contributed valuable insights, they often fall short in capturing key dynamics, particularly when dealing with cross-sectional dependence and slope homogeneity (Mustafa & Selassie, 2016). To overcome these limitations, this study employs the Cross-Sectional Augmented ARDL (CS-ARDL) approach. This second-generation technique is more robust, as it accounts for unobserved common factors and allows for heterogeneity in slope coefficients, thereby providing more accurate and reliable long-run estimations (Ahmad & Zhao, 2018a; Ditzen, 2021; Mir et al., 2024).

The significance of this study lies not only in its methodological innovation but also in the novel dimensions it introduces to the literature. First, although a substantial body of research has examined the nexus between energy investment and economic growth, there is a notable lack of empirical evidence in developing nations (Varga, 2006; Zelezinskii et al., 2021). Much of the existing literature has concentrated disproportionately on China. Often overlooking the diverse experiences and challenges faced by other developing economies. Second, previous studies have primarily focused on energy investment through public-private partnerships (PPP); this study distinguishes itself by incorporating both PPP and private sector investments (Hirooka, 2006).

This paper is organized as follows: Section 2 presents a review of the previous studies that analyzed the impact of energy investment on economic growth. Section 3 provides the model specification, data and methodology. Results and discussions are presented in Section 4. Finally, Section 5 concludes the study and provides recommendations.

## 2 Literature Review

This section explores the relationship between economic sustainability and energy investment by reviewing earlier work in this area. Research studies examining the link between energy investment and economic growth are compiled in Table 1.

**Table 1**

**Studies on Energy Investment and Economic Growth**

| Reference(s) | Country/Area | Time Period/Observation | Methodology | Main Results |
|---|---|---|---|---|
| (Samouilidis & Mitropoulos, 1983) | Global | 1983 | Theoretical | The analysis showed that investments in energy productivity affected the rate at which the non-energy capital stock was created, which in turn |

| | | | | |
|---|---|---|---|---|
| | | | | affected economic growth. When energy prices were rising, these effects seemed to be accentuated. |
| Lu et al. (2010) | Western China | 42 sectors 2002 | CEG Model MRS | The finding of the study indicated that household disposable income is growing at a rate of 0-8.94%, the GDP is growing at a rate of 0-8.92% and carbon dioxide emissions are growing at a rate of 0-11.10%. Investment growth is at a rate of 0-60%. Oil and gas production had the highest growth rate, at 0-19.47%. |
| Saibu (2012) | Nigeria | 1970-2010 | OLS | The findings showed that dependence on energy resources severely reduced investment. Furthermore, it was found that Nigeria's economic progress was hampered by energy abundance. |
| Markaki et al. (2013) | Greek | 2010-2020 | Input-output analysis | The results indicated that over the 2010–2020 period, h47.9 billion in investments would be needed; these would raise the country's GDP by an average of 9.4 billion annually and create 108,000 full-time equivalent jobs over the course of the study. Compared to the development of renewable energy sources (RES) in the power generation sector, the employment generated per h1 million investment in energy-saving projects for |

| | | | | |
|---|---|---|---|---|
| | | | | buildings and transportation is higher. |
| Hu (2014) | China | 1970-2010 | OLS | The study's findings revealed that, under the most basic scenario, China's economic growth rate dropped from 9.26% in 2011–2015 to 4.29% in 2021–2025. This demonstrated that China had begun a period of transformation. |
| Gakuo (2015) | Kenya | 1990-2013 | Descriptive statistics and OLS | According to the study, Kenya's economic growth throughout the study period was positively and significantly impacted by government investment in the construction of energy infrastructure. |
| Ahmad and Zhao (2018) | China | 31 provinces 2001-2016 | CCEMG | The study found that there was a positive and bilateral causal relationship between economic growth and energy investment. |
| He et al. (2019) | China | 150 listed companies | threshold regression model | The study's findings showed that green credit had a double-threshold effect on investment in renewable energy and impacted the green economy development index, categorized as promotion, restriction and further promotion |
| Polyakova et al. (2019) | Russia | 1998-2004 2010-2017 | Regression model | The analysis concluded that over the years 1998–2004 and 2010–2017, foreign investment in the manufacture of petrochemicals and energy supplies had a higher effect on economic growth. Investment in electricity generation increased as well, while other aspects of the business, such as mining, |

| | | | | |
|---|---|---|---|---|
| | | | | had a statistically negligible or even negative impact on economic growth. The findings demonstrated the need for structural changes to reroute capital flows away from oil and gas in order to prevent the long-term deterioration of economic growth. |
| Darraji and Bakir (2020) | 18 countries | 2008-2015 | FMOLS | The study's conclusions showed that, with inelastic elasticity, renewable energy had a beneficial impact on economic growth. Additionally, positive and significant relationships were found between economic growth and the other three independent variables with inelastic elasticity. |
| Dinçer et al. (2020) | 15 most nuclear energy user | 1990-2015 | VAR method | The results of the study indicated that no significant causal link between nuclear energy use and economic growth was found. However, the study determined that the utilization of nuclear energy promotes a country's financial progress. |
| Stamopoulos et al. (2021) | 15 industries | 2020 | Input-Output analysis | The findings showed that while the generation of lignite electricity still makes a major contribution to the Greek economy, investing in renewable energy offered a substantial chance for value addition and employment development. |

| | | | | |
|---|---|---|---|---|
| Jaradat (2022) | GCC Countries | 2010-2019 | Simple Regression Analysis | The study discovered that while investments in renewable energy had a negligible effect on economic growth in Bahrain, Kuwait and Oman, they had a favorable and considerable influence on the economies of the United Arab Emirates, the Kingdom of Saudi Arabia and Qatar. |
| Zahoor et al. (2022) | China | 1970-2016 | robust least square multiple regression analysis | The results demonstrated a negative association between CO2 emissions and ecological footprint and investments in renewable energy and the economic growth of China. Development of financial, value added in manufacturing, urbanization and CO2 emissions were all positively connected with China's economic growth. |
| Cortez et al. (2022) | Europe | 2008-2020 | Synthetic portfolio Approach | Greener companies outperform their less eco-friendly counterparts within the firms with environmental ratings, even though the gap had closed recently. Similarly in the energy sector green energy portfolios outperform than non-green counterparts. |
| Zhang (2022) | OECD | 2011-2020 | GMM | According to the study's findings, investments in renewable energy resources and green financing led to positive economic consequences, including an increase in GDP, FDI inflow and trade openness. It was also clear that countries' economies performed better when their |

| | | | | |
|---|---|---|---|---|
| | | | | emissions of greenhouse gases and carbon dioxide fell. |
| Wu (2023) | OECD | 2001-2019 | GMM | The study's findings showed that green financing and renewable energy investment resources significantly and positively impacted the economic performance of a few OECD members. |

These studies mostly concentrate on Chinese provinces, though limited focus on developing countries. Different approaches are used in each of these studies to measure results. However, the results of all studies remain the same a nation's economic growth trajectory is positively impacted by investments in energy productivity.

## 3 Model Specification, Data and Methodology

As this model is based on the growth equation, so based on the production function approach, we have taken labor and physical capital. In order to encapsulate social sustainability, we have used human capital index. Furthermore, we have taken two variables related to investment i) domestic investment (energy investment) and ii) foreign investment (foreign direct investment). Energy investment is the core variable in which we are interested. We used two variables for energy investment to check the robustness of the results energy investment with public-private participation and energy investment with private participation. The justification for using these two variables as proxies is that the first one depicts total energy sector investment made by public and private partnerships, whereas the second one only partially represents private sector energy investment. We have used foreign direct investment as a determinant of economic growth based on the multiplier effect, which states the change in income due to a change in investment and balance of payment theory, which refers that FDI being recorded as capital inflows in the balance of payment with other capital inflows. By comparing FDI inflows to GDP, we can evaluate the role of foreign direct investment in economic growth.

The functional form of the model is given as:

$$GDPPC = f(LFPR, GFCF, HCI, EIP, EIPP, FDI) \quad (1)$$

The econometric form of this model is given as:

$$GDPPC_{it} = \alpha_0 + \alpha_1 LFPR_{it} + \alpha_2 GFCF_{it} + \alpha_3 HCI_{it} + \alpha_4 EIP_{it} + \alpha_5 EIPP_{it} + \alpha_6 FDI_{it} + \varepsilon_{it} \quad (2)$$

Table 2 shows the description, unit of measurement and source of data. We have collected panel data for 88 developing nations spanning the years 1990–2022. Ten of these fall under the category of low-income countries, 38 are classified as lower-middle-income countries and 40 are designated as upper-middle-income nations. In total, there are a total 134 developing nations but we dropped out 46 countries due to the unavailability of the energy investment data. We have collected the data of all variables from the World Development Indicator database.

**Table 2**

**Variables Descriptions, Measurement Unit and Data Sources**

| | Description | Unit of Measurement | Data Source |
|---|---|---|---|
| **GDPPC** | Gross Domestic Product Per Capita Growth | Annual (%) | |
| **HCI** | Human Capital Index | Index | |
| **LFPR** | Labor Force Participation rate | (% of total population ages 15-64) (modeled ILO estimate) | |
| **GFCF** | Gross Fixed Capital Formation | Annual (%) | WDI |
| **EIP** | Investment in energy with private participation | % of GDP | |
| **EIPP** | Investment in energy with public-private participation | % of GDP | |
| **FDI** | Foreign Direct Investment, net inflows | % of GDP | |

The application of the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) technique has significantly addressed the issues of cross-sectional dependence and slope heterogeneity, which were frequently ignored in previous studies. By incorporating cross-sectional averages of the dependent and explanatory variables, the CS-ARDL method effectively controls for common factors influencing all units, thereby mitigating the bias and inconsistency arising from cross-sectional dependence. Additionally, the technique allows for heterogeneous slope coefficients across different units, providing flexibility and robustness in capturing the unique relationships between variables in diverse panels. This dual approach enhances the accuracy and reliability of the econometric analysis, leading to more valid inferences compared to traditional panel data models that often assume cross-sectional independence and homogeneous slopes. Long and short-run coefficients are analyzed by estimating a cross-sectional augmented Autoregressive Distributed Lag (CS-ARDL) model, which Chudik and Pesaran (2015) developed. The primary advantages of the CS-ARDL estimator are its ability to produce reliable results whether the series is co-integrated or not and its repressors can contain any mix of I(0) and I(1) processes (Chudik et al., 2017). It recognizes cross-sectional dependency because it is an ARDL version of the Dynamic Common Correlated Estimator where estimations are based on individual regression with lagged dependent variables and lagged cross-section averages (Chudik et al., 2017). Mean group estimates are allowed even with diverse slope coefficients. The CS-ARDL model's mean group version is based on adding cross-sectional averages (proxies for unobserved common components and their lags) to each cross-section's ARDL estimates (Chudik et al. 2017). Additionally, this approach holds up better when the weak exogeneity issue is problematic when the lag-dependent variable is included in the model. According to the authors, this problem of endogeneity can be largely bypassed by adding lags in cross-section averages in the model. The following regression is the basis of the CSARDL estimation:

$$y_{it} = \alpha_i + \sum_{l=1}^{p_y} \lambda_{l,i} y_{i,t-1} + \sum_{l=0}^{p_x} \beta_{l,i} x_{i,t-1} \sum_{l=0}^{p_\varphi} \varphi'_{i,l} \overline{z}_{i,t-1} + \varepsilon_{it} \quad (3)$$

The term $\overline{z}_{t-1}$ in Equation (4.27) denotes lagged cross-sectional averages $[\overline{z}_{t-1} = (\overline{y}_{i,t-1}, \overline{x}_{i,t-1})]$. The mean group estimations' long-run coefficients are:

$$\hat{\theta}_{CS-ARDL,i} = \frac{\sum_{l=0}^{p_x} \hat{\beta}_{l,i}}{1 - \sum_{l=1}^{p_y} \hat{\lambda}_{l,i}}, \theta_{MG} = \frac{1}{N}\sum_{i=1}^{N} \hat{\theta}_i \quad (4)$$

Each cross-section's estimation is indicated by $\hat{\theta}_i$. The CS-ARDL method's error-correcting version is:

$$\Delta y_{it} = \phi_i [y_{i,t-1} - \hat{\theta}_i x_{i,t}] - \alpha_i + \sum_{l=1}^{p_{y-1}} \lambda_{l,i} \Delta_l y_{i,t-1} + \sum_{l=0}^{p_x} \beta_{l,i} \Delta x_{i,t-1} \sum_{l=0}^{p_\varphi} \varphi_{i,l}^{'} \Delta \bar{z}_{i,t-1} + \mu_{it} \quad (5)$$

Where the error's correction speed of adjustment is indicated by $\phi_i$.

The present CS-ARDL version are given as:

The CS-ARDL long run and short run equation of this model is given as:

$$\begin{aligned}\Delta GDPPC_{it} &= \alpha_1 + \alpha_2 LFPR_{i,t-1} + \alpha_3 GFCF_{i,t-1} + \alpha_4 HCI_{i,t-1} + \alpha_5 EIP_{i,t-1} + \alpha_6 EIPP_{i,t-1} + \alpha_7 FDI_{i,t-1} \\ &+ \sum_{j=1}^{\rho_1} \beta_{ij} \Delta GDPPC_{i,t-j} + \sum_{j=0}^{\rho_2} \beta_{ij} \Delta LFPR_{i,t-j} + \sum_{j=0}^{\rho_3} \beta_{ij} \Delta GFCF_{i,t-j} + \sum_{j=0}^{\rho_4} \beta_{ij} \Delta HCI_{i,t-j} + \sum_{j=0}^{\rho_5} \beta_{ij} \Delta EIP_{i,t-j} \\ &+ \sum_{j=0}^{\rho_6} \beta_{ij} \Delta EIPP_{i,t-j} + \sum_{j=1}^{\rho_7} \beta_{ij} \Delta FDI_{i,t-j} + \varepsilon_{it}\end{aligned} \quad (6)$$

## 4 Results and Discussion

### *4.1 Descriptive Statistics*

Table 3 provides the descriptive statistics of the key variables used in this study. The mean values show the average levels of the economic indicators across income groups. For GDP per capita growth (GDPPC), upper-middle-income countries have the highest average growth (3.612%), while lower-middle-income countries exhibit near-zero mean (0.013%), suggesting stagnation. Human Capital Index (HCI) values are relatively stable across groups, with upper-middle-income countries showing higher human capital development. Labor Force Participation Rate (LFPR) is highest in lower-middle-income countries (56.725%) and lowest in developing countries (38.012%), indicating different levels of labor market engagement. Gross Fixed Capital Formation (GFCF) varies greatly, with low-income countries showing the highest mean (13.364%) but also high dispersion. FDI inflows as a percentage of GDP are most prominent in upper-middle-income countries (5.885%), with extremely high mean values in low-income countries (4.024%) driven by outliers.

**Table 3**

**Descriptive Statistics**

| | GDPPC | HCI | LFPR | GFCF | EIP | EIPP | FDI |
|---|---|---|---|---|---|---|---|
| **Developing Countries** | | | | | | | |
| **Mean** | 1.315 | 0.394 | 38.012 | 4.664 | 0.004 | 0.004 | 0.348 |
| **Median** | 0.541 | 0.393 | 38.573 | -5.786 | 0.001 | 0.001 | 0.275 |
| **Maximum** | 22.020 | 0.400 | 39.286 | 29.158 | 0.010 | 0.010 | 1.203 |
| **Minimum** | -22.584 | 0.389 | 33.648 | -9.381 | 0.000 | 0.000 | -0.013 |
| **Std. Dev.** | 9.177 | 0.006 | 1.619 | 21.289 | 0.005 | 0.005 | 0.326 |
| **Skewness** | -0.059 | 0.244 | -1.905 | 0.684 | 0.695 | 0.695 | 1.230 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Kurtosis** | 4.165 | 1.500 | 5.118 | 1.500 | 1.500 | 1.500 | 3.985 |
| **Jarque-Bera** | 1.313 | 0.311 | 26.138 | 0.516 | 0.523 | 0.523 | 4.977 |
| **Probability** | 0.519 | 0.856 | 0.000 | 0.773 | 0.770 | 0.770 | 0.083 |
| **Low-Income Countries** | | | | | | | |
| **Mean** | 0.854 | 0.362 | 50.650 | 13.364 | 0.018 | 0.018 | 4.024 |
| **Median** | 1.516 | 0.373 | 52.406 | 6.288 | 0.006 | 0.006 | 1.720 |
| **Maximum** | 90.832 | 0.432 | 80.350 | 2357.675 | 0.192 | 0.192 | 167.329 |
| **Minimum** | -48.429 | 0.286 | 14.341 | -294.162 | 0.000 | 0.000 | -202.824 |
| **Std. Dev.** | 7.782 | 0.036 | 16.531 | 109.221 | 0.040 | 0.040 | 15.463 |
| **Skewness** | 1.017 | -0.456 | -0.230 | 19.029 | 3.641 | 3.641 | 0.084 |
| **Kurtosis** | 36.796 | 2.265 | 2.026 | 406.631 | 15.451 | 15.451 | 88.108 |
| **Jarque-Bera** | 37732.220 | 3.942 | 41.438 | 3595510.000 | 546.119 | 546.119 | 176859.100 |
| **Probability** | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Lower-Middle-Income Countries** | | | | | | | |
| **Mean** | 0.013 | 0.361 | 56.725 | 4.921 | 0.001 | 0.001 | 3.563 |
| **Median** | -0.388 | 0.361 | 57.232 | 4.256 | 0.002 | 0.002 | 2.148 |
| **Maximum** | 11.222 | 0.362 | 58.352 | 26.518 | 0.003 | 0.003 | 40.167 |
| **Minimum** | -26.374 | 0.360 | 53.113 | -19.527 | 0.000 | 0.000 | -10.038 |
| **Std. Dev.** | 7.267 | 0.001 | 1.516 | 10.274 | 0.001 | 0.001 | 10.282 |
| **Skewness** | -1.103 | 0.316 | -1.067 | -0.234 | -0.447 | -0.447 | 1.589 |
| **Kurtosis** | 6.353 | 1.500 | 3.041 | 3.276 | 2.022 | 2.022 | 6.118 |
| **Jarque-Bera** | 22.820 | 0.331 | 6.263 | 0.259 | 0.293 | 0.293 | 28.092 |
| **Probability** | 0.000 | 0.847 | 0.044 | 0.879 | 0.864 | 0.864 | 0.000 |
| **Upper-Middle-Income Countries** | | | | | | | |
| **Mean** | 3.612 | 0.607 | 42.021 | 5.957 | 0.026 | 0.021 | 5.885 |
| **Median** | 4.994 | 0.625 | 38.514 | 4.417 | 0.004 | 0.002 | 6.433 |
| **Maximum** | 14.025 | 0.634 | 55.761 | 42.625 | 0.122 | 0.116 | 11.171 |
| **Minimum** | -27.567 | 0.544 | 27.534 | -20.619 | 0.002 | 0.000 | 1.283 |
| **Std. Dev.** | 7.900 | 0.043 | 9.531 | 12.972 | 0.043 | 0.042 | 2.770 |
| **Skewness** | -2.115 | -1.099 | 0.178 | 1.084 | 1.656 | 1.936 | 0.007 |
| **Kurtosis** | 8.614 | 2.289 | 1.421 | 4.921 | 4.243 | 4.914 | 1.740 |
| **Jarque-Bera** | 69.994 | 0.889 | 3.601 | 9.440 | 4.169 | 5.440 | 2.117 |
| **Probability** | 0.000 | 0.641 | 0.165 | 0.009 | 0.124 | 0.066 | 0.347 |

Standard deviation reflects data variability. GFCF and FDI show extreme dispersion in low-income countries, with standard deviations of 109.221 and 15.463, respectively, highlighting instability. GDPPC also shows high variability in developing and upper-middle-income groups. HCI, by contrast, has low variability across all categories. Skewness reveals data asymmetry; GDPPC is negatively skewed in developing and lower-middle-income groups, indicating frequent low values. LFPR shows strong negative skewness in developing and lower-middle-income groups, while FDI is positively skewed across all groups, especially in upper-middle-income countries. Kurtosis, measuring peakedness, is especially high for GDPPC and GFCF in low-income countries (36.796 and 406.631), indicating extreme outliers. The Jarque-Bera (JB) test results show that most variables, especially GDPPC, GFCF and FDI in low- and lower-middle-income groups, reject the null hypothesis of normal distribution (p-values = 0.000), indicating non-normality and the presence of skewed, heavy-tailed distributions.

*4.2 Correlation Analysis*

Table 4 shows the correlation analysis between GDP per capita growth and key economic indicators across different income-level country groups. In developing countries, the correlations between GDP growth and other variables are generally weak, indicating limited interdependence. There is a minimal association with labor force participation, human capital, capital formation and energy investments. Notably, the relationship with foreign direct investment appears slightly negative, suggesting that FDI may not consistently contribute to growth in these economies, possibly due to instability or lack of absorptive capacity.

**Table 4**

**Correlation Matrix**

| **Developing Countries** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **GDPPC** | **HCI** | **LFPR** | **GFCF** | **EIP** | **EIPP** | **FDI** |
| **GDPPC** | 1.000 | | | | | | |
| **HCI** | 0.054 | 1.000 | | | | | |
| **LFPR** | 0.102 | -0.083 | 1.000 | | | | |
| **GFCF** | 0.094 | -0.087 | 0.995 | 1.000 | | | |
| **EIP** | 0.157 | 0.100 | 0.109 | 0.095 | 1.000 | | |
| **EIPP** | 0.023 | 0.028 | 0.036 | 0.044 | -0.117 | 1.000 | |
| **FDI** | -0.045 | -0.012 | -0.025 | -0.040 | 0.131 | -0.849 | 1.000 |
| **Low-Income Countries** | | | | | | | |
| **GDPPC** | 1.000 | | | | | | |
| **HCI** | 0.007 | 1.000 | | | | | |
| **LFPR** | 0.291 | 0.137 | 1.000 | | | | |
| **GFCF** | 0.046 | 0.236 | 0.046 | 1.000 | | | |
| **EIP** | -0.086 | 0.251 | -0.337 | -0.223 | 1.000 | | |
| **EIPP** | -0.086 | 0.251 | -0.337 | -0.223 | 0.999 | 1.000 | |
| **FDI** | 0.239 | 0.399 | 0.186 | 0.179 | -0.175 | -0.175 | 1.000 |
| **Lower-Middle-Income Countries** | | | | | | | |
| **GDPPC** | 1.000 | | | | | | |
| **HCI** | 0.220 | 1.000 | | | | | |
| **LFPR** | 0.263 | 0.251 | 1.000 | | | | |
| **GFCF** | 0.281 | 0.226 | 0.110 | 1.000 | | | |
| **EIP** | -0.168 | 0.322 | -0.135 | -0.226 | 1.000 | | |
| **EIPP** | -0.166 | 0.120 | -0.139 | -0.231 | 0.987 | 1.000 | |
| **FDI** | -0.215 | 0.167 | -0.163 | -0.008 | -0.017 | -0.018 | 1.000 |
| **Upper-Middle-Income Countries** | | | | | | | |
| **GDPPC** | 1.000 | | | | | | |
| **HCI** | -0.259 | 1.000 | | | | | |
| **LFPR** | -0.4069 | -0.301 | 1.000 | | | | |
| **GFCF** | 0.041 | 0.404 | -0.355 | 1.000 | | | |
| **EIP** | 0.070 | 0.168 | -0.461 | 0.152 | 1.000 | | |
| **EIPP** | 0.070 | 0.168 | -0.461 | 0.152 | 0.988 | 1.000 | |
| **FDI** | 0.047 | -0.695 | 0.228 | -0.578 | -0.003 | -0.003 | 1.000 |

In contrast, low- and lower-middle-income countries exhibit somewhat stronger associations, particularly between GDP growth and labor force participation or capital formation, reflecting their reliance on labor and physical investment to stimulate growth. However, energy-related investments tend to show weak or even negative correlations, implying underutilization or inefficiency in this sector. In upper-middle-income countries, the pattern shifts, with mixed results. While GDP growth shows some positive links with investment indicators, it appears negatively associated with human capital and labor force participation, possibly reflecting structural changes or a growing reliance on capital-intensive sectors.

*4.3 Cross-Section Dependence Test*

Table 5 reveals statistically significant cross-sectional dependence across all variables and income categories, indicating substantial interconnections among countries within each group.

**Table 5**

**Pesaran's Cross-Sectional Dependence (CD) Test**

| Variable | Developing Countries | Low-Income Countries | Lower-Middle-Income Countries | Upper-Middle Income Countries |
|---|---|---|---|---|
| **GDPPC** | 22.511*** | 102.384*** | 111.367*** | 110.249*** |
| **HCI** | 72.787*** | 66.625*** | 65.899*** | 74.341*** |
| **LFPR** | 71.391*** | 22.991*** | 39.660*** | 53.278*** |
| **GFCF** | 91.394*** | 92.991*** | 47.672*** | 56.286*** |
| **EIP** | 27.827*** | 59.103*** | 32.921*** | 71.659*** |
| **EIPP** | 28.973*** | 59.103*** | 32.922*** | 71.650*** |
| **FDI** | 11.080*** | 0.291*** | 63.881*** | 42.543*** |

This implies that economic developments in one country may systematically influence others, necessitating models that account for such interdependence.

*4.4 Slope Homogeneity Tests*

Table 6 presents the results of the slope homogeneity tests based on Pesaran and Yamagata (2008) and Blomquist and Westerlund (2013).

**Table 6**

**Slope Homogeneity Test on Developing Countries**

| | **(Pesaran and Yamagata, 2008)** | **(Blomquist and Westerlund, 2013)** |
|---|---|---|
| | **Delta Test** | **HAC Robust Adjusted Delta Test** |
| **Developing Countries** | 34.123*** | -1.098*** |
| **Low-Income Countries** | 6.081*** | -2.825*** |
| **Lower Middle-Income Countries** | 23.794*** | -3.816*** |
| **Upper Middle-Income Countries** | 35.680*** | -4.717*** |

The significant test statistics across all income groups indicate the presence of slope heterogeneity, suggesting that the relationship between variables differs across countries within each group. This highlights the need for estimation techniques that accommodate heterogeneous slope coefficients in panel data analysis.

*4.5 Unit Root Test*

Table 7 indicates a mixed order of integration among the variables, with some series stationary at level while others are non-stationary.

**Table 7**

**Results of Second-Generation Panel Unit Root**

| **Second Generation Panel Unit Root Test** | | | | |
|---|---|---|---|---|
| **Cross-Section-Dependence based Im-Pesaran-Shin (CSDIPS) Unit Root Test** | | | | |
| **Developing Countries** | | | | |
| **Variables** | **Without Trend** | | **With Trend** | |
| | **Lags** | **Zt Statistics** | **Lags** | **Zt Statistics** |
| **GDPPC** | 0 | -29.804*** | 0 | -28.440*** |
| **HCI** | 0 | 0.555*** | 0 | 0.566*** |
| **LFPR** | 1 | -4.912*** | 1 | -0.098 |
| **GFCF** | 0 | 0.132*** | 0 | 0.875*** |
| **EIP** | 1 | 0.410 | 1 | 0.592 |
| **EIPP** | 0 | 0.547*** | 0 | 0.381*** |
| **FDI** | 0 | 0.332*** | 0 | 0.796*** |
| **Low-Incomee-Countries** | | | | |
| **GDPPC** | 0 | -15.785*** | 0 | -16.067*** |
| **HCI** | 1 | 2.972 | 1 | 3.242 |
| **LFPR** | 1 | -1.935* | 1 | -1.568* |
| **GFCF** | 0 | -5.923*** | 0 | -6.234*** |
| **EIP** | 1 | 3.352*** | 1 | 3.862*** |
| **EIPP** | 1 | 3.352*** | 1 | 3.862*** |
| **FDI** | 0 | -10.239*** | 0 | -10.342*** |
| **Lower-Middle-Income Countries** | | | | |
| **GDPPC** | 0 | -17.394*** | 0 | -16.810*** |
| **HCI** | 0 | 0.556*** | 0 | 0.495*** |
| **LFPR** | 0 | 0.923** | 0 | 4.628*** |
| **GFCF** | 0 | -18.585*** | 0 | -16.179*** |
| **EIP** | 0 | -3.699*** | 0 | -4.012*** |
| **EIPP** | 0 | -3.699*** | 0 | -4.012*** |
| **FDI** | 1 | 0.220 | 1 | 0.340 |
| **Upper-Middle-Income Countries** | | | | |
| **GDPPC** | 0 | -18.798*** | 0 | -16.809*** |
| **HCI** | 1 | 0.353 | 1 | 0.407 |
| **LFPR** | 1 | -2.929*** | 1 | -1.218 |
| **GFCF** | 0 | -17.528*** | 0 | -14.689*** |
| **EIP** | 0 | 2.417*** | 0 | 2.678*** |
| **EIPP** | 0 | 2.650*** | 0 | 2.987*** |
| **FDI** | 0 | -11.602*** | 0 | -10.360*** |

This variation across country groups and variables suggests the need to apply panel estimation techniques that can accommodate both I(0) and I(1) processes.

### *4.6 CS-ARDL Estimates*

The results of the long-run cross-sectionally augmented (CS-ARDL) analysis are presented in Table 8. The objective is to explore the relationship between economic growth and energy investment. In developing countries, low-income countries, lower middle-income countries and upper middle-income countries, the first variable is LFPR; the positive coefficient of LFPR suggests that an increase in the labor force participation rate is associated with an increase in economic growth which is highly statistically significant in all categories of countries expect upper middle-income countries. There are several reasons for this positive relationship. Firstly, from the economic theory of production function when large numbers of people are involved in economic activities, the productivity of the economy increases. There is a greater chance of specialization, innovation and efficiency gain when more people are working, which positively affects the overall economic activity or progress of the country (Weiss, 1992). Secondly, a greater number of well-educated and skilled laborers are typically implied by a higher labor force participation rate. More people entering the workforce means that the economy's total human capital grows. Higher degrees of competence, knowledge and skill may result from this, which ultimately increases economic output and productivity (Paudel and Perera, 2009). Thirdly, a large number of labor force provides great ideas and perspectives. This diversity raises the innovation that leads to technological advancement and development in the product and the production process. As innovation is the key factor of economic growth and development, the active and growing labor force increases creative ideas and innovation which leads to economic growth (Altaee et al., 2016). Fourthly, the income of the individual increases when more people are participating in economic activities which in turn increases the spending of consumers. Increased consumption stimulates the demand for goods and services, encouraging businesses to increase production to meet the increasing demand. GDP increases as production increases which contributes to the overall economic progress (Haque et al., 2019). Lastly, the dependency ratio—the proportion of working-age people to those with dependents, such as children and retirees—can decrease with an increased labor force participation rate. It is easier to maintain dependents when there is a smaller dependency ratio since a greater percentage of the population is actively working and contributing to the economy. In addition to allowing for more resources to be allocated towards profitable ventures, this can lessen the financial strain on social support systems and promote economic growth (Listiyono et al., 2021). This result is consistent with the following studies (Weiss, 1992; Paudel and Perera, 2009; Altaee et al., 2016; Haque et al., 2019; Listiyono et al., 2021).

The second variable is GFCF; the positive coefficient of GFCF suggests a positive relationship between gross fixed capital formation and economic growth which is statistically significant in all categories of the countries. An increase in the physical assets of the country during a specific period of time is called gross fixed capital formation. For number of reasons GDP per capita positively impacted by an increase in gross fixed capital formation. One of the main reasons of increase in the productivity is investment in advanced technology and machinery. With the help of this financial infusion, companies are able to update their manufacturing procedures, enabling employees to produce more in less time. As a result, there is a subsequent boost in overall productivity, which propels economic growth and raises GDP per capita as the economy becomes more resource-efficient (Solow, 1962). Moreover, the growth of fixed capital directly contributes to the creation of new jobs, which is a crucial factor of economic development. More labor is needed to build new factories and infrastructure, which lowers unemployment rates and boosts the number of people in employment. In addition to promoting the welfare of society, this employment inflow raises worker earnings, which in turn raises GDP per capita as household incomes grow (Apergis and Payne, 2010). An increase in gross fixed capital formation frequently occurs with an emphasis on innovation and technological improvement. As capital is allocated to research and development initiatives, economies experience technological advancement. This advancement in technology increases overall competitiveness, introduces new goods and services and streamlines industrial processes. As a result, there is an increase in GDP per capita and economic growth due to the advancement in technology that results (Adhikary, 2011). Another economic reason is the concept of economies of scale that is facilitated by gross fixed capital formation. Businesses can take advantage of economies of scale by expanding their fixed capital, which lowers average production costs. Its effectiveness maximizes the use of resources, which raises GDP per capita (Ali, 2015). This outcome is in line with the following studies (Solow, 1962; Apergis and Payne, 2010; Adhikary, 2011; Ali, 2015).

**Table 8**

**Long-Run and Short-Run CS-ARDL Estimates**

| Variables | Developing Countries | Low-Income Countries | Lower Middle-Income Countries | Upper Middle-Income Countries |
|---|---|---|---|---|
| **Short Run Results** | | | | |
| Δ **LFPR** | -5.277 | 7.655 | -4.792 | -22.039 |
| | (4.662) | (5.139) | (5.699) | (22.225) |
| Δ **GFCF** | 0.377*** | 0.097 | 0.130 | 0.527*** |
| | (0.083) | (0.191) | (0.209) | (0.150) |
| Δ **HCI** | 0.535 | -0.153 | -0.046 | -0.040 |
| | (0.357) | (0.185) | (0.221) | (0.067) |
| Δ **EIP** | -0.209 | -1.058 | -7.878 | -0.214 |
| | (0.267) | (0.937) | (7.754) | (0.533) |
| Δ **EIPP** | -0.276 | -1.058 | -6.778 | -0.223 |
| | (0.266) | (0.937) | (7.656) | (0.565) |
| c**FDI** | -5.524*** | -0.256 | 0.054 | 0.237* |
| | (2.021) | (0.352) | (0.275) | (0.122) |
| Δ **ECT(-1)** | -0.794*** | -1.142** | -0.871*** | -0.862*** |
| | (0.053) | (0.533) | (-0.162) | (0.091) |
| **Long Run Results** | | | | |
| **LFPR** | 0.069** | 0.260*** | 0.273*** | 0.064 |
| | (0.027) | (0.024) | (0.016) | (0.041) |
| **GFCF** | 0.026** | 0.055*** | 0.145*** | 0.067** |
| | (0.014) | (0.017) | (0.007) | (0.027) |
| **HCI** | 0.030*** | 0.144*** | 0.052*** | 0.045*** |
| | (0.007) | (0.007) | (0.002) | (0.010) |
| **EIP** | 0.115*** | -0.217*** | 0.077*** | 0.115*** |
| | (0.025) | (0.011) | (0.003) | (0.033) |
| **EIPP** | 0.119*** | -0.217*** | 0.087*** | 0.128*** |
| | (0.027) | (0.011) | (0.005) | (0.043) |
| **FDI** | 0.063** | 0.634*** | 0.148*** | 0.086** |
| | (0.028) | (0.074) | (0.007) | (0.036) |

The third variable is HCI; there is a positive relationship between human capital index and economic growth which is highly statistically significant across all categories of countries. An increase in the Human Capital Index (HCI), which measures health, education and overall human potential, significantly enhances economic sustainability, as reflected in GDP growth. First, improved human capital leads to higher productivity. When individuals receive better education and healthcare, they acquire the skills and physical capabilities needed to perform tasks efficiently. A healthier workforce also reduces absenteeism and enhances performance, enabling economies to produce more goods and services, thereby increasing GDP (PELINESCU, 2019).

Moreover, a well-educated population fosters innovation and technological progress. Education equips individuals with the ability to generate ideas, solve complex problems and adopt cutting-edge technologies. These advancements drive economic diversification and efficiency, enabling industries to grow sustainably. The better health and education outcomes increase workforce participation.

With fewer people constrained by illness or lack of skills, more individuals can actively contribute to the economy. A steady supply of skilled labor not only supports consistent economic output but also enhances the economy's ability to withstand and recover from financial shocks. This finding is matched with the following studies (Pelinescu, 2015; Sarwar et al., 2021).

The fourth and fifth variables are energy investment with private participation and energy investment with public-private participation; regardless of all income groups, energy investment and economic growth have a significant and positive relationship except in low-income countries. For several reasons, there is a considerable increase in GDP per capita growth and total economic development accompanying an increase in energy investment. Industries can be made more productive if there are more energy resources or investing in energy is one of the main factors (Pelinescu, 2015). Energy investment allows industries to operate more efficiently, which in turn raises productivity. Higher productivity then leads to greatly increased economic growth (Ahmad & Zhao, 2018b). The construction of energy infrastructure projects, including power plants and distribution networks, is often linked with energy investments. These not only stimulate economic activities but also create jobs and provide employment opportunities in local communities. These combined natural forces, rising employment and infrastructural development, lead to a significant addition to per capita income, enhancement of GNP and GDP per capita (Ahmad & Zhao, 2018b). The higher the energy investment is, the more will it lead to R&D (research and development) for efficiency improvement and the use of cleaner technology; it is also found to contribute to the total energy consumption efficiency. However, the most significant result of larger energy investment is the venture into energy source diversification. In other words, countries can make their energy more secure that has numerous alternative sources, including renewable sources. Diversified energy infrastructure can prevent shocks which ensure that countries are not reliant on an energy source for the future. This fosters economic stability so that prosperity can finally last (Ahmad et al., 2022). Finally, countries that invest in the renovation and expansion of energy infrastructure have a more competitive chance in the ever-evolving global economy. Companies will desire a source of energy that is both reliable enough and affordable for their operations, which is becoming more valuable every single day for foreign investment. The economy has become global, more competitive, more active and overall higher GDP per capita (Zahoor et al., 2022). For a number of reasons, increasing energy investment may hinder economic growth in low-income nations. There is a possibility of the crowding-out effect, in which money is taken away from vital industries like infrastructure, healthcare and education that are critical to long-term economic growth. Second, poorly focused energy expenditures that prioritize large-scale initiatives that exclusively benefit particular businesses or regions can lead to wasteful resource allocation, ignoring the need for equitable development and broader economic demands. A rise in reliance on imported energy supplies may worsen the economy's ability to grow overall by creating balance of payments problems and increasing susceptibility to global price swings. This result is consistent with the following studies (Ahmad & Zhao, 2018b; AlDarraji & Bakir, 2020; Samouilidis & Mitropoulos, 1983; Zahoor et al., 2022).

The last variable is FDI and the positive coefficient of it indicates a positive relationship between foreign direct investment and economic growth. It is highly statistically significant across all categories of countries. This relationship is due to several reasons. There are two types of FDI: brown FDI and Green FDI. Brown FDI refers to foreign direct investment where a company merges with an existing domestic firm to expand its operations whereas greenfield FDI involves establishing new business operations or facilities in a foreign country from the ground up, often to capitalize on market opportunities or leverage local resources and labor. So FDI has an enormous effect on the GDP of a host country because it brings capital that is necessary to improve methods of production and to modernize technology. This capital injection increases the output per worker and boosts overall productivity and efficiency. Accordingly, an increase in productivity has been the principal source of the rise of real GDP per capita in most countries. Further, FDI frequently leads to the creation of entirely new enterprises or to the expansion of existing enterprises within the host country. The job creation associated with this expansion is also essential to economic growth. Increased employment from FDI, then, raises GDP per capita and levels of household income (Blomström et al., 2003; Javorcik, 2004). Moreover, FDI makes it easier for foreign investors to transmit innovative technologies, managerial expertise and industry best practices to domestic sectors. This technology transfer boosts innovation in the host nation while also making domestic enterprises more competitive. Long-term, sustained economic growth can result from the adoption of cutting-edge technologies and creative behaviors (Carkovic & Levine, 2005). Furthermore, by attracting foreign companies from a range of industries, FDI encourages the diversification of a nation's economic base. Because of this variety, the economy is less dependent on any one industry and is hence more shock-resistant. Robust and persistent economic growth is facilitated by the capacity to withstand economic changes (Keller, 2010). Lastly, FDI gives regional companies access to international markets. By starting operations in a host nation, foreign investors provide domestic businesses the chance to grow globally. More exports could result from this expanded market access, increasing income and fostering economic expansion (Alfaro and Chauvin, 2020). This outcome is in line with the following studies (Blomström et al., 2003; Javorcik, 2004; Carkovic & Levine, 2005; Keller, 2010; Alfaro and Chauvin, 2020).

Table 8 also presents the short-run CS-ARDL analysis. In all cases i-e. developing countries, low-income countries, lower-middle-income countries and upper-middle-income countries error correction term has a negative coefficient of -0.794, -1.142,

-0.871 and -0.862 respectively which implies that deviation from short shocks toward long-run equilibrium can be corrected around about one year, three months and nighty-one days in developing countries, ten months and 15 days in low-income countries, one year, one month and twenty-five days in lower-middle-income countries and one year, one month and twenty-nine days in upper-middle-income countries.

## 5 Conclusions and Policy Recommendations

This study investigated the impact of energy investment on economic sustainability, with GDP per capita (GDPPC) as the dependent variable, using panel data from 88 developing countries spanning 1990–2022. The analysis included 10 low-income, 38 lower-middle-income and 40 upper-middle-income countries, with data sourced from the World Development Indicators. After conducting preliminary analyses such as descriptive statistics and correlation tests the study confirmed the presence of cross-sectional dependence and slope heterogeneity and identified a mixed order of integration using second-generation panel unit root tests. The CS-ARDL approach was employed to estimate both long-run and short-run effects. The results show that labor force participation rate (LFPR), gross fixed capital formation (GFCF), human capital index (HCI) and foreign direct investment (FDI) have a positive and statistically significant impact on GDP per capita across both aggregated and disaggregated income groups. Energy investment with private (EIP) and public-private (EIPP) participation also positively influences GDP per capita in developing countries and in both lower-middle- and upper-middle-income countries. However, in low-income countries, EIP and EIPP negatively affect economic sustainability likely due to the crowding-out effect, where energy investments divert essential resources from critical sectors such as health, education and infrastructure. Based on the research's findings, the following policies can be suggested:

- The findings of the study indicated that an increase in labor force participation leads to an increase the economic growth in all income groups. So, to improve economic growth, policymakers need to implement policies that promote a higher labor force participation rate in developing countries.
- The outcome of the study revealed that economic growth is positively impacted by gross fixed capital formation in all income groups. So, it is recommended that the government should

introduce such policies that encourage gross fixed capital formation to boost economic growth in developing countries.

- The finding shows that an increase in the human capital index improves economic growth in all categories of developing countries. So, it is suggested that planners should make such policies that promote social sustainability in order to enhance economic sustainability in developing countries.
- The result illustrates that an increase in both energy investment with private participation and energy investment with public-private participation improves economic growth in all income categories except low-income countries. So, the government should implement policies to increase the investment in energy sector both with private and public-private participation that can promote economic growth. In low-income countries, the planner should make policies to invest in renewable energy in order to improve economic growth.
- The finding also shows that economic growth is positively affected by foreign direct investment in all income categories. So, policymakers must implement policies that boost foreign direct investment to promote economic growth in developing countries.

**References**

Ahmad, M., & Zhao, Z.-Y. (2018a). Causal linkages between energy investment and economic growth: a panel data modelling analysis of China. *Energy Sources, Part B: Economics, Planning, and Policy*, *13*(8), 363-374.

Ahmad, M., & Zhao, Z.-Y. (2018b). Empirics on linkages among industrialization, urbanization, energy consumption, CO2 emissions and economic growth: a heterogeneous panel study of China. *Environmental Science and Pollution Research*, *25*(30), 30617-30632.

Ahmad, U. S., Usman, M., Hussain, S., Jahanger, A., & Abrar, M. (2022). Determinants of renewable energy sources in Pakistan: An overview. *Environmental Science and Pollution Research*, *29*(19), 29183-29201.

AlDarraji, H. H. M., & Bakir, A. (2020). The impact of renewable energy investment on economic growth. *Journal of Social Sciences (COES&RJ-JSS)*, *9*(2), 234-248.

Anarfo, E. B., Agoba, A. M., Sare, Y. A., & Gameti, D. K. (2021). Energy access and foreign direct investment in an emerging market: the Ghanaian perspective. *International Journal of Energy Sector Management*, *15*(5), 969-986.

Bhattacharyya, S. C. (2013). Financing energy access and off-grid electrification: A review of status, options and challenges. *Renewable and Sustainable Energy Reviews*, *20*, 462-472.

Blomquist, J., & Westerlund, J. (2013). Testing slope homogeneity in large panels with serial correlation. *Economics Letters*, *121*(3), 374-378.

Ditzen, J. (2021). Estimating long-run effects and the exponent of cross-sectional dependence: An update to xtdcce2. *The Stata Journal*, *21*(3), 687-707.

Hirooka, M. (2006). Innovation dynamism and economic growth: A nonlinear perspective. In *Innovation Dynamism and Economic Growth*. Edward Elgar Publishing.

Lee, C.-C., & Chang, C.-P. (2007). The impact of energy consumption on economic growth: Evidence from linear and nonlinear models in Taiwan. *Energy*, *32*(12), 2282-2294.

Lu, C., Zhang, X., & He, J. (2010). A CGE analysis to study the impacts of energy investment on economic growth and carbon dioxide emission: A case of Shaanxi Province in western China. *Energy*, *35*(11), 4319-4327.

Markaki, M., Belegri-Roboli, A., Michaelides, P., Mirasgedis, S., & Lalas, D. P. (2013). The impact of clean energy investments on the Greek economy: An input–output analysis (2010–2020). *Energy Policy*, *57*, 263-275.

Mir, T. A., Gopinathan, R., & Joshi, D. P. (2024). Revisiting long-run dynamics between financial inclusion and economic growth in developing nations: evidence from CS-ARDL approach. *Journal of Financial Economic Policy*, *16*(2), 176-193.

Mustafa, M., & Selassie, H. M. (2016). Macroeconomic dynamics of income growth: evidences from ARDL bound approach, gmm and dynamic ols. *European Journal of Business, Economics and Accountancy*, *4*(5), 60-71.

Narayan, P. K., & Smyth, R. (2008). Energy consumption and real GDP in G7 countries: new evidence from panel cointegration with structural breaks. *Energy Economics*, *30*(5), 2331-2341.

Pelinescu, E. (2015). The impact of human capital on economic growth. *Procedia Economics and finance*, *22*, 184-190.

Pelinescu, E. (2019). Human Capital Innovation and Knowledge Economy. Romanian Case. *Hyperion International Journal of Econophysics & New Economy*, *12*(2), 103–116.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of econometrics*, *142*(1), 50-93.

Sadorsky, P. (2011). Trade and energy consumption in the Middle East. *Energy Economics*, *33*(5), 739-749.

Saibu M Olufemi (2012) "Energy Resources, Domestic Investment and Economic Growth: Empirical Evidence from Nigeria" Iranica Journal of Energy & Environment 3 (4): 321-329

Samouilidis, J.-E., & Mitropoulos, C. S. (1983). Energy investment and economic growth: a simplified approach. *Energy Economics*, *5*(4), 237-246.

Sarwar, A., Muhammad, L., & Sigala, M. (2021). Unraveling the complex nexus of punitive supervision and deviant work behaviors: findings and implications from hospitality employees in Pakistan. *International Journal of Contemporary Hospitality Management*, *33*(5), 1437-1460.

Varga, A. (2006). The spatial dimension of innovation and growth: empirical research methodology and policy analysis. *European Planning Studies*, *14*(9), 1171-1186.

Were, M. (2015). Differential effects of trade on economic growth and investment: A cross-country empirical investigation. *Journal of african trade*, *2*(1), 71-85.

Wolde-Rufael, Y. (2009). Energy consumption and economic growth: the experience of African countries revisited. *Energy Economics*, *31*(2), 217-224.

Zahoor, Z., Khan, I., & Hou, F. (2022). Clean energy investment and financial development as determinants of environment and sustainable economic growth: evidence from China. *Environmental Science and Pollution Research*, *29*(11), 16006-16016.

Zelezinskii, A., Arhipova, O., Hodos, D., & Parsukov, D. (2021). Methodological approaches to assessing and forming prospects of innovative development of the regions. *Экономический вектор*(2 (25)), 51-59.

Zhang, X.-P., & Cheng, X.-M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological economics*, *68*(10), 2706-2712.