

## Role of Renewable Energy, FDI, and Trade Openness in Driving Economic Growth: Panel ARDL Evidence from South Asian Countries

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### Abstract

This study examines the impact of renewable energy (RN), foreign direct investment (FDI), and trade openness (TO) on economic growth in South Asian countries using panel data from 1999 to 2023. Panel unit root tests confirmed the stationarity of the data, while the autoregressive distributed lag (ARDL) approach was applied to assess both short- and long-run dynamics. The robustness of the long-run results was verified through pedroni and fisher estimations. Findings reveal that FDI, trade openness and urban population significantly promote short-run economic growth. Conversely FDI and urban population, renewable energy and trade openness negatively influence long-term growth, possibly due to inefficient capital allocation and profit repatriation. Short-run results indicate positive effects of GDP per capita and FDI, whereas renewable energy exerts a modest negative effect, likely reflecting initial investment costs or policy challenges. The significant and negative error correction term confirms adjustment toward long-run equilibrium. These findings offer important insights for policymakers, suggesting that South Asian countries should prioritize trade liberalization, optimize FDI utilization, and carefully manage renewable energy transitions to achieve sustainable economic growth.

**Keywords:** Economic growth, RN, FDI, TO, Sustainable development, South Asian countries

### Introduction

Energy plays a crucial role in financial, social, and environmental development for attaining sustainability in emerging economies (Bhattacharya & Bose, 2023; Degbedji et al., 2024). According to Alam et al. (2023), International Energy Agency claims that by 2040, energy use will increase approximately 19%. The high prices of fossil fuels and their reckless usage, which contribute to climate change and rising temperatures, pose a major challenge for human and environment, and may become the biggest obstacle to sustainable energy consumption (Idroes et al., 2024; Gilliam et al., 2023). Globally, the growing concern for energy security has compelled countries to move towards alternative sources of renewable energy (Raihan & Tuspekova, 2022a; Halkos & Aslanidis, 2023;

Murshed, 2024). The use of energy sources like wind, solar, biofuel and hydropower not only help in protecting the environment, instead it rise opportunities of employment and boosts economic growth (Algarni et al., 2023). Mostly the need of energy is fulfilled by fossil fuels due to which greenhouse gases are increasing, climate is changing, and facing energy insecurity (Shukla et al., 2017). Globally, this problem has increased the interest towards energy sources i.e., wind, hydro, and bioenergy (Abbas et al., 2018). The relationship among energy consumption and energy growth has been studied many times in economic literature, but still findings are different and unclear (Rahman & Mamun, 2016; Ozturk et al., 2010; Apergis & Payne, 2012). Mostly early studies focused on Total Energy Consumption, where Renewable Energy and Non-Renewable Energy were not studied separately. Recent studies have analyzed different types separately and noted the effects on economic growth (Apergis & Payne, 2011; Salim et al., 2014; Tugcu et al., 2012). Countries have different economic situations, econometric models, and regional conditions due to which the findings are different (Kahouli, 2017). Rapidly increasing economy and population caused an increase in energy consumption in South Asian countries (Shukla et al., 2017). Mostly the countries of this region are facing energy problems due to their dependence on fossil fuels as compared to renewable energy (Conte et al., 2012). Renewable energy not only fulfills demand, it also protects the environment via sustainable methods and helps in achieving long-term socio-economic goals (Abbas et al., 2018).

Economic growth is essential for developing countries because it not only reduces poverty and unemployment, it also improves the living standard of people (Liu et al., 2021). To achieve this goal, different methods are adopted, in which use of FDI is considered as an important economic source globally (Wang et al., 2023). FDI not only exchanges technology and knowledge, it also improves economic growth of the host countries via employment opportunities and productive assets (Onayemi et al., 2020). Technology and knowledge are majorly transferred to the developed countries through FDI (Ahmed et al., 2023). It is a well-known fact that FDI is one of the most efficient methods of employment, creating new businesses and establishing them, improving the standard of living, raising the income of workers, increasing a trade flow, and bringing substantial contribution to the overall economic growth and macroeconomic stability (Ahmed et al., 2023). All these advantages encourage the developing nations to formulate policies and plans to encourage FDI. In order to lure FDI, these nations enhance their business climate and provide tax incentives. The political and economic environments are also important in as far as attracting FDI is concerned. Thus, one can say that FDI has a significant influence on the growth and prosperity of a state (Nizam, 2022). The recent empirical research indicates that the influence of FDI on the economic growth varies among different nations and it is dependent on the different factors. According to Chaudhury et al. (2020), the impact of FDI on economic growth depends on which sector FDI has been invested in. Their research reveals that investment of FDI in different sectors, i.e., primary, secondary, and tertiary, has different effects. So, sector-wise policies are essential. Similarly, Rao et al. (2023) highlight that the stability of domestic investment, open trade policies, and macroeconomy improve the effects of FDI.

They argue that if governments support the private sector, then the benefits of FDI increase and it helps in long-term development. According to Bashir et al. (2014), the reason for China's fast development is better infrastructure, political stability, and good capability of absorbing FDI, which is different as compared to South Asian countries. This study claimed that if South Asian countries improve their infrastructure and stabilize their political conditions, then they can attract more FDI, and proper utilization of FDI boosts economic growth. Bhavan and Asghar (2011) research reveals that FDI has a strong and positive association with economic growth in South Asia. Often, it is bidirectional or unidirectional in different countries. Previous findings claimed that FDI boosts economic growth in South Asia when good policies are adopted, and FDI is invested in the best sectors and utilized appropriately.

Trade openness is often regarded as an important source of economic growth in South Asia. Trade openness has played an important role for making countries part of the global economy, diversifying exports, attracting FDI, and benefiting from knowledge and technology. But trade openness is not

always straightforward with economic growth as it depends on different factors. Huchet-Bourdon et al. (2018), claimed despite having similar trade level, every country has different trade structures such as export quality and variety, that effects the results of growth. Their findings suggest a non-linear association, where countries specializing in low-quality goods may not benefit from openness until they improve the sophistication and diversity of their exports. For instance, Hye et al. (2016) and Hye & Lau (2015) highlight the varying impact of trade openness in China and India using ARDL and rolling regression techniques. Their results confirm a positive long-term relationship between openness and growth, but also reveal temporary periods of negative association, indicating structural and policy-driven fluctuations. . In the context of South Asia, Bajwa and Siddiqi (2011) observed that after the implementation of SAARC, trade openness began to exhibit a more positive and stable correlation with GDP. Similarly, Nosheen et al. (2024) found that the effects of openness differ widely across South Asian countries, with nonlinear models capturing asymmetric responses more accurately — for example, positive impacts in India and Pakistan, but weaker or even negative effects in Bangladesh and Sri Lanka. Moreover, recent studies underscore the significance of human capital and institutional quality in mediating the trade–growth nexus. Amna Intisar et al. (2020) emphasize that trade openness enhances economic performance when accompanied by improvements in education, labor participation, and investment in human capital. Hassan et al. (2025) also point to the environmental implications of increased openness and industrialization in South Asia, suggesting that sustainable trade policies are vital for long-term growth.

This study analyzes the data from the period 1999-2023 of South Asian countries excluding Maldives and Afghanistan due to unavailability of data. In this research, economic growth is taken as dependent variable and renewable energy, FDI, and trade openness are independent variables. Additionally, GDP per capita and urbanization are included as control variables to capture the demographic and economic structure effect of different countries. The Panel ARDL method, which is well-suited for analyzing short-run and long-run relationships, is used especially when the order of variables is mixed and sample size is small. The findings of this study will be helpful for policymakers to understand how to achieve economic growth through sustainable energy, trade openness, and investment.

## Literature Review

### Renewable energy and Economic Growth

According to Wang et al. (2022), in OECD, countries the relationship between renewable energy and economic growth depends on country risk, when political and economic risks are low its impact becomes more positive. Pao and Fu (2013) claimed that use of total and non- hydro renewable energy increases economic growth that, supports sustainable development and global competition. Mahmood et al. (2019) argue that in Pakistan renewable energy and economic growth both affect CO<sub>2</sub> emissions while interaction of renewable energy and income also shapes the environment via the EKC model. Inglesi-Lotz (2016) asserted that the use of renewable energy enhances economic growth and plays an important role in environmental improvement. A strong and persistent relationship has been found between renewable energy consumption and economic growth in the developed countries of Europe (Ntanos et al., 2018). Yildirim et al. (2012) stated that no strong relationship was found between renewable energy and economic growth, only biomass waste affects GDP positively. Oliveira and Moutinho (2021) claimed in their review study that research on the relationship between renewable energy and economic growth is increasing, however in underdeveloped countries there is a lack of research. According to Djellouli et al. (2022) renewable energy helps in reducing CO<sub>2</sub> emissions, it does not support EKC hypothesis directly, while economic growth and FDI affect the environment. Omri et al. (2015) examined 17 countries and found that the relationship between renewable energy and economic growth varies across these countries. However, a strong bidirectional relationship was observed in Pakistan and USA.

**H1. There is a positive and significant relationship between REN consumption and economic growth.**

## **FDI and Economic Growth**

According to data from 1990-2019 FDI has increased economic growth in China, Romania, Namibia, Nigeria and Kenya. It improves economic competitiveness and productivity and also reduces costs (Amin et al., 2020). A stable positive relationship between FDI and economic growth has been found in China (Wang et al., 2022). According to Sunde (2023) there is a significant relationship among FDI, and economic growth, proper infrastructure and better utilization of resources is essential for its comprehensive benefits.

In Nigeria a significant relationship between FDI and economic growth has been found that FDI plays an important role in economic development (Ezeaku & Ugwuanyi, 2020). According to Olaniyan and Okemakinde (2021) there is a positive link between FDI inflows and economic growth, stable policies should be made and implemented to attract FDI. Umar and Abdullahi (2022) argued it is essential to make a good investment climate to attract FDI and via Granger causality test they proved a positive relationship between FDI and economic growth.

Overall, all these studies show that FDI plays a vital role in economic development and attracting sustainable FDI. Ciobanu (2021) claimed from 1991 to 2018 in Romania a long-term relationship has been found in FDI, trade, labour and economic growth. This study proves a long-term link between Real GDP and FDI that shows with the passage of time trade openness and labour force contribute towards economic growth. Increase in GDP, exports, imports and labour force affect FDI positively. Ayenew (2022) supports these findings while Makhoba and Zungu (2021) found a positive relationship between FDI and economic growth in South Africa. Empirical findings of Sub-Saharan Africa claimed FDI improves economic growth when infrastructure is better (Nketiah-Amponsah & Sarpong, 2019). According to Teunen et al. (2022) there is a unidirectional relationship between FDI and economic growth while Obisike and Onwuka (2020) found a bidirectional relationship among trade and economic growth and identify unidirectional causality between trade and FDI. Real GDP has a positive relationship with FDI-to-GDP ratio and a negative relationship with gross fixed capital formation (Mwitta, 2022). Lawal and Olusegun (2023) claimed in Nigeria there is a significant positive relationship between FDI and economic growth. FDI plays an important role in economic development.

**H2. There is a positive and significant connection between FDI and economic growth.**

## **Trade openness and economic growth**

According to Keho (2017), economic growth has the advantage of trade openness both in the short and the long term. Seti et al. (2025) claimed that if political and economic conditions of developing countries remain stable then trade openness contributes towards economic growth. Nam and Ryu (2024) argue that economic growth increases with higher trade volume. However, if trade barriers are fewer, then it is harmful to the GDP of developing countries. Huchet-Bourdon et al. (2018) asserted when a country exports high quality and more diverse products, then trade openness affects economic growth positively. Sometimes trade barriers support economic growth that is opposite to traditional outcomes (Yanikkaya, 2003). Tahir et al. (2014) argue based on a review of various studies that trade openness supports economic growth, a clear conclusion is difficult due to differences in research methods. Raghutla (2020) argues trade openness contributes to long-term growth and economic development. Banday et al. (2021) prove that, in BRICS countries, trade openness improves economic growth in the long run and causality towards FDI has also been observed.

**H3. There is a positive and significant connection between TO and economic growth.**

## **Research gap**

The existing literature has examined the relationship between renewable energy, foreign direct investment, trade openness, urbanization, and economic growth separately in different countries. The

results from previous studies have been mixed. The combined effect of these variables has not been studied in the context of South Asia. This study aims to fill this research gap. In this study we have employed advanced ARDL model analysis for comprehensive results. Additionally, we have explored the combined effect of renewable energy, foreign direct investment, trade openness, and urbanization on economic growth in South Asia.

## Methodology

### Data and data sources

In this study, data from 1999 to 2023 has been used to analyze the impact of foreign direct investment, renewable energy, trade openness, GDPPC and urbanization on economic growth. In this research, GDP growth is taken as the dependent variable while GDP per Capita (LGDPCC) is used as control variable, to understand the progress level of each country, both variables reflect different aspects, so they are not considered repetitive. This study includes six South Asian countries (Pakistan, India, Bhutan, Bangladesh, Nepal and Sri Lanka) while Maldives and Afghanistan have been excluded due to unavailability of data and data for all variables has been taken from World Development Indicators. Therefore, selection of time period and countries depends on the availability of data. All the details of variables and their measurements have been mentioned in Table 1. The figure.1. shows the flow of analysis.

**Table 1**  
**Description of data**

| Variables                 | Symbol | Description  | Source |
|---------------------------|--------|--|--------|
| Economic Growth           | EG     | GDP growth (annual %)  | WDI    |
| Foreign direct investment | FDI    | Foreign direct investment, net inflows (% of GDP)                  | WDI    |
| Gross Domestic Product    | GDPPC  | GDP per capita (current US\$)                                      | WDI    |
| Renewable energy          | RN     | Renewable energy consumption (% of total final energy consumption) | WDI    |
| Urbanization              | URN    | Urban population (% of total population)                           | WDI    |
| Imports                   | IMP    | Imports of goods and services (current US\$)                       | WDI    |
| Exports                   | EXP    | Exports of goods and services (current US\$)                       | WDI    |

### Econometric methodology

The study examines how foreign direct investment (FDI), renewable energy consumption (FDI), trade openness (TO) impacts economic growth concerning GDP and urbanization (URN). The following is the model specification:

$$EG_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 RN_{it} + \beta_3 TO_{it} + \beta_4 GDP_{it} + \beta_5 URN_{it} + \epsilon_{it} \quad (1)$$

In Eq. (1), EG is employed to quantify Economic growth, while RN indicates renewable energy consumption. FDI refers to foreign direct investment, TO indicate trade openness. In addition, GDP denotes Gross Domestic Product per capita, URN denotes urbanization, I and t denote the nation and time respectively.

### Descriptive Statistics

Before econometric analysis, to understand the data descriptive statistics are performed. This step is helpful in providing the basic idea of variables' distribution, average, and variation. In descriptive statistics, the values of mean, standard deviation, minimum, and maximum cover the sample of countries and time period. These stats help in identifying the unusual values or residuals in the data. The comparison of these values initially helps in identifying the relationship between variables, which

is later confirmed by econometric methods.

### Correlation Matrix

To understand the relationship between variables, a correlation matrix is used, which shows the linear relationship and direction among them. This step helps in diagnosing the issue of multicollinearity before applying the model. If the independent variables have a strong (positive or negative) relationship between them, then it's a sign of multicollinearity that may bias the regression results. Therefore, before empirical tests, correlation coefficient analysis is necessary to understand the data. The correlation matrix results are used to ensure that there is no issue of multicollinearity in the dataset.

### Cross sectional dependence

To analyze the relationship between the sample countries, before applying the panel unit root test, we use Pesaran (2004) cross-sectional dependence (CD) test. According to Pesaran (2007), results can be biased if panel unit root tests are applied while ignoring cross-sectional dependency. The purpose of CD tests is to check whether cross-sectional dependency exists. It means null hypothesis claim no cross-sectional dependency exists among the variables.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij} \right) \sim N(0, 1) \quad (2)$$

According to Equation (2),  $\hat{\rho}$  represent the cross-sectional relationship, N represents sample size and T represents time period. According to the CD test basic assumption is that countries should not be affected by each other, meaning there is cross-sectional independence. On the other hand, it is assumed that economies included in the sample are influenced by each other.

### Panel unit root tests

Checking the stationarity of the data is essential before long-term estimations. In this study, considering different macroeconomic variables, it is crucial to take into account the order of integration. Otherwise, the results may be biased and incomplete. The results can be biased in the presence of CD. Therefore, a panel unit root test is essential that accounts for this problem. Panel unit root tests of first generation are applied when the analysis is done without considering cross-sectional dependency. To check the stationarity of variables, four well-known tests (LLC, IPS, ADF-Fisher and PP-Fisher Chi square) were applied. These tests are flexible and capable of providing results according to each country and indicating whether variables are stationary at level or at 1st difference, as shown in Table 4.

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{k=1}^p \beta_{ik} \Delta y_{i,t-k} + \varepsilon_{it}$$

$$\bar{t}_N = \frac{1}{N} \sum_{i=1}^N t_i$$

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{k=1}^p \beta_k \Delta y_{i,t-k} + \varepsilon_{it}$$

$$P_{ADF-Fisher} = -2 \sum_{i=1}^N \ln(p_i) \sim \chi_{2N}^2$$

$$P_{PP-Fisher} = -2 \sum_{i=1}^N \ln(p_i^{PP}) \sim \chi_{2N}^2$$

### Panel cointegration test

In this study we use the Pedroni and Fisher-type Johansen panel cointegration tests to examine long-term association. These first-generation cointegration tests are used under the assumption of cross-sectional independence. Pedroni and Fisher (Johansen-based) methods examine long-term association using different statistics. The results presented in Table 4 indicate that no relationship exists between panel variables.

$$\Delta \hat{e}_{it} = \rho_i \hat{e}_{i,t-1} + \sum_{j=1}^p \gamma_{ij} \Delta \hat{e}_{i,t-j} + \mu_{it}$$

$$\chi_{Fisher}^2 = -2 \sum_{i=1}^N \ln(p_i) \sim \chi_{2N}^2$$

### Long-run estimation methods

The panel ARDL method is used to assess the short run and long run effect of any factor, like effect of foreign direct investment, renewable energy, trade openness, GDP per Capita, and urbanization on economic growth. GMM approaches are better in that case when there are multiple countries and time span is short, but in this study the scenario is different, that's why the panel ARDL method is more appropriate.

According to Pesaran and Shin (1995), the panel ARDL can be applied on datasets where variables are I(0), I(1) or mixed. The PMG estimators allow short run country specific difference whereas in long run provides relatively uniform results. Due to this approach, every country can have its own convergence rate, that may be influenced by internal or external shocks.

To select the optimal lag length, Akaike Information Criterion is used, and model is specified in an error correction form.

$$\begin{aligned} \Delta EG_{it} = & \gamma_i + \alpha_i^* \left( EG_{i,t-1} - \theta_{1i} RE_{i,t-1} - \theta_{2i} FDI_{i,t-1} - \theta_{3i} TO_{i,t-1} \right. \\ & \left. - \theta_{4i} GDPPC_{i,t-1} - \theta_{5i} URN_{i,t-1} \right) \\ & + \sum_{j=1}^{p-1} \phi'_{ij} \Delta EG_{i,t-j} + \sum_{j=0}^{q-1} \beta'_{1,ij} \Delta RE_{i,t-j} + \sum_{j=0}^{q-1} \beta'_{2,ij} \Delta FDI_{i,t-j} \\ & + \sum_{j=0}^{q-1} \beta'_{3,ij} \Delta TO_{i,t-j} + \sum_{j=0}^{q-1} \beta'_{4,ij} \Delta GDPPC_{i,t-j} + \sum_{j=0}^{q-1} \beta'_{5,ij} \Delta URN_{i,t-j} + \nu_{it} \end{aligned}$$

Where

$$ECT_{i,t-1} \equiv EG_{i,t-1} - \hat{\theta}_{1i} RE_{i,t-1} - \hat{\theta}_{2i} FDI_{i,t-1} - \hat{\theta}_{3i} TO_{i,t-1} - \hat{\theta}_{4i} GDPPC_{i,t-1} - \hat{\theta}_{5i} URN_{i,t-1}$$

If  $\theta_i$  is negative and significant, it implies variables may be cointegrated. By assuming long-run coefficients homogeneous and short-run heterogeneous PMG method is used, as suggested by Pesaran et al. (1999) suggest to use it. Final method was selected based on Hausman test.

**Table 2**  
**Descriptive statistics.**

|             | LEG      | LFDI     | LTO      | LRN      | LURN     | LGDPPC   |
|-------------|----------|----------|----------|----------|----------|----------|
| Mean        | 5.215094 | -0.34806 | -0.78919 | 3.982754 | 3.297331 | 7.099492 |
| Median      | 5.456388 | -0.22531 | -0.79851 | 3.914021 | 3.398059 | 7.096075 |
| Maximum     | 16.10478 | 1.771782 | 0.076961 | 4.521789 | 3.777028 | 8.3896   |
| Minimum     | -7.34679 | -4.83683 | -1.56065 | 3.218876 | 2.553888 | 5.340642 |
| Std. Dev.   | 3.017097 | 0.926777 | 0.408    | 0.358168 | 0.307338 | 0.706144 |
| Skewness    | -1.00258 | -1.24879 | 0.383795 | -0.03525 | -0.49075 | -0.08903 |
| Kurtosis    | 6.989579 | 6.77358  | 2.261926 | 2.014184 | 1.861972 | 2.395429 |
| Jarque-Bera | 118.7936 | 122.0134 | 6.756445 | 5.820113 | 13.45649 | 2.366715 |
| Probability | 0        | 0        | 0.034108 | 0.054473 | 0.001197 | 0.306249 |

**Table 3**  
**The findings of the correlation analysis**

|        | LY       | LFDI     | LTO      | LRN      | LURN    | LGDPPC |
|--------|----------|----------|----------|----------|---------|--------|
| LY     | 1        |          |          |          |         |        |
| LFDI   | 0.170104 | 1        |          |          |         |        |
| LTO    | 0.227394 | 0.129445 | 1        |          |         |        |
| LRN    | -0.00411 | -0.40814 | 0.566831 | 1        |         |        |
| LURN   | 0.183354 | 0.263905 | -0.18443 | -0.45744 | 1       |        |
| LGDPPC | -0.02354 | 0.318584 | 0.334463 | -0.19256 | 0.24367 | 1      |

**Table 4**  
**Panel unit root tests.**

|        | <i>I</i> (0)  |               |               |               | <i>I</i> (1)   |                |                |                |
|--------|---------------|---------------|---------------|---------------|----------------|----------------|----------------|----------------|
|        | LLC           | IPS           | ADF           | PP            | LLC            | IPS            | ADF            | PP             |
| LY     | (-4.1)<br>*** | (-3.8)<br>*** | (40.7)<br>*** | (79.1)<br>*** | (-9.6)<br>***  | (-10.1)<br>*** | (98.9)<br>***  | (498.6)**<br>* |
| LFDI   | (-5.0)<br>*** | (-4.3)<br>*** | (40.7)<br>*** | (28.6)<br>*** | (-7.2)<br>***  | (-7.4)<br>***  | (71.1)<br>***  | (117.8)**<br>* |
| LTO    | (-2.1)<br>*** | (-1.6)<br>**  | (19.6)<br>**  | (16.8)<br>*   | (-5.1)<br>***  | (-6.5)<br>***  | (63.5)<br>***  | (137.3)**<br>* |
| LRN    | (-1.3)<br>**  | (1.2)<br>*    | (5.1)<br>*    | (3.6)<br>*    | (-3.5)<br>***  | (-4.3)<br>***  | (42.7)<br>***  | (99.6)<br>***  |
| LURN   | (-1.8)<br>*** | (-0.7)<br>*   | (53.6)<br>*** | (37.9)<br>*** | (-20.5)<br>*** | (-33.1)<br>*** | (270.8)**<br>* | (82.6)<br>***  |
| LGDPPC | (-2.3)<br>*** |               |               | (23.1)<br>*** |                |                | (39.6)<br>***  | (72.8)<br>***  |
| C      |               | (0.4)<br>*    | (8.4)<br>*    | ***           | (-4.3)<br>***  | (-4.1)<br>***  | ***            | ***            |

**Table 5**  
**Cross-sectional dependence testing results**

| Variables | Pesaran CD | P- value |
|-----------|------------|----------|
| RN        | 16.26787   | 0        |
| FDI       | 3.384486   | 0.0007   |
| TO        | 3.145619   | 0.0017   |
| GDPPC     | 17.86717   | 0        |
| URN       | 16.90638   | 0        |
| EG        | 7.09854    | 0        |

**Table 6**  
**Pedroni Panel Cointegration Test Results**

| Test Statistics     | Statistic Value | Prob.  |
|---------------------|-----------------|--------|
| Panel v-Statistic   | -0.112477       | 0.5448 |
| Panel rho-Statistic | -0.1954         | 0.4225 |
| Panel PP-Statistic  | -6.392152       | 0      |
| Panel ADF-Statistic | -2.205808       | 0.0137 |
| Group rho-Statistic | 1.068888        | 0.8574 |
| Group PP-Statistic  | -7.929826       | 0      |
| Group ADF-Statistic | -1.825168       | 0.034  |

**Table 7**  
**Johansen Fisher Panel Cointegration Test Results**

| Hypothesized<br>CE(s) | No. of<br>Fisher<br>Stat. (from<br>trace<br>test) | Prob. | Fisher<br>Stat. (from<br>max-eigen<br>test) | Prob. |
|-----------------------|---|-------|---|-------|
| None                  | 214.9   | 0     | 120.5                                       | 0     |
| At most 1             | 124.5   | 0     | 68.28                                       | 0     |
| At most 2             | 124.6   | 0     | 74.21                                       | 0     |
| At most 3             | 114.1   | 0     | 89.67                                       | 0     |
| At most 4             | 48.14   | 0     | 37.39                                       | 2     |
| At most 5             | 28.35   | 9     | 28.35                                       | 9     |

**Table 8**  
**Panel ARDL results over the long and short term.**

| Variables                | Long-run    |             |           | Short-run   |              |         |
|--------------------------|-------------|-------------|-----------|-------------|--------------|---------|
|                          | Coefficient | t-Statistic | p-value   | Coefficient | t-Statistic  | p-value |
| LFDI                     | -0.30421    | -1.0917     | 0.277     | 0.86169     | 1.968485     | 0.0519  |
| LTO                      | -1.928688   | -1.4399     | 0.153     | 7.07016     | 2.490836     | 0.0145  |
| LRN                      | -8.56086    | -2.3491     | 0.020     | -14.9544    | -1.599207    | 0.1131  |
| LGDPPC                   | 1.393224    | 2.0366      | 0.044     | 16.1053     | 4.522704     | 0       |
| LURN                     | -15.34182   | -3.1492     | 0.002     | 221.986     | 0.317066     | 0.7519  |
| C                        |             |             |           | 62.0381     | 3.711225     | 0.0003  |
| ECM (-1)                 |             |             |           | -0.93944    | -7.067793    | 0       |
| Model Selection Criteria | Akaike info |             | Schwarz   |             | Hannan-Quinn |         |
|                          | criterion   |             | criterion |             | criter.      |         |
| p-value                  | 3.760768    |             | 4.73457   |             | 4.156475     |         |

### Results and Discussion

The results begin with descriptive statistics which provide basic information about average, spread, and distribution. According to Table 2, average values of all the variables range from -0.79(LTO) to 7.10(LGDPPC). In LEG and LFDI, skewness and kurtosis are high that indicate non-normality. Jarque bera test indicates, most variables are not normally distributed, only LGDPPC ( $p=0.306$ ) exhibits a normal distribution. These results justify the use of Panel ARDL model because this model also provides comprehensive results even when the data are not normally distributed.

Table 3 shows that most variables exhibit weak to moderate correlation. The correlation of LFDI with LGDPPC ( $r=0.32$ ) and LURN ( $r=-0.26$ ) is positive, while with LRN ( $r=-0.41$ ) its correlation is moderately relation is negative. The correlation of LTO with LGDPPC ( $r=0.33$ ) and LRN ( $r=0.57$ ) is strong positive. Correlation of each variable is less than 0.80, that indicates that there is no issue of multicollinearity.

Before the unit root test, it is necessary to check to cross section dependence of panel countries. Mostly in panel data, countries have associations due to culture, border or nation. For obtaining unbiased and reliable results, to control cross-sectional effects are necessary otherwise findings can be biased. According to Table 5, in all variables there is cross-sectional dependency, and p values are less than 0.05. CD tests indicate that panel units are not independent, so for checking stationary LLC, IPS, ADF and PP units root tests are applied. These tests are commonly used for examining the unit root in data. In Table 4, results on both levels  $I(0)$  and  $I(1)$  are shown. Results indicate most variables are non-stationary at level, but at 1st difference they become stationary that confirms their  $I(1)$ .

Variable i.e LEG, LFDI, LTO, LRN and LOGDPPC shows mixed results at level, but after 1st Panel cointegration technique is appropriate.

To examine long-term relationships Pedroni and Johansen Fisher panel tests are applied. The results

are shown in Table 6 & 7.

Pedroni test results such as Panel PP (-6.39,  $p=0.000$ ), Panel ADF (-2.20,  $p=0.0137$ ), Group PP (-7.93,  $p=0.000$ ) and Group ADF (-1.82,  $p=0.034$ ) —are significant at 5% level, that is prove of long-run cointegration among variables. Like this Johansen Fisher panel cointegration test also confirms long-run link, because from "None" to "At most 5" the Fisher stat of all variables is significant ( $p<5$ ). It means both tests confirms long term association exist in the data of South Asian countries.

Table 8 represents the results of panel ARDL model, that shows EG has short run and long run relationship with FDI, RN, TO, GDPPC and URN. Pooled mean group (PMG) is used to understand the data difference and reaction in different countries.

In the long run GDPPC (coefficient 1.3932,  $p=0.0444$ ) has significant and positive link with EG. The results indicate increase in GDPPC helps in continuous growth in South Asian countries. On the other hand, RN -8.5608 ( $p=0.0209$ ) and URN -15.3418 ( $p=0.0022$ ) have a significant but negative impact on economic growth. The results indicate that renewable energy is not properly used, and unnecessary spread of cities is reducing economic growth. Long run results represent coefficients of both FDI -0.3042 ( $p=0.2777$ ) and TO -1.9286 ( $p=0.1531$ ) are negative but statistically significant, that confirms both have no long run effect on economic growth.

Strong and highly significant, the coefficients of GDPPC in short run =16.1054( $p=0.000$ ) The results indicate that GDPPC can strongly influence economic growth in the short run, similarly, the openness of trade (coefficient= 7.0701,  $p=0.0145$ ) also has a significant and strong influence on the economic growth in the short run. Although the effect of FDI (coefficient=0.8617,  $p=0.0519$ ), can be considered as upto relatively important, showing that FDI can lead to economic growth, effect is not even greater. Conversely, it has been established that there is no significant and vital effect of renewable energy and urbanization on economic growth, which shows that they do not have any immediate effect. The value of the coefficient of ECM (-1) = -0.9394 which is significant ( $p=0.000$ ) proves the existence of long run relationship between variables. The negative sign shows that the deviation of long run equilibrium is 94 percent during one period of time, that is the evidence of rapid adjustment. The best panel ARDL model was chosen utilizing Akaike Information Criterion (AIC = 3.76), Schwarz Criterion (SC = 4.73), and Hannan-Quinn Criterion (HQ = 4.15). Of these three criteria (AIC, SC, HQ), one of the models would have the lowest value which was regarded as the best since it exhibits less error and does not overfitting. The findings of this panel ARDL model positively relate foreign direct investment and economic growth in the short-run. Nonetheless, it has negative long-term influence. According to the findings, an increment of 1 percent in the use of FDI led to 0.86 percent increment in the short-run economic growth and -0.30 percent decline in long-run economic growth. Just like Muyambiri, (2025), this paper asserts that FDI increases economic growth in the short run but in the long run it does not have a strong association with economic growth. According to the outcomes, a one percent increase in trade openness led to 7.07 percent led to economic growth and -1.93 percent reduction in the long run. Research findings according to this study show that, in the short run, the effect of trade openness is found to be positive and significant which conforms to the findings of other studies in the past. Equally, Oloruntuyi and Ojeka (2023), used the ARDL model on Nigerian data and the effect of the shortat trade openness was positive on economic growth in the short run and negative in the long run. Esaku (2021) asserted that short run increase in trade, exports, and imports results in increase in economic growth. Musila and Yiheyis (2015) claim that no special effect of trade openness in Kenya has been identified in the long run and in the short-run through capital, trade openness influences economic growth. These findings are in line with the current study, as long term effects may not be the same across countries, and trade openness has a short term effect on boosting the economy. Based on findings, a 1% change in the use of trade renewable energy led to -14.95% in the short term and -8.56 in the long term in economical growth. The results are comparable with those of the study of Rahman et al. (2023) which stated that in the long run, there is a negative correlation between renewable energy and economic growth in South Asian countries. In a study on Nigeria, Somoye et al. (2022) applied NARDL method and concluded that an increase in

the use of renewable energy has a positive effect on the economic growth in the short run, that means that an immediate use of renewable energy has a positive effect on the economy and can be a good source of the short-term growth. The NARDL approach was used by Salisu (2023) and stated that there is an asymmetric association between renewable energy and economic growth. His research findings show that the growth of an economy is affected by either influx or decline of renewable energy. All these findings indicate that the impacts of renewable energy cannot be seen clearly in long-term, though it has a positive influence in the short-term growth in Nigeria. 5. Conclusions and policy implications

### **Conclusions**

This study explores the relationship between renewable energy, FDI, Trade openness, urbanization, and economic growth using a dataset from 1999 to 2023 for South Asian countries. To check the consistency of data panel unit root tests such as LLC, IPS, ADF, and PP were employed. The panel ARDL method was used to examine the short run and long run relationships among factors. The findings reveal that FDI, trade openness, and urban population affect economic growth positively in the short run, while in long run FDI, renewable energy, trade openness and urbanization affect economic growth negatively. These effects may be due to non-effective use of capital and profit repatriation. FDI and GDPPC have positive impact in the short run while renewable energy has a minor negative impact. To further confirm the results Pedroni and Fisher cointegration tests were used. The results of this research suggest, to attain sustainable growth, south Asian countries should promote trade openness, energy efficient technologies and design effective strategies to attract FDI. FDI should be invested in beneficial sectors. This study also concludes that trade openness and proper utilization of FDI and effective use of renewable energy boost development.

### **Policy implications**

The results of this study provide valuable guidance for policymakers in South Asia. While renewable energy is becoming an important resource for development. Governments should formulate and implement policies for sustainable energy. For this government should strengthen institutions and design regulations for clean energy and develop local supply chain in solar and wind sectors. Government should provide training and education to people and improve their technical skills. The government should offer tax incentives, easy loans and subsidies like monetary benefits, to attract local and foreign investors for increased investment in green projects. Besides this the role of FDI is crucial in technology and economic productivity, so it should be directed towards beneficial projects. South Asian countries should focus on FDI that promotes technological transfer and innovation, especially in renewable energy and sustainable development sectors. South Asian countries should focus on FDI that promotes technological transfer and innovation, especially in renewable energy and sustainable development sectors. To gain the long-term benefits of FDI, such policies should be formulated that make investment landscape attractive such as ensuring economic stability, a strong legal system and a developed financial sector. Trade openness plays a crucial role in providing access to renewable technology, capital goods and innovation. Therefore, trade liberalization policies should be formulated in a way that supports the environment and economic competitiveness remains stable. South Asian countries can achieve development by aligning trade, energy and investment policies with effective planning.

### **Limitations and future research directions**

This study helps in understanding the relationship between renewable energy, foreign direct investment and trade openness in South Asia, but it also has some limitations. The scope of analysis is limited because the availability and consistency of data from different countries was an issue. Especially, data on solar, wind, hydro, and biomass were unavailable, that's why the clear effect of each source on economic growth remains ambiguous. The panel ARDL approach is suitable for small

sample sizes and mixed data. It does not cover the structural breaks, endogeneity or the effect of each county's effects properly. In future research, policies and institutions' differences can be better understood by using more advanced models, such as dynamic GMM or SEM and conducting time series analysis of each country separately. Furthermore, future researchers may study other related factors such as globalization, technology, institutional, and environmental factors for a better understanding of sustainable economic growth. Sector-wise impact of FDI should be analyzed, especially in renewable energy and technology industries, as this may be helpful for policy formulation. If regional-level or microdata is obtained, then the effects of clean energy and investment on productivity and development can be examined in depth. Such in-depth research studies will enhance future research and support the formulation of effective policies for the economic development of South Asia.

### **Declaration of Competing Interest**

The authors declared that they have no personal or financial interests that may have influenced this research.

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