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**ADAPTIVE ANALYSIS OF 3E FACTORS  
(ECONOMY, ENERGY, AND ENVIRONMENT)  
FOR RENEWABLE ENERGY GENERATION IN THE  
SOUTH AND SOUTH-EAST ASIAN REGION**

**Salva K K  
Zareena Begum Irfan**



**MADRAS SCHOOL OF ECONOMICS**

**Gandhi Mandapam Road  
Chennai 600 025  
India**

**September 2024**

*Adaptive Analysis of 3E Factors (Economy,  
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Generation in the South and South-East Asian  
Region*

**Salva K K**

Research Scholar, Madras School of Economics, Chennai  
[salva@mse.ac.in](mailto:salva@mse.ac.in)

**and**

**Zareena Begum Irfan**

Professor, Madras School of Economics, Chennai  
[zareena@mse.ac.in](mailto:zareena@mse.ac.in)

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Gandhi Mandapam Road  
Chennai 600 025  
India**

**Phone: 2230 0304/2230 0307/2235 2157**

**Fax: 2235 4847/2235 2155**

**Email : [info@mse.ac.in](mailto:info@mse.ac.in)**

**Website: [www.mse.ac.in](http://www.mse.ac.in)**

# **Adaptive Analysis of 3E Factors (Economy, Energy, and Environment) for Renewable Energy Generation in the South and South-East Asian Region**

**Salva K K and Zareena Begum Irfan**

## **Abstract**

*Growing energy demand in the context of unprecedented changes in the climatic pattern is a challenge of the period. In light of this scenario, renewable energy, the widely accepted alternative for having energy security would be worth examining. Since Asia is accountable for a major portion of global energy demand and emission, this study investigates the impact of renewable energy consumption along with non-renewable energy consumption on environmental degradation and economic growth in 24 developing countries of Asia from 1990 to 2018. To account for the panel specific heterogeneity and cross-sectional dependence, Pooled Mean Group model in Panel Auto Regressive Lag approach is used for analysis. Unlike most of the existing literature, this research work has considered ecological footprint as a proxy for environmental degradation, in addition to CO<sub>2</sub> emission. The result showed that both type of energy consumption have positive impact on economic growth, but renewable energy consumption also helps to reduce the emission and ecological footprint. This implies that for developing countries of Asia renewable energy is the best option for having energy security and economic growth without degrading the climate and environment. Further the existence of conservation hypothesis indicates that countries considered for the analysis could adopt energy conservation measures with no fear of hurdle being caused on economic growth. The result also showed that economic growth measured by GDP is increasing the emission and ecological footprint. This implies the need for a transition to an environmentally sustainable way for economic growth.*

**Keywords:** *Renewable and Non-renewable energy consumption, Ecological footprint, CO<sub>2</sub> emission, Economic growth*

**JEL Codes:** *Q42, O13, Q56, C23*

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## INTRODUCTION

Energy sector is responsible for almost three-quarters of the emissions that have caused the global average temperatures to rise by 1.1°C higher since the pre-industrial age, with visible impacts on weather and climate extremes ( *World Energy Outlook 2021*). Decarbonisation of energy sector is at the heart of the various climate actions taken to the date. Renewable energy (here after RE) is identified as a solution for reducing the emission without offsetting the energy demand. Two-third of the required reduction in energy related CO<sub>2</sub> emission for keeping the global temperature rise to less than 2°C can be attained from RE ( *IRENA-Climate policy-2017*).

The share of renewables in global electricity generation reached almost 29 percent in 2020 ( *Global Energy Review 2021*). Globally, renewable electricity capacity is forecast to increase by more than 60 percent between 2020 and 2026, reaching more than 4800 GW, equivalent to the current global power capacity of fossil fuels and nuclear combined (Executive summary-*Renewables 2021*). RE also have a greater role to play in attaining the Net Zero Emissions target of 2050.

Given the significant place that RE has attained in the climate actions, it is important to understand its environmental and economic impact. In the literature on energy economics a number of studies is found analyzing the impact of energy consumption, but those analyzing the impact of RE consumption in particular is limited. Furthermore, most of the studies on RE tried to find out its economic impact (Magnani and Vaona, 2013; Bozkurt and Destek, 2015; Bhattacharya *et. al.*, 2016; Armeanu *et. al.*, 2017; Behera and Mishra, 2020), but those analyzing the environmental impact is rare (Mahmood *et. al.*, 2019; He *et. al.*, 2019). None of the study is found analyzing the economic and environmental impact together. However for the policy purposes it is essential to consider them together. This study is an attempt to fill this gap by analyzing the economic and environmental impact of RE. Despite

the growth of RE, Non-RE still dominate the global power system (UN Environment, 2019), hence to get a consistent result about the impact of RE consumption and for comparing the relative influence of both type of energy consumption, Non-RE consumption is also a part of this analysis.

In this context this study aims to investigate the long run and short run relation between both type of energy consumption, economic growth, and environmental degradation in developing countries of Asia. Reason for choosing Asia includes; Asia is the region with largest energy consumption and carbon emission. U.S. Energy Information Administration (EIA) projected Asia's energy consumption to be half of the world's by 2050 (*EIA International Energy Outlook 2020*). Asia is a major cause for 40 per cent of increase in global anthropogenic CO<sub>2</sub> emission over the period of 1990 to 2014 (UN Environment, 2019). In 2020 Asia-Pacific region accounted for 52 percent of global CO<sub>2</sub> emissions (*Bp-Stats-Review-2021*). All these implies that Asian countries' transition to cleaner energy is critical for global efforts in tackling the climate change. Thus it seems appropriate to choose Asia as the study area to analyze the impact of RE consumption on environment and economic growth.

This study makes some important contribution towards the literature in energy economics. Rather than concentrating either on the environmental or on the economic impact of RE consumption, we examined both the impact. Energy policies taken to tackle the environmental issues without considering the economic impact could be detrimental. Same happens if the policies are taken by considering the economic impact alone. Hence our result showing both these impacts would be useful for policy purposes.

Second, unlike the existing studies we chose ecological footprint in addition to CO<sub>2</sub> emission to indicate the environmental degradation. Most of the existing studies analyzing the environmental impact of energy consumption (RE, Non-RE or both) had examined it by analyzing the

impact of energy consumption on carbon emission. But to get a clear picture regarding the environmental impact of RE it is essential to analyze how it is affecting the environmental resources. Since ecological footprint measures the natural resources consumed by a product or people, our analysis with that variable could provide some insights about the impact of RE consumption on environmental resources.

Third, along with RE consumption, we included Non-RE consumption as well in the analysis so that we can identify the relative impact of both type of energy consumption on economic growth and environmental degradation. Fourth, while dealing with panel data most of the studies assume that there is no panel specific heterogeneity and cross-sectional dependence. But the countries considered may be heterogeneous in nature and there may be cross-sectional dependence, hence to account for that present study used heterogeneous panel model, the ARDL.

The rest of the paper is organized as follows. Section 2 provides a review of the existing literature. Section 3 describes the model, variables, and the econometric methodology used for analysis. Section 4 presents the empirical findings. Section 5 discusses the result and section 6 provides the conclusion and policy recommendations.

## **LITERATURE REVIEW**

In the literature on energy economics a number of studies is found analyzing the energy-economic growth nexuses, but studies analyzing the environmental impact of energy consumption is very rare. This section provide a review of the existing studies which had examined environmental and or economic impact of energy consumption.

## **Literature on Energy-Economic Growth Nexus**

Researchers on energy-economic growth nexus are usually interested to find out the causal relation between energy consumption and economic growth (Charfeddine, 2017). Studies in this field have so far identified four hypothesis on the effect of energy consumption on economic growth; conservation hypothesis-unidirectional causality from economic growth to energy consumption, growth hypothesis-unidirectional causality from energy consumption to economic growth, feedback hypothesis-bidirectional causality between the two variables, and neutrality hypothesis-existence of no causality (Menegaki and Tugcu, 2016). Though a number of literature can be found on this topic a consensus regarding the true relation between energy consumption and economic growth is not existing, results varies depending on the methodology, country, time period, and the variables chosen for analysis (Omri, 2014).

Huang *et. al.*, 2008 used a panel of 82 countries to analyze the relation between economic growth and RE consumption. VAR model using System GMM showed bi-directional causality between the variables for the whole panel. But the sub-panel analysis showed no causality for low income countries, positive causality from economic growth to energy consumption for middle income countries and negative causality for high income countries. Existence of the conservation hypothesis made them to call for stringent conservation policies. Bozkurt and Destek, 2015 also made the same analysis but in four OECD countries using ARDL test of co- integration and Toda and Yamamoto procedure of causality test. They inferred that RE consumption increases GDP only in highly developed countries like US and Germany, where as it reduces the economic output for less developed countries like Italy and Turkey.

Bhattacharya *et. al.*, 2016 also followed the same path of analysis by using DOLS and FMOLS models. Panel of 38 countries was analyzed from 1991 to 2012. Since Non-RE was found playing a dominant role, they called for the promotion of RE for having sustainable economic

development. Unidirectional causality from output to capital, output to labor, and from Non-RE consumption to output in the short run were also examined. Koçak and Şarkgüneşi, 2017 also analyzed the effect of RE on economic growth, keeping labor and capital as the control variables. 9 Black Sea and Balkan countries were analyzed from 1990 to 2012. FMOLS and DOLS methods showed positive relation between the variables. Dumitrescu and Hurlin causality test showed the existence of feedback hypothesis.

Armeanu *et. al.*, 2017 analyzed the effect of RE production on economic growth in 28 EU countries. By using FMOLS and DOLS they found positive association between the variables. Panel VECM showed unidirectional causality from economic growth to RE production in both the short run and long run. Magnani and Vaona, 2013 did a panel analysis to examine the spillover effect of RE generation on output in Italian region. Dynamic OLS showed positive impact of RE on output. Short run Granger causality was also examined from RE generation and employment to output. Instead of RE Bildirici, 2013 analyzed the causal relation between biomass energy consumption and economic growth. ARDL bound testing approach of co-integration and dynamic ECM showed that biomass energy consumption was a stimulus for economic growth.

Menegaki and Tugcu, 2016 reviewed the existing studies that had examined the energy-economic growth nexus using GDP as a proxy of welfare. They had also made the similar analysis for 15 emerging countries using two additional proxies of welfare. Result was consistent in a majority of the cases, but the direction of causality varied substantially between the countries and with respect to the proxies.

While testing for energy-economic growth nexus some studies had included environmental factors in the analysis. A few of such studies are included here. Behera and Mishra (2020) examined the relationship between energy consumption (RE and Non- RE) and economic growth in

G7 countries by including carbon emission, energy price, capital, and labor as the additional variables. Their PMG model showed long run positive impact of energy price, capital, and labor force on economic growth, and short run causality from Non-RE consumption and capital to economic growth. Same analysis with DOLS showed that in the long run energy price, carbon emission, Non-RE, and labor force had positive influence on economic growth whereas capital and RE had negative influence.

Saint Akadiri *et. al.*, 2019 examined the effect of RE consumption on economic growth, keeping CO<sub>2</sub> emission and fixed capital as the control variables. 28 EU countries were analyzed from 1995 to 2015. Panel ARDL models of PMG and DFE, showed positive relation between RE and economic growth in the long run. They also found bidirectional causality between economic growth, and RE consumption, CO<sub>2</sub> emission, and fixed capital formation respectively.

Mensah *et. al.*, 2019 examined the causal link of economic growth, fossil fuel consumption, carbon emission and oil price in 22 African countries from 1990 to 2015. PMG model showed positive impact of carbon emission, oil price, and energy consumption on economic growth. But energy consumption was found to accelerate the emission. Bidirectional causality between economic growth and energy consumption and between energy consumption and emission was found in the long run and the short run.

### **Literature Analyzing the Environmental Impact of Energy Consumption**

Shaari *et. al.*, 2020 analyzed the effect of oil and gas consumption, national output, and population on CO<sub>2</sub> emission in 20 Organization of Islamic Cooperation (OIC) countries for a period of 1990 to 2017. By using the ARDL-PMG model oil and gas were found increasing the emission in both the short run and the long run. Output was found

increasing the emission in the long run but population reduced emission in the short run.

He *et. al.*, 2019 analyzed non-linear relation between RE investment and green economy development from the perspective of green credit using threshold effect model. Their analysis with 150 RE listed companies of China from 2004 to 2015 showed two threshold green credit in the effect of RE investment on green economy development index. This indicates the significance of RE in promoting green economic development.

Munir and Riaz, 2019 used Nonlinear ARDL model to examine the relation between energy and electricity consumption and CO<sub>2</sub> emission in Bangladesh, India, and Pakistan. Non-linear relation was found between CO<sub>2</sub> emission, and electricity consumption and coal consumption respectively in the long run. In the short run non-linear relation was found between CO<sub>2</sub> emission, and coal, gas, and electricity consumption respectively in Bangladesh and Pakistan. In addition to the individual effect of RE consumption, Mahmood *et. al.*, 2019 examined how its interaction with economic growth effects CO<sub>2</sub> emission. Analysis was made for Pakistan from 1980 to 2014 using 3SLS and ridge regression. Individually RE consumption was found reducing the emission but its interaction with GDP increases the emission, indicating that economic growth diminishes the positive effect that RE had on environment. They also found the existence of EKC hypothesis.

Bhuiyan *et. al.*, 2018 used panel fixed effect and quantile regression models to analyze the impact of climate change, energy sources, and growth specific factors on bio-diversity loss in Asia. Impact of these factors on aquaculture production, forest area, GEF biodiversity index, and fisheries production was examined and the result was found varying with respect to each of the variables.

Zaman *et. al.*, 2016 analyzed the environmental impact of biofuel production in regions of East Asia and Pacific, Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, SouthAsia, and Sub Saharan Africa, over the period of 1990 to 2013. Panel GMM technique was used to examine the impact of biofuel production on the climate change, agricultural land, natural resources, water resources, and biodiversity. Biofuel production was found accelerating the HCFCs emission and reducing the water productivity. But it helped in reducing the natural resource depletion and improving biodiversity index. However different result was found in region specific analysis. Authors emphasized the need for evaluating energy policies after accounting for climate, agriculture, water, natural resources and ecology.

### **Literature Analyzing the Environmental Impact of Economic Growth Along with Energy Consumption**

Environmental impact of economic growth is a highly researched topic. A few of such studies had also incorporated the energy consumption in the analysis. Following section provide a review of such studies. Liu and Liang, 2019 tried to understand the dynamic relationships between energy consumption, economic growth and biodiversity in LMC (Lancang-Mekong Cooperation) countries from 1991 to 2014. ARDL model with dynamic simulation process showed bi-directional causality between GDP and bio-capacity.

Charfeddine, 2017 analyzed the relationship between environmental degradation and economic growth in Qatar from 1970 to 2015. Along with GDP, effect of electricity consumption and some socio-economic and financial variables were examined. EKC hypothesis was supported for CO<sub>2</sub> emission but the relation was U-shaped for ecological footprint. Feedback hypothesis between the economic growth and electricity consumption made the author to call for alternative options like the promotion of RE for reducing the adverse impacts of electricity consumption without hindering the economic activities. Bi-directional

causality was also found between the economic growth and environmental degradation.

Zeb *et. al.*, 2014 analyzed the relationship among RE production, CO<sub>2</sub> emission, poverty, GDP, and natural resource depletion in 5 SAARC countries from 1975 to 2010. FMOLS result showed negative relation between RE and CO<sub>2</sub>. RE had positive relation with GDP and poverty, this later relation implies that unemployment increases with a transition to renewable source of electricity generation.

Pao and Tsai, 2011 analyzed the dynamic relation between energy consumption, economic output, FDI, and CO<sub>2</sub> emission in BRIC countries using panel co-integration and Panel VECM procedure. Emission was found to be elastic to energy consumption and output but inelastic to FDI. Existence of EKC hypothesis was also supported.

Apergis and Payne, 2010 analyzed the economic growth, energy consumption, and CO<sub>2</sub> emission nexus in 11 countries of Commonwealth of Independent States (CIS) for the period of 1992 to 2004. By using FMOLS they found the existence of EKC hypothesis and positive relation between energy consumption and emission. Panel VECM showed bidirectional causality between emission and energy consumption in the long run, and unidirectional causality from energy consumption and economic growth respectively to emission in the short run. Shortrun bidirectional causality between energy consumption and economic growth indicated the presence of feedback hypothesis. Similarly Soytas *et. al.*, 2007 analyzed for EKC hypothesis in US by incorporating energy consumption. Toda– Yamamoto procedure of causality showed no causality from economic growth to CO<sub>2</sub> emission but unidirectional causality from energy consumption to emissions. Hence they concluded that contrary to EKC hypothesis economic growth could not become a solution to environmental problems.

Regarding the effect of energy consumption especially of RE on economic growth and environment, existing studies provided a mixed result. This indicates the necessity of conducting region or country specific studies, hence present study tries to examine that impact of RE from the perspective of developing countries of Asia.

## **METHODOLOGY**

### **Theoretical Model**

This study tried to find out the environmental and economic impact of RE consumption. Hence two separate models; one to analyze the environmental impact and the second to analyze the economic impact are performed. To get a consistent result and for the comparison purposes Non-RE consumption is also included in the analysis.

### ***Model Analyzing the Environmental Impact***

To analyze the impact of RE and Non-RE consumption on environment present study used CO<sub>2</sub> emission and ecological footprint as the indicators of environmental degradation. RE and Non-RE consumption are the main explanatory variables. Existing studies have pointed out that in addition to energy consumption certain socio-economic variables also determines environmental degradation. Hence to avoid the problem of omitted variable bias this study considered some of such variables in the analysis.

Most of the existing studies provided evidences for economic growth as a major determinant of the environmental degradation (Behera and Mishra, 2020; Shaari *et. al.*, 2020; Liu and Liang, 2019; Mahmood *et. al.*, 2019; Mensah *et. al.*, 2019; Panayotou, 1993; Soytas *et. al.*, 2007). Present study also included economic growth as a control variable and expects a positive impact on environmental degradation. Another variable used by the existing literature is the trade openness, but a consistent result is not existing about its impact. Mahmood *et. al.*, (2019) and Kasman and Duman (2015) showed evidence for positive relation between CO<sub>2</sub> emission and trade openness in Pakistan, and EU member

countries respectively. But Charfeddine (2017) and Sharma (2011) found the relation to be inconclusive. However Charfeddine's analysis with ecological footprint showed evidence for positive relation. Other variable used in the analysis is the urbanization. An increase in the urban population would create more pressure on urban resource which in turn create more pollution. In this regard some studies found a positive relation between environmental degradation and urbanization (Kasman and Duman, 2015; Rizk and Slimane, 2018). But some other studies found the relation to be negative (Sharif Hossain, 2011; Sharma, 2011). A study by Charfeddine, 2017 found the effect of urbanization to be changing in accordance with the variables used as the indicators of environmental degradation. To analyze the impact of all the specified variables on the environment following model is proposed<sup>1</sup>;

$$co_{2it} = A re_{it}^{\alpha_{1i}} non-re_{it}^{\alpha_{2i}} gdp_{it}^{\alpha_{3i}} trade_{it}^{\alpha_{4i}} urban_{it}^{\alpha_{5i}} \quad (1.a)$$

$$footprint_{it} = A re_{it}^{\alpha_{1i}} non-re_{it}^{\alpha_{2i}} gdp_{it}^{\alpha_{3i}} trade_{it}^{\alpha_{4i}} urban_{it}^{\alpha_{5i}} \quad (1.b)$$

The subscript *i* and *t* denote country and time period respectively. *A* is the technology parameter. CO<sub>2</sub> and footprint represent CO<sub>2</sub> emission and ecological footprint<sup>2</sup>, *re* and *non-re* represent renewable and non-renewable energy consumption, *gdp*, *trade*, and *urban* represent GDP per capita, trade openness, and urbanization respectively. Here  $\alpha_1$ ,  $\alpha_2$ ,  $\alpha_3$ ,  $\alpha_4$ , and  $\alpha_5$  are the elasticity of environmental indicators with respect to each of the independent variables. Logarithmic transformation of the equations is given by;

$$\ln co_{2it} = \ln A_{it} + \alpha_{1i} \ln re_{it} + \alpha_{2i} \ln non-re_{it} + \alpha_{3i} \ln gdp_{it} + \alpha_{4i} \ln trade_{it} + \alpha_{5i} \ln urban_{it} \quad (2.a)$$

$$\ln footprint_{it} = \ln A_{it} + \alpha_{1i} \ln re_{it} + \alpha_{2i} \ln non-re_{it} + \alpha_{3i} \ln gdp_{it} + \alpha_{4i} \ln trade_{it} + \alpha_{5i} \ln urban_{it} \quad (2.b)$$

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<sup>1</sup> Two equations are specified to indicate that environmental impact is analyzed with two proxies

<sup>2</sup> Ecological footprint adds up all the productive areas for which a population, a person or a product competes. It measures the ecological assets that a given population or product requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions.

$\ln A_{it} = \alpha_{0i} + \varepsilon_{it}$ , where  $\alpha_{0i}$  captures the country specific fixed effects and  $\varepsilon_{it}$  measures the deviations from the long run equilibrium relationship.

### **Model Analyzing the Economic Impact**

To analyze the economic impact of RE and Non-RE consumption we followed the path of some of the recent literature on energy-economic growth nexus (Behera and Mishra, 2020; Mensah *et al.*, 2019; Bhattacharya *et al.*, 2016; Bozkurt and Destek, 2015; Magnani and Vaona, 2013; Huang *et al.*, 2008). That is we used the neo-classical growth model within the framework of Cobb Douglas production function, where RE and Non-RE consumption along with labor and capital are used as inputs. The model can be specified as follows;

$$gdp_{it} = A re_{it}^{\beta_{1i}} non-re_{it}^{\beta_{2i}} k_{it}^{\beta_{3i}} l_{it}^{\beta_{4i}} \quad (3.a)$$

The subscripts  $i$  and  $t$  denote country and time period respectively. GDP denote the dependent variable GDP per capita.  $A$  is the technology parameter,  $re$ ,  $non-re$ ,  $k$ , and  $l$  are RE consumption, Non-RE consumption, fixed capital, and labor force participation respectively. Here  $\beta_1$ ,  $\beta_2$ ,  $\beta_3$ , and  $\beta_4$  are elasticity of output with respect to RE consumption, Non-RE consumption, capital, and labor force respectively. To reduce the issue of heteroskedasticity data is transformed into natural logarithmic form. Log linear form of the production function is given by

$$\ln gdp_{it} = \ln A_{it} + \beta_{1i} \ln re_{it} + \beta_{2i} \ln non-re_{it} + \beta_{3i} \ln k_{it} + \beta_{4i} \ln l_{it} \quad (3.b)$$

$$\ln A_{it} = \beta_{0i} + \varepsilon_{it},$$

where  $\beta_{0i}$  captures the country specific fixed effects, if any and  $\varepsilon_{it}$  measures the deviations from the long run equilibrium relationship.

### **Data and their Source**

This study has analyzed a panel of 24 developing countries of Asia (Armenia, Azerbaijan, Bangladesh, Cambodia, China, Georgia, India, Indonesia, Islamic Republic of Iran, Iraq, Jordan, Kazakhstan,

Kyrgyzstan, Lebanon, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Sri Lanka, Tajikistan, Thailand, Uzbekistan, and VietNam) from 1990 to 2018. Choice of panel unit and time period is dictated by the availability of data on the variables chosen for analysis. Explanation of the variables used and their data source is provided in table1.

**Table 1: Summary of Data Set**

| Variable      | Explanation                                                                                                                                | Source                              |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| co2           | CO2 emission (metric tons per capita)                                                                                                      | WDI                                 |
| foot<br>print | Total ecological footprint (GHA)                                                                                                           | Global ecological footprint network |
| gdp           | GDP per capita (constant 2015 US\$)                                                                                                        | WDI                                 |
| re<br>non-re  | Renewable energy consumption (percent share in total final energy consumption)                                                             | WDI                                 |
| k<br>l        | Non-renewable energy consumption (percent share of coal, natural gas, and petroleum and other liquids in total primary energy consumption) | US EIA                              |
| trade         | Gross fixed capital formation (percent of GDP)                                                                                             | WDI                                 |
| urban         | Labor force participation rate, total (percent of total population within the age 15-64)                                                   | WDI                                 |
|               | Trade (percent of GDP)                                                                                                                     | WDI                                 |
|               | Urban population (total)                                                                                                                   |                                     |

**Source:** compiled by authors

### ***Econometric Approach***

Often analysis with panel data assumes the existence of no panel specific heterogeneity and crosssectional dependence. But Bhattacharya *et. al.*, 2016 reported that homogeneity hypothesis is veryoften rejected and the differences in the estimates between countries can be large. This authors had alsospecified that if cross-sectional dependence is not dealt with proper estimation techniques, panel estimators won't be better than single time-series. Mensah *et. al.*, 2019 specified that presence of panel

specific heterogeneity and cross sectional dependence within the variables plays a significant role in the selection of other econometric tests like unit root and co-integration. Hence the present study tested for cross sectional independence using Pesaran CD test and panel specific heterogeneity using Pesaran-Yamagata's homogeneity test. In the presence of cross sectional dependence and heterogeneity within the panel units, first generation unit root test results in inefficient estimators (Bhattacharya *et. al.*, 2016; Mensah *et. al.*, 2019) which necessitate the use of second generation test for identifying the integration order of the variables. Hence this study used CIPS (Cross-sectionally Augmented IPS) test for analyzing the stationarity of the variables. Existence of long run relationship between the variables is tested using Pedroni co-integration test. Finally long run and short run relationship between the variables is estimated using panel ARDL (Auto Regressive Distributed Lag) model. This model is widely used by considering its advantage over the conventional co-integration methods; it is applicable no matter of the integration order of the variables i.e. the variables can be I (0), I (1) or mix of both (Mensah *et. al.*, 2019; Saint Akadiri *et. al.*, 2019). Further it can deal with endogeneity problems, and it can report both the short-run and long-run co-efficients within a single model.

### ***Panel ARDL Model***

An ARDL (p,q)<sup>3</sup> model can be expressed as follows. Where p and q are the lag order of dependent and independent variables respectively.

$$y_{i,t} = \mu_i + \sum_{j=1}^p \lambda_{i,j} y_{i,t-j} + \sum_{j=0}^q \delta_{i,j} z_{i,t-j} + \varepsilon_i \quad (4)$$

Here  $i=1,2,\dots,N$  is for countries and  $t = 1,2,\dots,T$  is for time period.  $y$  is the dependent variable,  $z$  is a vector of explanatory variables. While  $\mu$  is the country-level fixed effects,  $\lambda$ , represents the coefficient of the lagged dependent variable and  $\delta$  represents the coefficients of the lagged independent variables. A common feature of co-integrated variables is that they will make short run adjustment to any deviation from the long

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<sup>3</sup> Specification of ARDL equations with the variables used in this study is provided in the appendix

run equilibrium, hence the model can be represented in the form of Error Correction Model (ECM) as follows;

$$\Delta y_{i,t} = \phi_i (y_{i,t-1} - \theta_i Z_{i,t}) + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta Z_{i,t-j} + \varepsilon_{i,t} \quad (5)$$

Where

$$\phi_i = -\left(1 - \sum_{j=1}^p \lambda_{i,j}\right), \quad \theta_i = -\frac{\sum_{j=0}^q \delta_{i,j}}{\phi_i}, \quad \lambda^*_{i,j} = -\sum_{d=j+1}^p \lambda_{i,d} \quad \text{and} \quad \delta^*_{i,j} = -\sum_{d=j+1}^q \delta_{i,d}$$

Here the former part of the equation 5,  $\phi_i (y_{i,t-1} - \theta_i Z_{i,t})$  represents the speed of adjustment in the dependent variable to a deviation from the long-run equilibrium level, while the latter part represents the short-run dynamics.  $\theta_i$  Shows the long run relationship between the dependent and independent variables.  $\delta^*_{i,j}$ 's are the short term coefficients of the explanatory variables. Whereas  $\delta_{i,j}$ 's are the long term co-efficients.  $\phi_i$  represents Error Correction Term (ECT). Long run equilibrium relationship between the variables requires  $\phi_i$  to be negative and significant. ARDL model can be estimated by three different estimators: the MG (Mean Group) estimator of Pesaran and Smith (1995), the PMG (Pooled MG) estimator developed by Pesaran *et. al.* (1999), and the DFE (Dynamic Fixed Effect) estimator. MG estimator runs separate regressions and produce different and heterogeneous coefficients for every panel unit for the long run and the short run. Coefficients of the model are calculated from the un-weighted average of estimated coefficients of panel units. In PMG estimator short-run estimates including the intercept, the speed of adjustment, and the error variance will be heterogeneous but the long-run slope coefficient is limited to be homogenous. The third estimator DFE is similar to the PMG estimator but the long run and the short run slope coefficients, error variances and the speed of adjustment coefficient are equal across all countries but it allows

panel specific intercepts<sup>4</sup>. Hausman test is used to choose one among the three estimators. Null hypothesis of the test is that homogeneity restrictions hold. Non rejection of null hypothesis between PMG and MG indicates the existence of long run homogeneity hence PMG estimator is to be preferred over MG. In the similar way, between PMG and DFE, non-rejection of null hypothesis prefers PMG over DFE.

Existence of equilibrium relationship indicates that there will be granger causality at least in one direction. As there is panel specific heterogeneity and cross sectional dependencies in the data we used Dumitrescu-Hurlin pairwise granger causality test to analyze the causal relationship.

## **EMPIRICAL RESULT**

### **Descriptive Statistics**

Descriptive statistics of the variables is shown in Table 2. It is clear that countries chosen for this analysis on average emit CO<sub>2</sub> of 2.85 metric tons/capita with a standard deviation (SD) of 2.79. These countries on average requires 25.3crore GHA of natural resources with a SD of 74.6. RE on average contribute 28.49 percent to total final energy consumption, whereas Non-RE share in primary energy consumption on average is 85.33 percent, this indicates that regardless of Asia's stand on promoting RE, Non-RE still plays a major role in meeting the regions' growing energy demand. SD of energy consumption (26.524 for RE and 18.204 for Non-RE) indicates that significant variation is there in the energy mix across the Asian countries. These countries on average hold a per-capita income of US\$2850 with a SD of 2295.48 US\$. It is also clear that trade in the concerned countries is playing a significant role in the economy, i.e. on an average trade contributes 80 percent to GDP, but SD of 41.07 indicates significant variation across the countries. A large number of urban population can also be found in the countries, on an

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<sup>4</sup> Information on these three estimators of ARDL is obtained from (Samargandi *et. al.*, 2015; and Shaari *et. al.*, 2020).

average urban population consists of 5.38 lakh people. Mean value of capital (24.35 percent) indicates that countries considered for this analysis uses only around 1/4<sup>th</sup> of their GDP for capital formation. Mean value of 64 percent for the labor indicates that a significant portion of the working age group are either employed or seeking for employment.

The table also talks about the distribution of the series, a series is said to be normally distributed if the values of skewness and kurtosis are 0 and 3 respectively. Here the skewness values shows that Non-RE consumption and labor force rate are negatively skewed and all the other variables are positively skewed, whereas kurtosis values shows that all the variables except RE consumption and labor force participation are leptokurtic, they both are platykurtic. Thus the variables under concern are not normally distributed. This is further confirmed by the Jarque-Bera test, i.e. the null hypothesis of normal distribution is rejected for all the variables.

**Table 2: Descriptive Statistics of the Variables**

|             | CO <sub>2</sub> | Footprint | GDP      | RE       | Non-RE    | trade    | urban    | k        | l         |
|-------------|-----------------|-----------|----------|----------|-----------|----------|----------|----------|-----------|
| Mean        | 2.850609        | 2.53E+08  | 2850.344 | 28.49525 | 85.33633  | 80.21436 | 53803921 | 24.35206 | 64.52920  |
| Median      | 1.898893        | 51416138  | 2026.937 | 23.84150 | 94.94668  | 73.72373 | 9623064. | 23.96899 | 63.91500  |
| Maximum     | 15.55134        | 5.54E+09  | 11075.58 | 95.11971 | 99.89555  | 220.4068 | 8.30E+08 | 57.71025 | 88.57000  |
| Minimum     | 0.049721        | 3215892.  | 364.8811 | 0.300300 | 18.55494  | 0.020999 | 1245680. | 0.734463 | 41.53000  |
| Std. Dev.   | 2.795803        | 7.46E+08  | 2295.489 | 26.52419 | 18.20461  | 41.07739 | 1.28E+08 | 7.977983 | 13.07459  |
| Skewness    | 1.734074        | 4.816580  | 1.301233 | 0.639695 | -1.672358 | 0.778935 | 3.652386 | 0.236252 | -0.036828 |
| Kurtosis    | 6.801358        | 27.79096  | 4.299363 | 2.281042 | 5.096089  | 3.356417 | 16.86326 | 4.157431 | 2.008266  |
| Jarque-Bera | 767.8730        | 19983.75  | 244.3163 | 62.00982 | 442.7521  | 72.25664 | 7120.941 | 44.41256 | 28.67987  |
| Probability | (0.000)         | (0.000)   | (0.000)  | (0.000)  | (0.000)   | (0.000)  | (0.000)  | (0.000)  | (0.000)   |
| Observation | 696             | 678       | 693      | 691      | 682       | 679      | 696      | 682      | 696       |

s

Source : computed by authors

## Pesaran-Yamagata's Homogeneity Test

To test whether there is panel specific heterogeneity this study used Pesaran and Yamagata's homogeneity test (2008). The test is based on the difference of the weighted fixed effects estimator imposing slope homogeneity, and cross sectional unit specific OLS regression model. Large values of the test statistic imply a disagreement between the two estimates and therefore the null hypothesis of slope homogeneity can be rejected (Bersvendsen and Ditzen, 2021). Table 3 shows the result of homogeneity test for the three model used in the study. As per the result delta and adjusted delta statistics are significant at 1 percent

significance level in all the three models, hence the null hypothesis of slope homogeneity is rejected. This indicates that heterogeneous panel model should be used for analysis.

**Table 3: Results of the Pesaran-Yamagata's Homogeneity Test**

|                | CO2 model | Footprint model | GDP model |
|----------------|-----------|-----------------|-----------|
| Delta          | 15.397*** | 10.724***       | 8.879***  |
| Adjusted delta | 18.325*** | 12.801***       | 10.292*** |

**Notes:** \*\*\* indicates statistical significance at 1 percent level

**Source:** computed by authors

**Table 4: Results of Cross-Section Independence Test**

|                      | CO2       | Footprint | GDP       | RE       | Non-RE    | Labor     | Capital  | Trade     | Urban     |
|----------------------|-----------|-----------|-----------|----------|-----------|-----------|----------|-----------|-----------|
| CD-<br>test<br>value | 11.303*** | 64.949*** | 70.427*** | 5.353*** | 17.320*** | 89.460*** | 5.108*** | 11.339*** | 89.460*** |

**Notes:** variables are used in natural logarithmic form, \*\*\* indicates statistical significance at 1 percent level

**Source:** computed by authors

### ***Pesaran CD Test***

Cross sectional dependence within the panel variables is tested using cross sectional dependence test proposed by Pesaran (2015). This test is based on the correlation co-efficient between panel units and it can be performed either for the error term or for the variables. Null hypothesis is that the error term (or variable) is weakly cross sectional dependent, i.e. correlation between observations of unit  $i$  and  $j$  in time  $t$  is zero. Result of Pesaran CD test for the variables is presented in table 4 where the null hypothesis is rejected at 1 percent significance level for all the variables. Thus the result shows that cross-sectional dependence is presented within the variables.

### ***Panel Unit Root Test***

Since the second generation unit root test can account for cross sectional dependence, CIPS test is used to test the stationarity of the variables. Null hypothesis assumes that all the series are non-stationary with the alternative a fraction of the series being stationary. Result of the test is provided in table 5. It is clear that the variables CO<sub>2</sub> emission, footprint,

GDP, and urbanization are stationary at levels (at 5 percent significance level) whereas the remaining variables become stationary at their first difference indicating that variables under concern are of mixed order of integration. Before proceeding to make the variables stationary it is appropriate to check whether they exhibit any long run relationship, hence the study tested for the presence of long run relationship using Pedroni's co-integration test.

### ***Panel Co-Integration Test***

Pedroni proposed seven test statistics under the null of no co-integration in a heterogeneous panel with one or more non stationary regressors; the panel v-statistic, panel rho-statistic, panel PP-statistic (nonparametric), panel ADF-statistic (parametric), group rho-statistic, group PP statistic (nonparametric), and group ADF-statistic (parametric). Results of the test with CO<sub>2</sub> emission, footprint and GDP as dependent variables are presented in table 6.a, 6.b, and 6.c. In the test with CO<sub>2</sub> and footprint as dependent variables, out of the seven statistics four have rejected the null hypothesis of no co-integration. In the case of GDP five statistics rejected the null of no co-integration. Therefore we conclude that variables considered for analyzing the environmental and economic impact of RE and Non-RE consumption exhibits long run equilibrium relationship.

**Table 5: Result of CIPS Panel Unit Root Test**

| Variable        | Level (constant) | Level (constant and trend) | First difference |
|-----------------|------------------|----------------------------|------------------|
| CO <sub>2</sub> | -2.21069**       |                            |                  |
| Footprint       | -2.34462**       |                            |                  |
| Gdp             | -2.95999***      |                            |                  |
| Re              | -1.08052         | -1.67922                   | -3.40871***      |
| non-re          | -1.27521         | -1.95457                   | -3.72120***      |
| Capital         | -2.14780*        | -2.62300*                  | -3.36899***      |
| Labor           | -1.52838         | -2.17368                   | -2.56532***      |
| Trade           | -1.30000         | -1.69995                   | -2.94248***      |
| Urban           | -2.39076***      |                            |                  |

**Note:** Variables are used in natural logarithmic form, \*, \*\*, \*\*\* indicates statistical significance at 1 percent, 5 percent, and 10 percent level respectively.

**Source:** analyzed by authors

**Table 6a: Pedroni Panel Co-Integration Test Results with CO2 as Dependent Variable**

|                                                                  | Statistic | Prob.     | Weighted Statistic | Prob.     |
|------------------------------------------------------------------|-----------|-----------|--------------------|-----------|
| Alternative hypothesis: common AR coefs. (within-dimension)      |           |           |                    |           |
| Panel v-Statistic                                                | -0.244358 | 0.5965    | -2.278226          | 0.9886    |
| Panel rho-Statistic                                              | 1.593917  | 0.9445    | 2.821589           | 0.9976    |
| Panel PP-Statistic                                               | -2.012985 | 0.0221**  | -2.044400          | 0.0205**  |
| Panel ADF-Statistic                                              | -3.141583 | 0.0008*** | -6.227122          | 0.0000*** |
|                                                                  | Statistic | Prob.     |                    |           |
| Alternative hypothesis: individual AR coefs. (between-dimension) |           |           |                    |           |
| Group rho-Statistic                                              | 4.050376  |           | 1.0000             |           |
| Group PP-Statistic                                               | -1.703846 |           | 0.0442**           |           |
| Group ADF-Statistic                                              | -4.841809 |           | 0.0000***          |           |

**Notes:** Variables CO2, RE, Non-RE, gdp, trade, urban Trend assumption: No deterministic trend. Lag selection: Automatic based on AIC with lags from 3 to 5 Newey-West automatic bandwidth selection with Bartlett kernel. \*\*\*, \*\* Denote rejection of null hypothesis of no co-integration at 1 percent and 5 percent significance level respectively

**Source:** Estimated by authors

**Table 6.b: Pedroni Panel Co-Integration Test Results With Footprint as Dependent Variable**

|                                                                  | Statistic | Prob.     | Weighted Statistic | Prob.     |
|------------------------------------------------------------------|-----------|-----------|--------------------|-----------|
| Alternative hypothesis: common AR coefs. (within-dimension)      |           |           |                    |           |
| Panel v-Statistic                                                | -0.222732 | 0.5881    | -4.904745          | 1.0000    |
| Panel rho-Statistic                                              | 3.240958  | 0.9994    | 2.089757           | 0.9817    |
| Panel PP-Statistic                                               | -3.534838 | 0.0002*** | -5.832076          | 0.0000*** |
| Panel ADF-Statistic                                              | -5.087883 | 0.0000*** | -6.216168          | 0.0000*** |
|                                                                  | Statistic | Prob.     |                    |           |
| Alternative hypothesis: individual AR coefs. (between-dimension) |           |           |                    |           |
| Group rho-Statistic                                              | 3.961863  | 1.0000    |                    |           |
| Group PP-Statistic                                               | -5.206051 | 0.0000*** |                    |           |
| Group ADF-Statistic                                              | -7.022800 | 0.0000*** |                    |           |

**Notes:** Variables footprint, re, non-re, gdp, trade, urban Trend assumption: Deterministic intercept and trend. Lag selection: Automatic based on AIC with lags from 3 to 5 Newey-West automatic bandwidth selection with Bartlett kernel. \*\*\*Denote rejection of null hypothesis of no co-integration at 1 percent significance level

**Source:** Estimated by authors

**Table 6.c: Pedroni Panel Co-Integration Test Results with GDP as Dependent Variable**

|                                                                  | Statistic | Prob.     | Weighted<br>Statistic | Prob.     |
|------------------------------------------------------------------|-----------|-----------|-----------------------|-----------|
| Alternative hypothesis: common AR coefs. (within-dimension)      |           |           |                       |           |
| Panel v-Statistic                                                | 6.050970  | 0.0000*** | 10.21168              | 0.0000*** |
| Panel rho-Statistic                                              | 0.816583  | 0.7929    | 2.241999              | 0.9875    |
| Panel PP-Statistic                                               | -3.694129 | 0.0001*** | -2.107941             | 0.0175**  |
| Panel ADF-Statistic                                              | -3.593812 | 0.0002*** | -1.949839             | 0.0256**  |
|                                                                  | Statistic | Prob.     |                       |           |
| Alternative hypothesis: individual AR coefs. (between-dimension) |           |           |                       |           |
| Group rho-Statistic                                              | 4.728524  | 1.0000    |                       |           |
| Group PP-Statistic                                               | -1.681733 | 0.0463**  |                       |           |
| Group ADF-Statistic                                              | -2.930655 | 0.0017*** |                       |           |

**Notes:** Variables GDP, RE, Non-RE, capital, labor Trend assumption: Deterministic intercept with trend. Lag selection: Automatic based on AIC with lags from 3 to 5 Newey-West automatic bandwidth selection with Bartlett kernel. \*\*\*, \*\* Denote rejection of null hypothesis of no co-integration at 1 percent and 5 percent significance level respectively.

**Source:** Estimated by authors

### ***Panel ARDL model***

Confirmation of long run equilibrium relationship between the variables (of different order of integration) of heterogeneous panels with cross sectional dependence implies the scope of using ARDL model for estimating the short run and long run parameters. Since ARDL model can be estimated using PMG, MG and DFE, we used Hausman test to choose the appropriate method. For all the estimation used in this study we failed to reject the null hypothesis of the Hausman test indicating that pooling of long run coefficients is supported hence we choose PMG over MG. Similarly when the test is performed to choose between PMG and DFE, we cannot reject the null hypothesis, thus PMG estimator is chosen for final analysis. Since the purpose of this study is to find out the environmental and economic impact of RE along with Non-RE consumption, separate analysis is performed for analyzing both the impact.

**Table 7: ARDL Model on Environmental Impact**

| Independent variable | Dependent variable |          |         |           |       |         |
|----------------------|--------------------|----------|---------|-----------|-------|---------|
|                      | CO <sub>2</sub>    |          |         | footprint |       |         |
|                      | Coeff              | SE       | P value | Coeff     | SE    | P value |
| <b>Long run</b>      |                    |          |         |           |       |         |
| re                   | -0.419***          | 0.094819 | 0.0000  | -0.037**  | 0.017 | 0.030   |
| non-re               | 1.021***           | 0.136285 | 0.0000  | 0.276***  | 0.053 | 0.000   |
| gdp                  | 1.115***           | 0.107482 | 0.0000  | 0.325***  | 0.016 | 0.000   |
| trade                | -0.130***          | 0.046155 | 0.0052  | 0.093***  | 0.022 | 0.000   |
| urban                | -0.435***          | 0.060684 | 0.0000  | 0.852***  | 0.025 | 0.000   |
| ECT                  | -0.146***          | 0.038245 | 0.0002  | -0.415*** | 0.099 | 0.000   |
| <b>Short run</b>     |                    |          |         |           |       |         |
| D.re                 | -0.664**           | 0.261    | 0.011   | -0.176**  | 0.081 | 0.029   |
| D.non-re             | 0.596              | 0.406    | 0.143   | 1.350**   | 0.638 | 0.035   |
| D.gdp                | 0.313*             | 0.176    | 0.077   | 0.356*    | 0.193 | 0.065   |
| D.trade              | 0.021              | 0.062    | 0.738   | -0.023    | 0.045 | 0.610   |
| D.urban              | 1.040              | 2.695    | 0.700   | -1.497    | 2.483 | 0.547   |
| constant             | -0.587             | 0.180    | 0.001   | -0.131    | 0.101 | 0.195   |
| Hausman test         | .62                |          | .987    | .85       |       | 0.974   |

**Source:** analyzed by authors using E-Views10. Variables are used in natural logarithmic form. Model selection criteria is AIC, chosen model is ARDL (3, 2, 2, 2, 2, 2).

\*\*\*, \*\*, \* indicates statistical significance at 1 percent, 5 percent, and 10 percent respectively. Huasman test is for MG/PMG (this test is used after running ARDL model with the software stata)

### ***ARDL/PMG Result for Environmental Impact***

While analyzing the impact of energy consumption on the environment most of the existing studies used CO<sub>2</sub> emission to indicate the environmental degradation. In addition to the impact on emission this study intends to find out how RE and Non-RE consumption is affecting the natural resources. Hence we choose ecological footprint to indicate natural resources and ARDL model has run with CO<sub>2</sub> emission and ecological footprint respectively as the dependent variable. Estimation result has provided in table 7.

Result of the ARDL model with CO<sub>2</sub> emission as dependent variable shows that RE consumption has a negative impact on CO<sub>2</sub> emission in both the short run and the long run. That is a percentage increase in RE consumption reduces CO<sub>2</sub> emission by .41 percent in the long run and .66 percent in the short run. Whereas Non-RE consumption

is found to have a positive impact in the long run, that is a percentage increase in Non-RE consumption is found increasing the CO<sub>2</sub> emission by 1.02 percent. But its impact is insignificant for the short run. Regarding the influence of economic growth on emission, a positive impact is found for both the long run and the short run, i.e. a percentage increase in GDP increases CO<sub>2</sub> emission by 1.12 percent in the long run and by .31 percent in the short run. The other two determinants, trade openness and urbanization showed negative impact on the emission. That is a percentage increase in the trade and urban population reduces the emission in the long run by .13 percent and .44 percent respectively. They don't have any significant impact in the short run. Error correction term (ECT) in the model is found to be negative and significant which confirms the Pedroni's co-integration test result. Quantitative value of ECT, -0.146 informs that any deviation from the equilibrium relation would get corrected by 14.6 percent in the next period.

ARDL model with footprint consumption also provide somewhat similar result. RE consumption is found to have a negative impact on ecological footprint in both the time period, i.e. a percentage increase in RE consumption reduces ecological footprint by 0.04 percent in the long run and by .18 percent in the short run. As in the case of CO<sub>2</sub> emission, Non-RE consumption has a positive impact on the ecological footprint. That is a percentage increase in Non-RE consumption increases ecological footprint by .28 percent in the long run and by 1.4 percent in the short run. When it comes to the impact of economic growth on ecological footprint, a percentage increase in GDP is found accelerating the ecological footprint by .33 percent in the long run and .36 percent in the short run. Unlike the impact on CO<sub>2</sub> emission trade openness and urbanization increases the ecological footprint. That is a percentage increase in the trade and urban population is found increasing the ecological footprint by .09 percent and .85 percent respectively in the long run. But they don't have any significant impact in the short run. Here also ECT appeared to be negative and significant. Value of the ECT,

-0.415 indicates that any deviation from the equilibrium will be corrected by 42 percent.

Thus the result with two alternate proxies for environment indicates that RE consumption helps to reduce the emission and ecological footprint in both the short run and the long run. But Non-RE consumption increases emission in the short run and ecological footprint in both the time period. This indicates that transition from Non-RE to RE is essential for reducing the emission and protecting the natural resources. The result further indicates that economic growth in the countries considered is coming at the risk of increased emission and ecological footprint. This implies that while planning for economic growth considerable attention should be given to environment and its protection. Trade and urbanization is found reducing the emission but increasing the ecological footprint in the long run.

Since PMG estimation can provide country specific result for short run estimators, it is interesting to find out how the energy consumption and the other variables are effecting the environment in each of the individual countries. Country specific result for environmental impact is provided in table 8.a and b. It is clear that in 19 out of the 24 countries RE consumption is found to reduce CO<sub>2</sub> emission. But in the remaining countries; Cambodia, Georgia, Iran, Iraq, and Malaysia, it is found to increase the emission. The result also shows that Non-RE consumption increases the emission in seven countries, and reduces it in six countries. For the remaining countries Non-RE doesn't have any significant impact. When it come to the effect of economic growth, for a majority of the countries (13 out of 24), GDP is found increasing the emission, but in Lebanon, Philippines, and Kyrgyzstan this effect is negative. Trade openness is found reducing the emission in Armenia, Cambodia, Nepal, and Vietnam, but in 17 countries it increases the emission. Finally the variable urbanization is found having a significant impact on CO<sub>2</sub> emission only in Lebanon.

**Table 8.a: Short Run Country Specific Effect on CO2 Emission**

| Country     | Re        | non-re    | Gdp       | Trade     | Urban   |
|-------------|-----------|-----------|-----------|-----------|---------|
| Armenia     | -0.339*** | -0.255*   | 0.871***  | -0.630*** | 39.433  |
| Azerbaijan  | -0.300*** | -3.827    | 0.474***  | 0.204***  | -0.002  |
| Bangladesh  | -1.386*** | 2.285     | -0.316    | 0.155***  | 11.221  |
| Cambodia    | 0.386**   | 1.18***   | 2.85***   | -0.955*** | 14.705  |
| China       | -0.519*** | 1.516*    | 0.336*    | 0.047***  | 4.147   |
| Georgia     | 0.153**   | 0.553**   | 0.555**   | 0.455***  | -24.939 |
| India       | -0.268*   | 1.089**   | 0.030     | 0.008     | -13.147 |
| Indonesia   | -0.726*** | 2.106     | -0.108    | 0.028***  | -2.469  |
| Iran        | 0.089***  | 5.252     | 0.100**   | 0.020***  | -20.191 |
| Iraq        | 0.065***  | 1.772     | 0.161***  | 0.006***  | 8.639   |
| Jordan      | -0.230*** | 3.315     | 0.391     | 0.067***  | 1.025   |
| Kazakhstan  | -0.305*** | -1.260    | -0.37     | 0.149**   | 1.84    |
| Kyrgyzstan  | -0.555*** | -0.545*** | -0.611*** | 0.641***  | 17.888  |
| Lebanon     | -0.176*** | -3.737*** | -0.500**  | 0.117***  | -2.374* |
| Malaysia    | 0.044***  | 2.143     | 0.467***  | 0.022     | 8.766   |
| Mongolia    | -0.108*** | 1.499     | 0.475**   | 0.083***  | 8.95    |
| Nepal       | -6.136*** | -0.327*** | 1.874***  | -0.147*** | -2.723  |
| Pakistan    | -0.975*** | 0.122**   | 0.102**   | 0.001     | -8.474  |
| Phillipines | -1.131*** | -0.751**  | -0.516*** | 0.07***   | 1.003   |
| Srilanka    | -1.728*** | 1.017***  | 0.158     | 0.252***  | -8.976  |
| Tajikistan  | -1.266*** | -0.113*** | 0.55***   | 0.003*    | -13.417 |
| Thailand    | -0.154*** | 1.28      | 1.084***  | 0.045***  | -0.050  |
| Uzbekistan  | -0.143*** | -1.0369   | -1.51     | 0.017***  | 2.49    |
| Vietnam     | -0.237*** | 1.038***  | 0.97      | -0.154*** | 1.611   |

**Note:** \*\*\*, \*\*, \* indicates statistical significance at 1 percent, 5 percent, and 10 percent respectively. Variables are in natural logarithmic form.

**Source:** analyzed by authors

| Country     | Re        | non-re    | Gdp       | Trade     | Urban     |
|-------------|-----------|-----------|-----------|-----------|-----------|
| Armenia     | -0.090*** | 0.047     | 0.707***  | 0.136**   | 6.200     |
| Azerbaijan  | 0.285***  | 8.966     | 0.502***  | 0.187***  | -3.316    |
| Bangladesh  | -0.214    | 1.460     | -1.540    | 0.010     | 4.102     |
| Cambodia    | 0.260***  | -0.525*** | 1.031**   | -0.249*** | 1.851     |
| China       | -0.337*** | 2.398**   | -0.290*   | -0.043*** | 2.224     |
| Georgia     | 0.230***  | 0.301***  | 1.246***  | 0.334***  | -8.921    |
| India       | 0.111     | -0.309    | -0.018    | -0.129*** | -24.313   |
| Indonesia   | -0.265*** | -0.858    | 0.326***  | 0.023***  | 3.972     |
| Iran        | 0.031***  | -1.864    | -0.051**  | -0.165*** | -35.175   |
| Iraq        | 0.135***  | 4.917     | 0.180***  | 0.013***  | 6.268     |
| Jordan      | 0.103***  | 0.711     | 3.171***  | -0.165*** | 3.141*    |
| Kazakhstan  | -0.206*** | 11.134    | 1.810*    | -0.777*** | 1.790     |
| Kyrgyzstan  | -0.242*** | 0.168**   | 0.337     | 0.254***  | 12.014    |
| Lebanon     | -0.282*** | -1.195    | 0.213**   | -0.081*** | 0.411     |
| Malaysia    | 0.185***  | 1.822     | 0.655***  | -0.284*** | 7.980     |
| Mongolia    | 0.182***  | 1.951     | -0.229**  | 0.012**   | -3.665    |
| Nepal       | -1.379*** | -0.120*** | -0.143    | 0.002     | -2.845    |
| Pakistan    | -0.784**  | 0.487*    | 0.446     | 0.003     | -8.456    |
| Philippines | -0.522*** | -1.859**  | 0.784*    | 0.11**    | -22.0184  |
| Srilanka    | -0.713*** | -0.275*** | -0.218    | 0.15      | -7.699*** |
| Tajikistan  | -0.528*** | -0.296*** | -0.707*** | -0.16***  | 22.858    |
| Thailand    | -0.014    | 3.390     | 1.318***  | 0.105***  | -0.69745  |
| Uzbekistan  | -0.042*** | 1.572**   | -0.563**  | 0.035***  | 5.496***  |
| Vietnam     | -0.134*** | 0.385**   | -0.412    | 0.121***  | 2.868     |

**Note:** \*\*\*, \*\*, \* indicates statistical significance at 1 percent, 5 percent, and 10 percent respectively. Variables are in natural logarithmic form

**Source:** analyzed by authors

When it comes to the country specific effect on ecological footprint, out of 24 countries RE consumption is found to reduce ecological footprint in 13 countries, but it has increased in 8 countries, and for the remaining 3 countries it is insignificant. Non-RE consumption is found to increase ecological footprint in 6 countries, but it reduces it in 5 countries, and for the remaining countries it appears to be insignificant. The result also shows that for half of the countries considered GDP increases the ecological footprint. But in China, Iran, Mongolia, Tajikistan, and Uzbekistan ecological footprint reduces with GDP. Trade is found to increase ecological footprint in 11 countries and

reduce it in 9 countries. Urbanization has positive significant impact for Jordan and Uzbekistan, and negative impact for Sri-Lanka.

### ***ARDL/PMG Result for Economic Impact***

To adopt appropriate energy policies, in addition to the environmental impact of energy consumption it is also essential to find out the economic impact. Hence this study used ARDL/PMG model to find out how RE and Non-RE consumption is affecting the economic growth. Result of the model is provided in table 9. The result shows that both type of energy consumption increases GDP in the long run, i.e. a percentage increase in RE and Non-RE consumption could increase GDP by .13 percent and 2.45 percent respectively. But in the short run a percentage increase in RE consumption is found to reduce GDP by .08 percent, whereas Non-RE consumption is found to be insignificant. Regarding the impact of other growth determinants, capital and labor are found insignificant in the long run. Whereas in the short run a percentage increase in capital increases GDP by .1 percent, but a percentage increase in labor force participation reduces GDP by 1.6 percent. ECT of the model is found to be negative and significant, thereby confirming the existence of long run equilibrium relationship. The co-efficient value of ECT, -0.04 implies that any short run deviation from the equilibrium would get corrected by 4 percent in the subsequent period.

**Table 9: ARDL Model on Economic Impact**

| Independent variable | Dependent variable; GDP |       |         |
|----------------------|-------------------------|-------|---------|
|                      | Coeff                   | SE    | P value |
| <b>Long run</b>      |                         |       |         |
| re                   | 0.136**                 | 0.069 | 0.049   |
| non-re               | 2.448***                | 0.707 | 0.001   |
| k                    | 0.06                    | 0.057 | 0.287   |
| l                    | 0.071                   | 0.744 | 0.924   |
| ECT                  | -0.04*                  | 0.021 | 0.064   |
| <b>Short run</b>     |                         |       |         |
| D.re                 | -0.082*                 | 0.043 | 0.055   |
| D.non-re             | 0.17                    | 0.721 | 0.814   |
| D.k                  | 0.103***                | 0.039 | 0.008   |
| D.l                  | -1.623*                 | 0.848 | 0.057   |
| constant             | -0.076                  | 0.074 | 0.301   |
| Hausman test         | .41                     |       | .982    |

**Source:** analyzed by authors using E-Views 10. Variables are in natural logarithmic form. Model selection criteria is AIC, chosen model is ARDL (4, 3, 3, 3, 3). \*\*\*, \*\*, \* indicates statistical significance at 1 percent, 5 percent, and 10 percent respectively. Hausman test is for MG/PMG (test is performed after running ARDL model with the software stata)

From the result it is clear that Non-RE consumption brings higher growth than RE consumption. But the potential threat it can cause on the environment is higher. Though transition to RE could bring lesser growth than Non-RE, it could provide additional benefit in the form of environmental protection. Hence for having sustainable economic development it is essential to deviate from the path of limitless growth.

**Table 10: Short Run Country Specific Effect on GDP**

| Country     | Re        | non-re    | Capital   | Labor      |
|-------------|-----------|-----------|-----------|------------|
| Armenia     | -0.046*** | 0.099***  | 0.663***  | -2.923***  |
| Azerbaijan  | 0.043***  | 0.075     | -0.108*** | -0.276     |
| Bangladesh  | -0.132*** | 1.219*    | 0.070***  | -0.231***  |
| Cambodia    | -0.780*** | -0.361*** | 0.174***  | 0.594**    |
| China       | -0.137*** | -0.422    | -0.079*** | 1.093      |
| Georgia     | -0.191*** | -0.364*** | 0.053***  | 0.165      |
| India       | -0.334*** | -0.504**  | 0.105***  | -1.531*    |
| Indonesia   | 0.026     | 0.652     | 0.329***  | 1.392**    |
| Iran        | 0.169***  | 11.891    | -0.128*** | 1.044      |
| Iraq        | -0.125    | -1.127    | -0.031*** | -3.090     |
| Jordan      | 0.087***  | 0.359     | 0.055***  | 0.035      |
| Kazakhstan  | 0.010***  | 2.825     | 0.167***  | 3.794*     |
| Kyrgyzstan  | 0.069***  | 0.156***  | -0.154*** | 0.183      |
| Lebanon     | 0.079***  | 0.023     | 0.006**   | -12.255*** |
| Malaysia    | 0.200***  | 2.456**   | 0.228***  | -1.179**   |
| Mongolia    | -0.122*** | -11.250   | 0.041***  | -1.559*    |
| Nepal       | -0.280**  | 0.114***  | -0.066*** | -13.480    |
| Pakistan    | -0.062*** | 0.122***  | 0.129***  | -0.284***  |
| Philippines | -0.223*** | -0.710*** | 0.329***  | -0.132     |
| Srilanka    | 0.035***  | 0.011*    | 0.306***  | -0.054     |
| Tajikistan  | -0.320*** | -0.216*** | 0.009***  | -0.721     |
| Thailand    | 0.093***  | -0.910    | 0.332***  | -0.783**   |
| Uzbekistan  | -0.001*** | -0.163*** | -0.006*** | -9.115***  |
| Vietnam     | -0.021*** | 0.095***  | 0.047***  | 0.366      |

**Note:** \*\*\*, \*\*, \* indicates statistical significance at 1 percent, 5 percent, and 10 percent respectively. Variables are in natural logarithmic form

Using the advantage of PMG model, we have also examined how the impact of energy consumption and other growth determinants varies across the countries in the short run. The result is provided in the table 10. It is clear that in half of the countries considered RE consumption reduces GDP in the short run, whereas a positive effect is found in 9 countries, for the remaining 3 countries RE consumption doesn't have any impact on GDP. When it come to the effect of Non-RE consumption it is found increasing the GDP in 8 countries, but it reduces GDP in 6

countries. For the remaining 10 countries Non-RE is found to be insignificant. Capital formation is found increasing the GDP in a majority of the countries (17 out of 24), for the remaining countries the relation is found to be negative. Labor participation is found reducing the GDP in 9 countries but a positive impact is found for 3 countries, and for the remaining 12 countries it appears to be insignificant.

### ***Panel Causality Test***

Identification of causal relation is essential for determining appropriate policies (Charfeddine, 2017). Hence to find out the direction of causality Dumitrescu and Hurlin pairwise granger causality test is used. This test allows for panel specific heterogeneity and cross sectional dependence. Causal relation between the variables considered in the model analyzing environmental and economic impact is provided in Table 11 and 12<sup>5</sup> respectively.

Since this study used CO<sub>2</sub> emission and ecological footprint as the indicators of environment, causal relation is examined separately for these variables. Hence table 11 is divided into two part: 11.a showing causal relation for CO<sub>2</sub> and 11.b for ecological footprint. The result shows similar causal relation for both these indicators of environment. There is bidirectional causal relation between environmental indicators, and GDP and urbanization respectively. Unidirectional causality is found to exist from environmental indicators to RE consumption<sup>6</sup> and trade openness respectively. No causal relation is existing between Non-RE consumption and environmental indicators.

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<sup>5</sup> Though all the possible causal relation between the variables is examined, for simplicity only those showing the relation between the dependent variables and each of the independent variables is presented here.

<sup>6</sup> Though causal relation is found from RE consumption to ecological footprint, it is significant only at 10 percent level.

**Table 11.a: Causal Relation between CO2 and the Variables Used In Environmental Impact Analysis**

| Null Hypothesis:                        | Zbar-Stat. | Prob.  |
|-----------------------------------------|------------|--------|
| re does not homogeneously cause co2     | 0.16304    | 0.8705 |
| co2 does not homogeneously cause re     | 5.04468*** | 5.E-07 |
| Non-re does not homogeneously cause co2 | 0.89082    | 0.3730 |
| Co2 does not homogeneously cause non-re | 1.20973    | 0.2264 |
| gdp does not homogeneously cause co2    | 10.4491*** | 0.0000 |
| Co2 does not homogeneously cause gdp    | 9.76583*** | 0.0000 |
| trade does not homogeneously cause co2  | 1.59624    | 0.1104 |
| Co2 does not homogeneously cause trade  | 2.18642**  | 0.0288 |
| urban does not homogeneously cause co2  | 10.3383*** | 0.0000 |
| Co2 does not homogeneously cause urban  | 7.50923*** | 6.E-14 |

**Note:** \*\*\*,\*\* denoted rejection of null hypothesis at 1 percent and 5 percent respectively

**Source:** calculated by authors

**Table 11.b: Causal Relation Between Footprint and the Variables Used in Environmental Impact Analysis**

| Null Hypothesis                                | Zbar-Stat. | Prob.  |
|------------------------------------------------|------------|--------|
| LRE does not homogeneously cause LFOOTPRINT    | 1.91942*   | 0.0549 |
| LFOOTPRINT does not homogeneously cause LRE    | 2.95236*** | 0.0032 |
| LFF does not homogeneously cause LFOOTPRINT    | -0.68754   | 0.4917 |
| LFOOTPRINT does not homogeneously cause LFF    | 1.43188    | 0.1522 |
| LGDP does not homogeneously cause LFOOTPRINT   | 11.0499*** | 0.0000 |
| LFOOTPRINT does not homogeneously cause LGDP   | 2.08296**  | 0.0373 |
| LTRADE does not homogeneously cause LFOOTPRINT | 0.90043    | 0.3679 |
| LFOOTPRINT does not homogeneously cause LTRADE | 2.80678*** | 0.0050 |
| LURBAN does not homogeneously cause LFOOTPRINT | 14.3597*** | 0.0000 |
| LFOOTPRINT does not homogeneously cause LURBAN | 6.36726*** | 2.E-10 |

**Note:** \*\*\*,\*\*,\* denoted rejection of null hypothesis at 1 percent, 5 percent, and 10 percent respectively

**Source:** calculated by authors

**Table 12: Causal Relation Between GDP and the Variables Used in Economic Impact Analysis**

| Null Hypothesis:                       | Zbar-Stat. | Prob.  |
|----------------------------------------|------------|--------|
| LRE does not homogeneously cause LGDP  | -0.19010   | 0.8492 |
| LGDP does not homogeneously cause LRE  | 2.83263*** | 0.0046 |
| LFF does not homogeneously cause LGDP  | 0.30451    | 0.7607 |
| LGDP does not homogeneously cause LFF  | 2.39485**  | 0.0166 |
| LK does not homogeneously cause LGDP   | 0.35491    | 0.7227 |
| LGDP does not homogeneously cause LK   | 4.84249*** | 1.E-06 |
| LLFR does not homogeneously cause LGDP | 0.29825    | 0.7655 |
| LGDP does not homogeneously cause LLFR | 2.11410**  | 0.0345 |
| LFF does not homogeneously cause LRE   | 1.28963    | 0.1972 |
| LRE does not homogeneously cause LFF   | 0.94664    | 0.3438 |

**Note:** \*\*\*,\*\* denoted rejection of null hypothesis at 1 percent, and 5 percent level of significance

**Source:** calculated by authors

When it comes to the causal relation between GDP and other variables used in the analysis, it is clear that unidirectional causality is existing from GDP to each of the other variables; RE and Non-RE consumption, capital, and labor. Unidirectional causality from GDP to both the energy consumption indicates conservation hypothesis. This means that the countries considered for this analysis can implement energy conservation measures without the fear of having any impact on economic growth.

## DISCUSSION ON THE EMPIRICAL FINDINGS

This study aims to find out how renewable and non-renewable energy consumption is affecting the environment and economy of Asia. Hence 24 developing countries of Asia are analyzed from 1990 to 2018. In line with the existing studies (Shaari *et. al.*, 2020; Mensah *et. al.*, 2019; Bhattacharya *et. al.*, 2016) we have found the existence of homogeneity and cross sectional dependence across our panel units. In addition, CIPS test confirms that the variables under concern are of mixed order of integration and Pedroni co-integration tests indicates the existence of

long run relation between the variables. Hence ARDL model is used to obtain the short run and long run estimates. Dumitrescu-Hurlin pairwise granger causality test is used to examine the causal relationship between the variables.

Separate analysis is performed to identify the environmental and economic impact of energy consumption. Environmental impact is analyzed by using CO<sub>2</sub> emission and ecological footprint as the indicators of environmental degradation. The result shows that RE consumption helps in protecting the environment i.e. its expansion results in reduced emission and ecological footprint in both the short run and the long run. But Non-RE consumption on the other hand results in increased emission and ecological footprint in the long run. Our findings on the impact of RE consumption fully agrees with Zeb *et. al.*, 2014 and Mahmood *et. al.*, 2019. In the former study electricity production from renewable sources was found reducing CO<sub>2</sub> emission in 5 SAARC countries; India, Bangladesh, Nepal, Pakistan and Sri-Lanka. Whereas the latter study showed RE consumption was reducing CO<sub>2</sub> emission in Pakistan but the effect was found diminishing with economic growth. Our result about the impact of Non-RE consumption on CO<sub>2</sub> emission is in consonant with Shaari *et. al.*, 2020 who had found oil and gas consumption contributing to increased emission in both the short run and the long run for a panel of 20 OIC countries. We agrees to some extent with the findings of Charfeddine, 2017 who had found electricity consumption leading to a reduction in the CO<sub>2</sub> emission and an increase in the ecological footprint in Qatar. Our findings are also in consonant with many other studies; Mensah *et. al.*, 2019 who found positive effect and two way causality between energy consumption and carbon emission in both the long run and the short run for 22 African economy, Pao and Tsai, 2011 who found emission to be elastic to energy consumption, and showed unidirectional causality from energy consumption to emission for Brazil, Russia, India, and China., Munir and Riaz, 2019 who found oil, gas, coal, and electricity consumption leading to increased emission in the long run in south Asian countries of Bangladesh, India, and Pakistan, and Soytas *et. al.*, 2007

who found unidirectional Granger causality from energy consumption to carbon emissions in the US. Contrary to the result of the existing studies our result showed unidirectional causality running from environmental indicators to renewable energy consumption.

While analyzing the environmental impact of energy consumption this study included GDP, trade openness, and urbanization as the control variables. Hence the result provide some insights on how these variables impact the environment. The result indicates that economic growth in the countries considered for the analysis is coming at the risk of the environment i.e. increase in GDP is found accelerating the emission and ecological footprint in both the short run and the long run. Bidirectional causality is also existing between GDP and environmental indicators, which indicates that considerable attention should be adopted while going for emission reduction and resource conservation measures otherwise economic growth may be affected. Our result is in consonant with Charfeddine (2017) and Shaari et al (2020) with respect to the effect of economic growth on environmental degradation in Qatar, and OIC countries respectively. We also agrees with Pao and Tsai (2011) who found the existence of EKC hypothesis and bidirectional causality between output and emission for BRIC countries, Mahmood et al (2019) who for Pakistan found that economic growth, in addition to its direct impact on environment, reduces the positive impact that RE consumption has on CO<sub>2</sub> emission, and Zeb et al (2014) who had found GDP leading to increased CO<sub>2</sub> emission in 5 SAARC countries of India, Bangladesh, Nepal, Pakistan and Sri-Lanka. Liu and Liang (2019) also found bi-directional causality between economic growth and environmental degradation for LMC (Lancang-Mekong Cooperation) countries. Contrariwise Soytaş et al (2007) couldn't found any causality between economic growth and emission for US.

Regarding the impact of other two control variables, trade openness and urbanization; CO<sub>2</sub> emission is found to decrease with the expansion of these variables in the long run, but ecological footprint

increases with it. When it come to the causal relation, unidirectional causality is found from environmental indicators to trade openness, but bidirectional causality is found between environmental indicators and urbanization. This result partially agrees with Charfeddine (2017), who had found trade openness and urbanization accelerating the ecological footprint in Qatar, but they appeared to be insignificant for CO<sub>2</sub> emission. But Mahmood et al (2019) found CO<sub>2</sub> emission to be increasing with trade openness in Pakistan. Their causal relation agree with the present result i.e. unidirectional causality from CO<sub>2</sub> emission to trade openness.

Our analysis to find out the economic impact of energy consumption shows that, both types of energy consumption contributes to GDP in the long run, however Non-RE consumption is making more contribution. But for the sake of the environment and planet it is essential to sacrifice some growth in the name of a transition to sustainable energy sources. In the short run RE consumption is found to reduce GDP. This implies that transition to RE would cause a fall on economic growth, but the long run result indicates that such an economic fall will not persist for a long period. We have also found unidirectional causality running from GDP to both type of energy consumption, thereby supporting the conservation hypothesis. Our result is in consonant with the studies like Saint Akadiri et al (2019) who for a panel of 28 EU countries found positive influence of RE consumption on economic growth in the long run and negative effect in the short run, Bhattacharya et al (2016) who for a panel of 38 countries found RE and Non RE consumption contributing to GDP in the long run, and with Armeanu et al (2017) who found RE production positively influencing the economic growth for 28 EU countries, their result also supported the conservation hypothesis. We also partially agrees with Mensah et al (2019) who found positive impact of and bidirectional causality between Non-RE and economic growth in both the long run and the short run for 22 African economy. But our result disagrees with Bozkurt and Destek (2015) inference that RE consumption increases GDP only in developed countries and it will get reduced in developing countries. We also disagrees with Behera and

Mishra (2020) whose PMG model for G7 countries showed RE and Non-RE to be insignificant for economic growth in the long run, and Non-RE contributing to economic growth in the short run, and with Magnani and Vaona (2013) who found short run positive granger causality from RE generation to output for the Italian region.

Impact of other growth determinants, capital and labor is found to be insignificant in the long run but in the short run former is found increasing the GDP and the latter reducing it. We also found unidirectional causality running from GDP to each of these variables. But these result couldn't fully agrees with the existing studies. Saint Akadiri et al (2019) found a positive impact of capital on economic growth in both the short run and long run and bidirectional causality between them. Behera and Mishra (2020) for G7 countries found capital, and labor force contributing to economic growth in the long run. Mensah et al (2019) for African countries found capital contributing to economic growth in both the long run and the short run, but labor was found to be insignificant. Bhattacharya et al (2016) and Magnani and Vaona (2013) also found long run relation of capital and labor with GDP to be positive.

## **CONCLUSION AND POLICY RECOMMENDATION**

Unprecedented changes in the climatic pattern made the world aware about the need of a cleaner planet. Among the alternative measures taken for combating the climate change, RE by considering its potential for reducing the energy related emission has gained attention. But to consider it as a sustainable solution it is essential to find out how it is affecting the economic growth and the environmental resources. In this context present study estimates the environmental and economic impact of renewable energy consumption using a panel of 24 developing countries of Asia from 1990 to 2018. We have also incorporated the effect of Non-renewable energy consumption.

Presence of panel specific heterogeneity and cross-sectional dependence, and the existence of co-integrated relation among the variables of mixed order of integration made us to utilize ARDL model of PMG for analysis. The result showed that; RE consumption reduces environmental degradation in both the long run and short run whereas Non-RE consumption results in increased degradation. On the other hand both type of energy consumption is found accelerating the economic growth. Thus from the perspective of economic and environmental growth, it is the renewable energy that could be promoted for attaining energy security. Hence we would suggest the policy makers especially those from developing countries to proceed with their current motive for promoting renewable energy and to adopt further measures for its massive acceleration.

We have found GDP growth resulting in increased emission and ecological footprint in both the long run and the short run indicating that economic growth in the countries concerned is coming at the expense of environment. This could be a serious problem since most of the countries considered for this analysis are at their developing stage continuation of economic growth resulting in increased emission and ecological footprint could be expected for the years to come. Hence significant measures for emission reduction and resource conservation have to be adopted by these countries. But the existence of bidirectional causal relation between GDP and the environmental indicators could be a challenge, because it indicates the possibility for emission reduction and resource conservation measures to adversely affect the economic growth. So we would suggest the policy makers to find out the measures that could reduce the emission and ecological footprint with minimal or no impact on economic growth. RE promotion could be an example for such a measure because it can reduce the energy related emission and provide energy security without reducing the economic growth. Though a reduction in economic growth can be expected following the transition to RE, our result implies that it won't persist for a long period i.e. in the long RE could contribute to economic growth.

We have found unidirectional causality from economic growth to both type of energy consumption. This indicates the existence of conservation hypothesis. Hence the countries considered for analysis can adopt energy conservation and efficiency measures without the fear of affecting their economic growth.

Emission is found to decrease with the growth of trade and urbanization in the long run but ecological footprint is found to increasing with them. This could be because the countries considered may be adopting significant measures for reducing the emission but they may not give much attention for protecting other environmental resources. Hence instead of focusing only on emission reduction measures these countries should also be concerned about their natural resources and should try to implement some measures for reducing the ecological footprint.

Based on these empirical findings it can be inferred that instead of depending on fossil based energy sources, developing countries of Asia should try for a transition to renewable energy for having energy security and economic growth without deteriorating the valuable environment. In addition to the adoption of emission reduction measures they must also be concerned about environmental resources and adopt measures for reducing the ecological footprint. Since most of the countries in Asia are at their developing stage considerable attention is required to ensure that their development is not coming at the risk of resource exploitation and carbon emission.

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## APPENDIX

### ARDL model used in the study

To examine the environmental and economic impact of energy consumption, separate ARDL model is run for each indicators of environment and economic growth respectively. By using the variables of this study ARDL equation shown in equation 5 can be expressed as follows.

$$\begin{aligned}
 \Delta lnco2_{i,t} &= \beta + \phi_i [lnco2_{i,t-1} - \theta_i (lnre_{i,t} + lnnonre_{i,t} + lngdp_{i,t} + \\
 &lntrade_{i,t} + lnurban_{i,t})] + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta lnco2_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnre_{i,t-j} + \\
 &\sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnnonre_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lngdp_{i,t-j} + \\
 &\sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lntrade_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnurban_{i,t-j} + \varepsilon_{i,t} \\
 \Delta lnfootprint_{i,t} &= \beta + \phi_i [lnfootprint_{i,t-1} - \theta_i (lnre_{i,t} + lnnonre_{i,t} + \\
 &lngdp_{i,t} + lntrade_{i,t} + lnurban_{i,t})] + \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta lnfootprint_{i,t-j} + \\
 &\sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnre_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnnonre_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lngdp_{i,t-j} + \\
 &\sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lntrade_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnurban_{i,t-j} + \varepsilon_{i,t} \\
 \Delta lngdp_{i,t} &= \beta + \phi_i [lngdp_{i,t-1} - \theta_i (lnre_{i,t} + lnnonre_{i,t} + lnk_{i,t} + lnlabor_{i,t})] \\
 &+ \sum_{j=1}^{p-1} \lambda^*_{i,j} \Delta lngdp_{i,t-j} \\
 &+ \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnre_{i,t-j} \\
 &+ \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnnonre_{i,t-j} \\
 &+ \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnk_{i,t-j} + \sum_{j=0}^{q-1} \delta^*_{i,j} \Delta lnlabor_{i,t-j} + \varepsilon_{i,t}
 \end{aligned}$$

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