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**Article**

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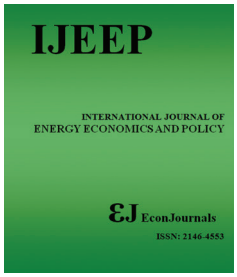
**Provided in Cooperation with:**
International Journal of Energy Economics and Policy (IJEEP)

*Reference:* Akbar, Ahsan/Gul, Azeem et. al. (2024). Impact of renewable and non-renewable energy resources on CO2 emission : empirical evidence from SAARC. In: International Journal of Energy Economics and Policy 14 (1), S. 141 - 149. https://www.econjournals.com/index.php/ijeep/article/download/15049/7656/35597. doi:10.32479/ijeep.15049.



International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(1), 141-149.

# Impact of Renewable and Non-Renewable Energy Resources on $CO_2$ Emission: Empirical Evidence from SAARC

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**Received:** 24 July 2023 **Accepted:** 27 November 2023 **DOI:** https://doi.org/10.32479/ijeep.15049

**ABSTRACT**

When assessing sustainability performance, researchers often ignore the implications of combining energy, economic, and environmental factors. To address this void, we assess the consequence of energy disaggregation proceeding carbon emissions in SAARC nations. The majority of energy resources are renewable and non-renewable, which contributes to a rise in carbon dioxide emissions. This study aims to provide a thorough understanding of the energy utilization dioxide emissions nexus. The panel data sets covering the period 1971-2020 for the SAARC nations have been used for analysis. The dataset was used to assess the effect of renewable and non-renewable energy consumption on emissions of carbon dioxide by factoring in other $CO_2$-producing variables such as urbanization, primary and secondary education, globalization, and economic development. Panel Fully Modified Ordinary Least Squares (FMOLS) was used to examine the connection. According to research comparing the impact of renewable and non-renewable energy consumption upon Carbon dioxide emission, whereas non-renewable energy consumption increases $CO_2$ emissions, renewable energy consumption decreases them. Urbanization, globalization, primary education, and economic growth increase carbon emissions, while secondary education contributes to environmental quality improvement via $CO_2$ reduction. Therefore, increasing the usage of renewable energy and enhancing awareness through higher education may help SAARC nations to reduce pollution emissions.

**Keywords:** Renewable and Non-renewable Energy, Carbon Dioxide Emission, SAARC, Economic Growth
**JEL Classifications:** F1, F6

## 1. INTRODUCTION

Global warming emerges as a serious topic of discussion and a global phenomenon because of its threat to sustainable development (Rafiq et al., 2022). It poses a substantial danger to the environment and to anthropological well-being. One of the main reasons for global environmental problems is due to $CO_2$ emissions. Carbon dioxide emissions have been the primary source of severe environmental pollution, affecting human life regardless of economic development. In 2018, carbon dioxide emissions from the global energy industry rose by 1.7%, the sharpest proportion of growth since 2013, and more than 70% faster than that of the average rate of growth between 2010 and 2018 (IEA, 2019). The global warming danger has been intensified by humans, which has led to the rise in carbon emissions levels in the atmosphere ($CO_2$). Globally, the buildings and construction industry are seeing a rise in emissions and energy consumption, little progress on new and current regulations, and a continued decline in energy-

efficiency investment returns. The universal economy has expanded considerably during the past several decades due to industrialization and urbanization. Many economies rely on energy sources mainly fossil fuels for the increased impact of industrialization and urbanization, each of these activities leads to global warming and environmental degradation (Nasim et al., 2023).

Numerous academics, the majority of whom are economists, have examined the drivers of $CO_2$ emissions using the Kuznets Curve theory (Saudi et al., 2019). As per Economic Kuznet Curve (EKC) hypothesis, rising wealth increases pollution throughout the early stages of economic development until the relationship between income and pollution becomes negative. This phenomenon is shown using a reversed U-shaped connector. In other words, the inverted U-shaped relationship between income and emissions will occur precisely when a country reaches a certain level of economic development, at which energy and renewable energy technologies become affordable.

Renewable energy is a less carbon-intensive and more ecological energy source that is gaining popularity because of the negative environmental consequences of fossil fuel usage and unpredictable, expensive, and changing energy costs. Renewable energy is generated from sources that have an infinite supply. This category covers energy derived from water, wind, sunlight, and biomass. Renewable energy has grown at an impressive rate in recent years, owing mostly to dramatic efficiency improvements for renewables. Q1 2020 shows a 1.5% increase in worldwide renewable energy usage over Q1 2019. Clean energy generation is expected to grow by much more than 33% (IEA, 2019). According to Rahman and Velayutham, (2020), only 10% of energy in the United States is renewable and low carbon (mostly hydroelectric energy). Nonrenewable energy sources provide 85% of global energy consumption-from nonrenewable energy resources such as oil, coal, and natural gas. Education is a precondition for fast global economic growth (Kayani et al., 2023). Education promotes economic development and via various channels improves people's lives. Environmental education is a means of convincing individuals to decrease $CO_2$ emissions. It also has a key part in a successful global response to climate change (Gylfason, 2001).

Education quality may assist to enhance the economic situation of any economy, while also increasing the public's environmental consciousness Alkhateeb et al. (2020). Among the numerous policy strategy employed by countries (which include direct and indirect regulations interventions by the government), efforts to raise awareness of environmental issues among civil society can be accomplished through environmental education, cultural norms and behavior patterns, and moral preaching, all of which can contribute significantly to a higher environmental quality in the future. A country's energy resources rely a lot upon human resources and educational institutions, and education may be critical in a multi-level economic system. Balaguer and Cantavella (2018) stated that the educational system can offset $CO_2$ emissions caused by income growth because wealth development is difficult to control, increasing knowledge is always a good option since the environmental impacts of economic activity may be mitigated without making matters worse.

In addition to energy and education, globalization is a significant factor in determining $CO_2$ emissions. Globalization has developed into one of the most amazing forces on the planet. It is acknowledged as a unit and is referenced as an economic route that affects nations through integration with information and technology exchanges on a social, economic, and political level Shell and Zheng (2015). Omri et al. (2019) reported that Education is more significant in influencing pollution than measures of health and wealth. Globalization is by far the most controversial, diverse phenomenon and is regarded as an emotional force. Tremendous development in urbanization and globalization has been observed in both developing and developed nations (Hasnisah et al., 2019). But urbanization in underdeveloped nations has been found to occur quicker than those in industrialized nations (Shahbaz et al., 2016).

Economic globalization describes the practice through which various economies are becoming more interconnected, and the effects of this trend have been studied. Increasing interconnectedness between national economies has been brought about by globalization. This has also changed the world's political dynamics. Many past enemies have become allies or have at least moved into economic cooperation because of globalization. However, there is still no agreement in academics on the environmental impact of such business cooperation. (Navarro, 1998; Jorgenson and Givens, 2014; Lv and Xu, 2018; You and Lv, 2018; Xie et al., 2023). Historically, urbanization and economic growth have been seen as intrinsically connected phenomena. Urbanization has served an essential role in driving Chinese economic growth; it has generated severe environmental issues which pose huge difficulties for sustainable growth Liu et al. (2008); Liu Yansui et al. (2014); Liu and Diamond (2005). China's expansive economy's rapid expansion in recent times has unavoidably resulted in rapid increase of $CO_2$ emissions (Martins et al., 2023). Additionally, rapid urbanization has resulted in an increase in $CO_2$ emissions as a consequence of urban infrastructure development and household consumption (Peters et al., 2007). The relationship between economic growth and greenhouse gas emissions is one of the most important empirical relationships (Kayani et al., 2023). A thorough economic study of trade-offs between $CO_2$ emissions and economic development is, however, still inadequate for realistic climate change strategies.

SAARC region's economy is growing at a higher rate than that of the global economy. Additionally, it raises energy consumption, owing to increased economic development and fast population rise. Renewable energy is by far the most effective technique in this area for meeting energy demand since South Asia is abundant in renewable energy sources including natural gas, oil, coal, solar, thermal, and hydroelectric energy Sikder et al. (2022). Renewable energy sources account for 12.9% of the overall energy production in South Asia (SA). Renewable energy sources are expected to provide 43% of energy demand in 2030 and 77% in 2050. Additionally, these renewable energy (RE) resources contribute to the reduction of greenhouse gas (GHG) emissions by averting 560 gigawatts (GT) of $CO_2$ emissions (Proskurina et al., 2016). Overall consumption of Non-renewable energy in South Asia is 71.54% out of which Bangladesh has the highest consumption of 73.8% followed by India with 73.6 and Pakistan with 61.6%

(Bekun, 2022; Noor et al., 2023). Based on our study, the following hypothesis $H_0$: Renewable and non-renewable energy resources have no significant impact on $CO_2$ emissions. While renewable and non-renewable energy resources have a significant impact on $CO_2$ emissions.

The purpose of this study is to determine the impact of renewable energy consumption and non-renewable energy usage on SAARC's carbon dioxide emissions. According to our research in south Asian countries, existing literature focuses on either the impact of renewable energy consumption on $CO_2$ or the impact of renewable energy resources on growth; however, this research analyzes the impact of $CO_2$ emissions from both renewable and non-renewable energy sources, as well as economic growth. Additionally, it emphasizes the important role of education in decreasing carbon emissions. The rest of the article contains the following sections. Section 2 contains a literature review. Section 3 discusses methodology, whereas Chapter 4 discusses data, data sources, and variable formation. Additionally, Chapter 5 will provide estimated findings obtained using econometric methods. The thesis is concluded in Chapter 6.

## 2. LITERATURE REVIEW

Alom (2014) investigate the impact of carbon emissions with other variables in five South Asian countries and discovered causal relationships between energy use and $CO_2$ emissions, and also between $CO_2$ emissions and real GDP in the short run. However, in the long run, observed no causal correlation between Economic growth and $CO_2$ emissions or energy use (Arshad et al., 2020). Boontome et al. (2017) found that there was only one cause-and-effect link between non-renewable energy consumption and $CO_2$ emissions: Increase in non-renewable energy usage causes rise in $CO_2$ emissions. Renewable energy uses significantly reduced pollution in South Asia, East Asia, Pacific, Central and Eastern Europe, Americas, Western Europe, Al-Mulali et al. (2016). Farhani and Shahbaz (2014) confirmed the existence of the EKC hypothesis, while also reported that per capita consumption of electricity generated by renewable energy sources increased $CO_2$ emissions. Another research, Bulut and Inglesi-Lotz (2019) used the nonlinear auto regressive distributed lag (NARDL) method to evaluate asymmetric connections between renewable energy and non-renewable energy consumption on industrial output (IP) in the United States, utilizing data collected on a monthly basis during 2000-2018. The results showed that both non-renewable and renewable energy indorsed industrial development in the United States: An increase in NRE had a larger effect on IP than a reduction in NRE, while an increase in RE had a smaller impact on IP than a decrease in RE.

Azam and Khan (2015) analyzed the effects of urbanization on environmental pollution and degradation measured by carbon emissions for four South Asian countries. They report that in Bangladesh and India, urbanization expansion had a substantially negative significant effect on the environment, whereas in Sri Lanka it was substantially positive and insignificant in Pakistan. Also, Anwar et al. (2020) found that urbanization, trade openness, economic growth significantly affects $CO_2$ emission causing environmental degradation and serious health issues in the selected nine Far East countries. Inglesi-Lotz and Dogan (2018), focused on $CO_2$ emissions of the ten most power producers in Sub-Saharan Africa and concluded that the major factors had confirmed long term relation. Increased non-renewable energy resources produced more pollution whereas using renewable energy supplies would reduce pollution. Paper also observed Unidirectional causation flows from non-renewable energy/fossil fuel emissions, to trade, and from trade to non-renewable energy emissions. Balaguer and Cantavella's gave empirical results that, on the whole, increase in education and a rise in per capita $CO_2$ emissions have offset each other throughout the time span that has been examined (1950-2014). Furthermore, recently it has been shown that both per capita income growth and education expansion may help decrease emissions. Saidi and Omri (2020) found that there had been a bidirectional causal relationship between economic development and renewables in the short and long-term using the Vector Error correction test. Also, economic growth was linked to $CO_2$ emissions in both cases. Saidi and Hammami (2015) examine the impact of economic growth and $CO_2$ emissions on energy usage for a global panel of 58 countries using the Generalized Method of Moments (GMM). Empirical data from four global panels demonstrated a significant positive impact of $CO_2$ emissions and economic growth (EG) on energy usage and utilization. Tahir et al. (2021) concluded that there was unidirectional causation between economic expansion, globalization, and financial development and environmental deterioration, as well as between emissions and energy consumption.

Zhang et al. (2017), Mehmood et al. (2019) evaluated the Environmental Kuznets Curve (EKC) hypothesis for different time spans in Pakistan. Their results strongly supported the EKC's existence and so concluded, renewable energy had a major part in decreasing carbon dioxide emissions, with nonrenewable energy use being the leading cause. Also, bi-directional causality befell among renewable energy usage and $CO_2$ emission. Alkhateeb et al. (2020) found that elementary schooling could not influence $CO_2$ emissions, but high schools had a negative impact on carbon dioxide ($CO_2$). In long term, a U-shaped connection among emissions of CO2 and economic development was established and Kingdom is in the first stage. Mehmood (2021) findings indicate that although education and renewable energy reduced $CO_2$ emissions, foreign direct investment (FDI) and natural resources harmed the ecosystem. Renewable energy, education, GDP, and $CO_2$ emissions all had a positive correlation with diverse causality results. Navarro (1998) and Aeknarajindawat et al. (2020) globalization favorably promotes economic development, but study continues to investigate if globalization impacts environmental contamination. Also, Lv and Xu (2018) and Hasnisah et al. (2019) examined the influence of economic globalization on Carbon dioxide ($CO_2$) emissions in 15 developing nations. The findings showed that in the long term, a rise of 1% in economic globalization lowered $CO_2$ emissions by −0.11%, which are stable in various estimate methods. Martínez-Zarzoso and Maruotti (2011) findings indicated that urbanization had a U-shaped connection with $CO_2$ emissions. McGee and York (2018) concluded that urbanization had an impact on ecosystems that was symmetrical with rising urbanization. An

urban population decrease lowered $CO_2$ emissions more than an urban population rise.

$CO_2$ emissions are closely related to economic growth, that is a significant determinant for consumption and production in the global economy. Our best knowledge shows that most of the research in the Southern Asian area address the link between energy consumption usage and carbon dioxide emissions in existing literatures. This research divides energy consumption into renewable and non-renewable energy use, and empirically analyses the impact on emissions of carbon dioxide. The focus of this section is to give a short summary of trends in SAARC nations in economic development, education, urbanization, energy use, globalization, and pollutant emissions. The data shows that SAARC nations still use a substantial quantity of energy despite a significant reduction in energy consumption during recent years. Examining the trend in non-renewable energy usage reveals that SAARC nations still rely on this kind of energy. Additionally, since most South Asian nations import crude oil, their reliance on a particular source of energy increases oil costs which harms the environment and accelerates global warming.

### 2.1. Theoretical Framework, Methodology and Data

Numerous studies in the current literature place an emphasis on Solow (1988) conventional macroeconomic growth model, which does not contain energy as a component of production but instead views the economy as a closed system in which products are created using capital and labor inputs. Though, the importance of energy as a component of production has increased in recent decades. The Cobb-Douglas form is a frequently used production function that is well-suited for determining connections across output and economic variables.

$$Y_t = K_t^{\alpha} L_t^{\beta}$$

Where $Y_t$ denotes total production at time t, $L_t$ denotes labor, $K_t$ denotes capital, and A is the technological parameter. $\alpha$ and $\beta$ determine the production elasticities about capital and labor. Recent economic development literature implies that labor, capital, technical advancement, and energy are the fundamental components of economic growth in industrialized nations. Therefore, models of economic growth (EG) are built on five variables: Output, energy, labor, capital and technological progress (Yuan et al., 2008). This study, based on previous research (Nourzad, 2000; Liao et al., 2010; Yuan et al., 2008), presents a Cobb-Douglas production function in the following mathematical form, which adds energy as an input in addition to the two standard inputs (capital[K] and labor [L]).

$$Y_t = A K_t^{\alpha} L_t^{\beta} E_t^{\gamma}$$

Where $E_t$ denotes energy and $\gamma$ is the output's elasticity with regard to energy. According to Arbex and Perobelli (2010) and Liao et al. (2010), energy is classified into two types: Clean energy (renewable) and non-clean energy (non-renewable), and the manufacturing process utilizes both types of energy. As a result, the preceding function is modified as follows:

$$Y_t A K_t^{\alpha} L_t^{N_t^{\gamma 2}\beta} R_t^{\gamma 1}$$

Here $R_t$ denotes renewable energy sources and $N_t$ denotes non-renewable energy sources. Here, $\gamma 1$ and $\gamma 2$ denote the output's elasticity in terms of renewables and non-renewables, respectively. The logarithmic version of the growth model results in the following log-linear form:

$$ln\, Yt = ln\, A + \alpha\, ln\, Kt + \beta\, ln\, Lt + \gamma 1\, ln\, Rt + \gamma 2\, ln\, Nt + ut$$

The dependent variable, Y, represents real GDP, whereas the independent variables, K, L, R, and N, indicate labour, renewable, capital, and non-renewable energy consumption, respectively. The economic justifications for $\alpha$, $\beta$, $\gamma 1$, and $\gamma 2$ are the output elasticities with regard to capital, labour, renewable energy, and non-renewable energy.

By including energy consumption, environmental emissions, and economic development into a modelling framework, we may examine their connection. These studies examine the relationship between these three factors by merging the literature on the EKC hypothesis with the literature on energy consumption increase Richmond and Kaufman (2006); Ang (2007); Apergis and Pyne (2010) and Wang et al. (2011). The EKC is a relation among environmental quality and economic development that has been hypothesized. It implies that many indices of environmental degradation incline to deteriorate as contemporary economic expansion continues, at least till average income reaches a certain level. In summary, its central message tends to imply that economic development is the answer to pollution.

### 2.2. Econometric Model

The model is built using the Mahalik et al. (2021) approach. Mehmood (2021) highlights nexus among $CO_2$ emissions, Education, Natural Resource, FDI, Renewable Energy (REC) and GDP using simple linear model and explore the relationship between RE, Education and environment degradation in G11 countries. Mahmood et al. (2019) employed simple model to analyze nexus between TR, RE, NRE, GDP and $CO_2$ emissions and find the EKC hypothesis.

By the following Mahalik et al. (2021) general form of the model is used:

$CO_2 = F$ (GDPC, PER, SER, URB, EGI, $NRE$, RE)

Where $CO_2$ stand for Carbon Dioxide Emissions, GDPC for Real Economic Growth, PER for Primary Education, SER for Secondary Education, URB for Urbanization, EGI for Economic Globalization Index, NRE for Non-Renewable Energy, and RE for Renewable Energy. The above model will likely to be valid and more accurate when an increase in Economic Growth will cause an increase in $CO_2$ that is expected sign for economic growth is likely to be positive. Also, the coefficient of primary education and non-renewable energy are expected to be positive. Globalization and Urbanization can either be positively or negatively significant depending on level of economic growth and development. Renewable Energy and Secondary Education are expected to

have a negative sign referring an increase in RE will reduce $CO_2$ emissions and more education may also have a beneficial impact on reducing environmental degradation.

### 2.3. Nature of the Data and Variables

The research makes use of a panel data collection that was collected from secondary sources; World Development Indicators (WDI). Data is collected for eight nations which are Pakistan, Afghanistan, India, Bangladesh, Maldives, Nepal, Sri Lanka, Bengal from 1990 to 2020 based on data accessibility. Description of the Variables. Carbon dioxide emissions ($CO_2$) (metric tons per capita) as a proxy for environmental degradation, renewable energy consumption (RE) as a percentage of total energy consumption, and nonrenewable energy consumption (NRE) as a percentage of total energy consumption are utilized in the study. Gross enrolment in primary (PER) and secondary (SER) schools, as well as urbanization (URB) as a proxy for urban population % of total population, GDPC (constant 2010 US$) as a proxy for economic growth (EG) and economic globalization index (EGI). The operational definition of the variables as in Appendix A.

## 3. RESULTS AND DISCUSSIONS

Table 1 shows that emissions of carbon dioxide and other variables are stationary at 1st difference from both ADF and PP unit-root tests. Thus, the various panel unit root tests provide the same findings and enhance the reliability and validity of these tests. And so, when all variables are stationary at I (1), FMOLS is used for estimation.

According to Table 2, the findings of the FMOLS method showed that the long-term relation of $CO_2$ emissions in relation to RE and NRE. Economic development on a real per capita basis contributes substantially to carbon emissions in South Asian nations. The findings demonstrate the fossil fuel energy consumption has a statistically significant effect on carbon emissions in Asia's emerging countries. In the majority of SAARC countries, fossil fuels constitute critical energy resources; Oil and coal and natural gas has been the primary source of energy. As a moment, the widespread burning of fossil fuels to increase output and stimulate economic development in emerging countries; a major source of carbon emissions and global warming (Kang et al., 2016; Boopen and Harris, 2012; Hanif, 2018; Chen and Lei, 2018).

However, as a result of inefficient technology in emerging countries, huge use of non-renewable resources such as fossil fuels results in increased waste and excessive carbon dioxide emissions into the environment (Martins et al., 2022). Furthermore, low-priced fossil fuels offer an appealing energy option for these countries looking to boost local manufacturing, but at the expense of the environment (Xie et al., 2023). One might argue that having a good natural environmental resource is frequently considered a luxury in impoverished nations. The empirical findings of this research show that renewable energy usage has a negative significant effect on carbon dioxide emissions in emerging Asian countries (Inglesi-Lotz and Dogan 2018; Bhattacharya et al., 2017); thus, renewable energy contributes to carbon dioxide emission reduction. The study observes the effect of elementary (primary) and secondary schooling on carbon emissions. As a result, we find that elementary education has a significantly positive sign, indicating that a lack of knowledge and awareness results in increased carbon emissions. Whereas as education level increases, emissions decrease, and therefore secondary education has a negative effect on $CO_2$. Education increases environmental awareness, and citizens begin to exert pressure on government agencies to implement effective climate policies. Environmental quality begins to improve as a result of successful policy execution. Additionally, Puukka discovered that education had aided in the sustainable growth of OECD countries. Our findings also support those of Bano et al. who discovered that education reduces environmental pollution. Public awareness increases the demand for greener energy use, which benefits air pollution. This result is consistent with Balaguer and Cantavella's (2018) results for Australia, but contradicts Jiang's (2015) findings for China, where no inverted U-shaped relationship between education and $CO_2$ was seen because many researchers are in favor of validating the EKC hypothesis among education and $CO_2$.

In terms of the connection betwixt urbanization and $CO_2$ emissions, it is revealed that when urbanization grows, $CO_2$

**Table 1: Unit root test**

| Variable | ADF | | PP | | Conclusion |
|---|---|---|---|---|---|
| | LEVEL | 1st difference | LEVEL | 1st difference | |
| $CO_2$ | 2.84804 | 221.707*** | 2.29932 | 221.882*** | I (1) |
| | 0.9999 | 0.0000 | 1.0000 | 0.0000 | |
| GDPC | 0.38948 | 40.8570*** | 0.39034 | 43.5671*** | I (1) |
| | 1.0000 | 0.0006 | 1.0000 | 0.0002 | |
| PER | 8.12594 | 134.659*** | 8.12742 | 118.534*** | I (1) |
| | 0.9450 | 0.0000 | 0.9450 | 0.0000 | |
| SER | 2.16963 | 77.6007*** | 1.05769 | 96.6921*** | I (1) |
| | 1.0000 | 0.0000 | 1.0000 | 0.0000 | |
| URB | 7.62581 | 12.7837*** | 36.6357 | 13.3427*** | I (1) |
| | 0.9592 | 0.0000 | 0.0024 | 0.0000 | |
| EGI | 10.3538 | 204.268*** | 9.84990 | 213.572*** | I (1) |
| | 0.8475 | 0.0000 | 0.8743 | 0.0000 | |
| NRE | 2.28501 | 97.1774*** | 2.00005 | 135.681*** | I (1) |
| | 0.9937 | 0.0000 | 0.9963 | 0.0000 | |
| RE | 16.3661 | 84.7811*** | 9.90777 | 123.196*** | I (1) |
| | 0.4277 | 0.0000 | 0.8714 | 0.0000 | |

**Table 2: Regression results of FMOLS**

| Variable | Coefficient | SE | t-Statistic | Prob. |
|---|---|---|---|---|
| GDPC | 2.60E-13 | 7.20E-15 | 36.15923 | 0.0000 |
| PER | 0.002122 | 0.000255 | 8.305246 | 0.0000 |
| SER | −0.000732 | 0.000199 | −3.675862 | 0.0006 |
| URB | 0.004331 | 0.000893 | 4.848506 | 0.0000 |
| EGI | 0.004002 | 0.000336 | 11.91444 | 0.0000 |
| NRE | 0.009624 | 0.000362 | 26.55698 | 0.0000 |
| RE | −0.004243 | 0.000264 | −16.08764 | 0.0000 |

emissions increase as well. This conclusion is similar to Alam et al. (2007)'s findings for Pakistan and in China by Zhang and Lin's (2012) findings. Similarly, Liddle and Lung (2010) discover a significant correlation betwixt urbanization and $CO_2$ emissions from transportation in the OECD nations. The finding of a direct connection between urbanization and $CO_2$ emissions disagrees with the findings of Fan et al. (2006), Hossain (2011), Sharma (2011), who all conclude that urban population has a negative effect on $CO_2$ emissions in high-income and recently industrialized nations. According to much research, the relationship between urbanization and emissions is complicated, even in nations with comparable wealth and development levels. However, industrialized and highly urbanized nations are clearly better equipped to attain low carbon intensity via the adoption of new energy technology. In industrialized nations, it seems that the connection between urbanization and emissions is best described by the EKC theory.

## 4. CONCLUSION

Energy plays a vital component in economic growth (EG) and increased urbanization. On the contrary, side, growing worldwide anxiety about the environmental consequences of energy consumption has piqued interest in the relationship betwixt energy use, economic growth, and the environment. The global economies have struggled to create a clean environment without discrimination to economic development. The purpose of this study is to evaluate the effect of renewable energy and non-renewable energy use on carbon emissions and energy consumption using a neoclassical model of economic growth and the EKC theory. Additionally, the current study analyses the increasing impacts of non-renewable energy and renewable energy demand on the environment to assess the potential for non-renewable energy sources to substitute clean energy sources. Energy and education are recognized as the key variables affecting $CO_2$ emissions, together with economic growth (GDP), urbanization and globalization. Additionally, this research examines the relationship betwixt these factors and the usage of renewable and non-renewable energy sources. Finally, an empirical study investigates the effect of education, urbanization, globalization, GDP, and energy usage (renewable and not renewable) on carbon dioxide ($CO_2$) emissions for SAARC countries for the time spanning 1971-2020. In this study, the econometric panel techniques, unit root, and FMOLS are used.

The data indicate that SAARC nations are stimulating economic development with the usage of renewable and non-renewable energy. Comparing their coefficient magnitudes, however, shows that non-renewables remain the primary kind of energy used in economic development. Similarly, urbanization findings indicate that non-renewable energy performs a major role for industrial production i.e. the positive impact of globalization and urbanization indicates an increase in $CO_2$ emission. Economic growth (GDP) also had a positive and significant effect on $CO_2$. The positive effect of primary education and the negative effects of secondary education on $CO_2$ emissions directly indicates that SAARC nations may enhance air quality by raising awareness via education. Governments may increase environmental awareness in the curriculum, including environmental benefits and energy efficiency, and develop a social habit for sustainable environmental energy-saving activities. SDGs 4, 7, and 13 (Quality education, Affordable and clean energy, and Climate action) can also be accomplished via this method.

The findings also show that though education influences economic development positively and substantially as decreases $CO_2$ emissions, there is a significant and positive impact of NRE while the negative impact of RE on $CO_2$ emissions. Soon, fossil fuels cannot be replaced by renewable energy sources. SAARC needs to use alternative renewable energy sources as a remedy to the climate problems. Governments ought to develop and execute appropriate investment support policies in renewable energy capacity to ensure a persistent and sustainable increase in renewable energy usage. Urban planners may take significant climate change action by upgrading public transit networks, improving building energy efficiency, and boosting energy supply from renewable sources. Also, they need to discourage the impact of globalization and urbanization to promote greener energy consumption and production technologies. In addition, incentive structures should be provided to clean technology user groups for using renewable energy. Policymakers need a transition away from fossil fuels and toward renewable energy in a way that may not damage economic development. The function of education in promoting environmental regulations will be beneficial in this case. Observed countries should thus have to raise their education expenditure.

## 5. FUNDING

The open access of this research is funded by the Excellence Project 2023 at the Faculty of Informatics and Management, University of Hradec Kralove, Czech Republic.

## REFERENCES

Aeknarajindawat, N., Suteerachai, B., Suksod, P. (2020), The impact of natural resources, renewable energy, economic growth on carbon dioxide emission in Malaysia. International Journal of Energy Economics and Policy, 10(3), 211-218.

Alam, S., Fatima, A., Butt, M.S. (2007), Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation. Journal of Asian Economics, 18(5), 825-837.

Alkhateeb, T.T.Y., Mahmood, H., Altamimi, N.N., Furqan, M. (2020), Role of education and economic growth on the $CO_2$ emissions in Saudi Arabia. Entrepreneurship and Sustainability, 8, 195.

Al-Mulali, U., Ozturk, I., Solarin, S.A. (2016), Investigating the

environmental Kuznets curve hypothesis in seven regions: The role of renewable energy. Ecological Indicators, 67, 267-282.
Alom, K. (2014), Economic growth, $CO_2$ emissions and energy consumption: Evidence from panel data for South Asian region. Journal of Knowledge Globalization, 7(1), 43-63.
Ang, J.B. (2007), $CO_2$ emissions, energy consumption, and output in France. Energy Policy, 35(10), 4772-4778.
Anwar, A., Younis, M., Ullah, I. (2020), Impact of urbanization and economic growth on CO2 emission: A case of Far East Asian countries. International Journal of Environmental Research and Public Health, 17(7), 2531.
Apergis, N., Payne, J.E. (2010), Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy, 38(1), 656-660.
Arbex, M., Perobelli, F.S. (2010), Solow meets Leontief: Economic growth and energy consumption. Energy Economics, 32(1), 43-53.
Arshad, Z., Robaina, M., Botelho, A. (2020), Renewable and non-renewable energy, economic growth and natural resources impact on environmental quality: Empirical evidence from south and Southeast Asian countries with CS-ARDL modeling. International Journal of Energy Economics and Policy, 10(5), 368.
Azam, M., Khan, A.Q. (2016), Urbanization and environmental degradation: Evidence from four SAARC countries-Bangladesh, India, Pakistan, and Sri Lanka. Environmental Progress and Sustainable Energy, 35(3), 823-832.
Balaguer, J., Cantavella, M. (2018), The role of education in the environmental Kuznets curve. Evidence from Australian data. Energy Economics, 70, 289-296.
Bekun, F. (2022), Mitigating emissions in India: Accounting for the role of real income, renewable energy consumption and investment in energy. International Journal of Energy Economics and Policy, 12(1), 188-192.
Bhattacharya, M., Churchill, S.A., Paramati, S.R. (2017), The dynamic impact of renewable energy and institutions on economic output and $CO_2$ emissions across regions. Renewable Energy, 111, 157-167.
Boontome, P., Therdyothin, A., Chontanawat, J. (2017), Investigating the causal relationship between non-renewable and renewable energy consumption, $CO_2$ emissions and economic growth in Thailand. Energy Procedia, 138, 925-930.
Boopen, S., Harris, N. (2012), Energy use, emissions, economic growth and trade: Evidence from Mauritius. Resource and Energy Economics, 30, 50-65.
Bulut, U., Inglesi-Lotz, R. (2019), Which type of energy drove industrial growth in the US from 2000 to 2018? Energy Reports, 5, 425-430.
Chen, W., Lei, Y. (2018), The impacts of renewable energy and technological innovation on environment-energy-growth nexus: New evidence from a panel quantile regression. Renewable Energy, 123, 1-14.
Fan, Y., Liu, L.C., Wu, G., Wei, Y.M. (2006), Analyzing impact factors of $CO_2$ emissions using the STIRPAT model. Environmental Impact Assessment Review, 26(4), 377-395.
Farhani, S., Shahbaz, M. (2014), What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate $CO_2$ emissions in MENA region? Renewable and Sustainable Energy Reviews, 40, 80-90.
Gylfason, T. (2001), Natural resources, education, and economic development. European Economic Review, 45(4-6), 847-859.
Hanif, I. (2018), Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. Energy Strategy Reviews, 21, 16-24.
Hasnisah, A., Azlina, A.A., Taib, C.M.I.C. (2019), The impact of renewable energy consumption on carbon dioxide emissions: Empirical evidence from developing countries in Asia. International Journal of Energy Economics and Policy, 9(3), 135.
Hossain, M.S. (2011), Panel estimation for $CO_2$ emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy, 39(11), 6991-6999.
IEA. (2019), Global Energy and $CO_2$ Status Report 2019. Paris: IEA. Available from: https://www.iea.org/reports/global-energy-co2-status-report-2019
Inglesi-Lotz, R., Dogan, E. (2018), The role of renewable versus non-renewable energy to the level of $CO_2$ emissions a panel analysis of sub-Saharan Africa's Big 10 electricity generators. Renewable Energy, 123, 36-43.
Jiang, Y. (2015), Foreign direct investment, pollution, and the environmental quality: A model with empirical evidence from the Chinese regions. The International Trade Journal, 29(3), 212-227.
Jorgenson, A.K., Givens, J.E. (2014), Economic globalization and environmental concern: A multilevel analysis of individuals within 37 nations. Environment and Behavior, 46(7), 848-871.
Kang, Y.Q., Zhao, T., Yang, Y.Y. (2016), Environmental Kuznets curve for $CO_2$ emissions in China: A spatial panel data approach. Ecological Indicators, 63, 231-239.
Kayani, U.N., Sadiq, M., Aysan, A.F., Haider, S.A., Nasim, I. (2023), The impact of investment, economic growth, renewable energy, urbanisation, and tourism on carbon emissions: Global evidence. International Journal of Energy Economics and Policy, 13(1), 403-412.
Liao, Q., Wu, Z., Xu, J. (2010), A new production function with technological innovation factor and its application to the analysis of energy-saving effect in LSD. Modelling and Simulation, 6(4), 257-266.
Liddle, B., Lung, S. (2010), Age-structure, urbanization, and climate change in developed countries: Revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. Population and Environment, 31, 317-343.
Liu, J., Diamond, J. (2005), China's environment in a globalizing world. Nature, 435(7046), 1179-1186.
Liu, Y., Fang, F., Li, Y. (2014), Key issues of land use in China and implications for policy making. Land Use Policy, 40, 6-12.
Liu, Y., Wang, L., Long, H. (2008), Spatio-temporal analysis of land-use conversion in the eastern coastal China during 1996-2005. Journal of Geographical Sciences, 18(3), 274-282.
Lv, Z., Xu, T. (2018), Is economic globalization good or bad for the environmental quality? New evidence from dynamic heterogeneous panel models. Technological Forecasting and Social Change, 137, 340-343.
Mahalik, M.K., Mallick, H., Padhan, H. (2021), Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective. Renewable Energy, 164, 419-432.
Mahmood, N., Wang, Z., Hassan, S.T. (2019), Renewable energy, economic growth, human capital, and $CO_2$ emission: An empirical analysis. Environmental Science and Pollution Research, 26, 20619-20630.
Martínez-Zarzoso, I., Maruotti, A. (2011), The impact of urbanization on $CO_2$ emissions: Evidence from developing countries. Ecological Economics, 70(7), 1344-1353.
Martins, J.M., Gul, A., Mata, M.N., Haider, S.A., Ahmad, S. (2023), Do economic freedom, innovation, and technology enhance Chinese FDI? A cross-country panel data analysis. Heliyon, 9(6), e16668.
Martins, J.M., Haider, S.A., Pereira, J.M., Mata, M.N., Abreu, A. (2022), Innovation management on waste biorefineries. In: Handbook of Waste Biorefinery: Circular Economy of Renewable Energy. Cham: Springer International Publishing. p915-932.
McGee, J.A., York, R. (2018), Asymmetric relationship of urbanization and $CO_2$ emissions in less developed countries. PLoS One, 13(12), e0208388.
Mehmood, U. (2021), Contribution of renewable energy towards

environmental quality: The role of education to achieve sustainable development goals in G11 countries. Renewable Energy, 178, 600-607.
Mohsin, M., Kamran, H.W., Nawaz, M.A., Hussain, M.S., Dahri, A.S. (2021), Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. Journal of Environmental Management, 284, 111999.
Nasim, I., Boukhris, M., Kayani, U.N., Bashir, F., Haider, S.A. (2023), Exploring the links between renewable energy, FDI, environmental degradation, and international trade in selected developing countries. International Journal of Energy Economics and Policy, 13(6), 418.
Navarro, V. (1998), Neoliberalism,"globalization," unemployment, inequalities, and the welfare state. International Journal of Health Services, 28(4), 607-682.
Noor, M., Khan, D., Khan, A., Rasheed, N. (2023), The impact of renewable and non-renewable energy on sustainable development in South Asia. Environment, Development and Sustainability, 1-18.
Nourzad, F. (2000), The productivity effect of government capital in developing and industrialized countries. Applied Economics, 32(9), 1181-1187.
Omri, A., Euchi, J., Hasaballah, A.H., Al-Tit, A. (2019), Determinants of environmental sustainability: Evidence from Saudi Arabia. Science of the Total Environment, 657, 1592-1601.
Peters, G.P., Weber, C.L., Guan, D., Hubacek, K. (2007), China's growing $CO_2$ emissions a race between increasing consumption and efficiency gains. Environmental Science and Technology, 41, 5939-5944.
Proskurina, S., Sikkema, R., Heinimö, J., Vakkilainen, E. (2016), Five years left-how are the EU member states contributing to the 20% target for EU's renewable energy consumption; the role of woody biomass. Biomass and Bioenergy, 95, 64-77.
Rafiq, M., Akbar, A., Maqbool, S., Sokolová, M., Haider, S.A., Naz, S., Danish, S.M. (2022), Corporate risk tolerance and acceptability towards sustainable energy transition. Energies, 15(2), 459.
Rahman, M.M., Velayutham, E. (2020), Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. Renewable Energy, 147, 399-408.
Richmond, A.K., Kaufmann, R.K. (2006), Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecological Economics, 56(2), 176-189.
Saidi, K., Hammami, S. (2015), The impact of $CO_2$ emissions and economic growth on energy consumption in 58 countries. Energy Reports, 1, 62-70.
Saidi, K., Omri, A. (2020), The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries. Environmental Research, 186, 109567.
Saudi, M.H.M., Sinaga, O., Jabarullah, N.H. (2019), The role of renewable, non-renewable energy consumption and technology innovation in testing environmental Kuznets curve in Malaysia. International Journal of Energy Economics and Policy, 9(1), 299-307.
Shahbaz, M., Loganathan, N., Muzaffar, A.T., Ahmed, K., Jabran, M.A. (2016), How urbanization affects $CO_2$ emissions in Malaysia? The application of STIRPAT model. Renewable and Sustainable Energy Reviews, 57, 83-93.
Sharma, S.S. (2011), Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. Applied Energy, 88(1), 376-382.
Shell, H.G., Zheng, L. (2015), The interaction effects of globalization and institutions on international capital flows. International Journal of Economics and Finance, 7(4), 12-22.
Sikder, M., Wang, C., Yao, X., Huai, X., Wu, L., KwameYeboah, F., Dou, X. (2022), The integrated impact of GDP growth, industrialization, energy use, and urbanization on $CO_2$ emissions in developing countries: Evidence from the panel ARDL approach. Science of the Total Environment, 837, 155795.
Solow, R.M. (1988), Growth theory and after. The American Economic Review, 78(3), 307-317.
Tahir, T., Luni, T., Majeed, M.T., Zafar, A. (2021), The impact of financial development and globalization on environmental quality: Evidence from South Asian economies. Environmental Science and Pollution Research, 28(7), 8088-8101.
Wang, S.S., Zhou, D.Q., Zhou, P., Wang, Q.W. (2011), $CO_2$ emissions, energy consumption and economic growth in China: A panel data analysis. Energy Policy, 39(9), 4870-4875.
Xie, X., Khan, S., Rehman, S., Naz, S., Haider, S.A., Kayani, U.N. (2023), Ameliorating sustainable business performance through green constructs: A case of manufacturing industry. Environment, Development and Sustainability, 1-33, Retrieved From: https://doi.org/10.1007/s10668-023-03569-3.
You, W., Lv, Z. (2018), Spillover effects of economic globalization on $CO_2$ emissions: A spatial panel approach. Energy Economics, 73, 248-257.
Yuan, J.H., Kang, J.G., Zhao, C.H., Hu, Z.G. (2008), Energy consumption and economic growth: Evidence from China at both aggregated and disaggregated levels. Energy Economics, 30(6), 3077-3094.
Zhang, B., Wang, B., Wang, Z. (2017), Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan. Journal of Cleaner Production, 156, 855-864.
Zhang, C., Lin, Y. (2012), Panel estimation for urbanization, energy consumption and $CO_2$ emissions: A regional analysis in China. Energy Policy, 49, 488-498.

# APPENDIX

## Appendix A

| Variable | Definition of variable |
|---|---|
| $CO_2$ emissions (metric tons per capita) | Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. |
| School enrollment, primary (% gross) | Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music. |
| School enrollment, secondary (% gross) | Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject-or skill-oriented instruction using more specialized teachers. |
| GDP (constant 2010 US$) | GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used. |
| Renewable energy consumption (% of total final energy consumption) | Renewable energy consumption is the share of renewable energy in total final energy consumption. |
| Fossil fuel energy consumption (% of total) | Fossil fuel comprises coal, oil, petroleum, and natural gas products. |
| Urban population (% of total population) | Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division. |
| Overall Globalization | Globalization is defined as the worldwide movement toward economic, financial, trade and communications integration. Globalization implies the opening of local and nationalistic perspectives to a broader outlook of an interconnected and interdependent world with free transfer of capital, goods, and services across national frontiers. |