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The Role of Renewable Energy, Human Capital, and Carbon Emissions in Driving Economic Growth among South Asian Countries

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Abstract: *This study examines the influence of renewable energy consumption, human capital, and carbon emissions on economic growth in South Asian nations, specifically Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. The study uses data from 1990 to 2021, a panel cointegration test, and the Fully Modified Ordinary Least Squares (FMOLS) model to look at how these variables are related. The findings show a positive correlation between economic growth and carbon emissions, while the use of renewable energy reduces these emissions. Human capital is pivotal, as elevated education and skill development contribute to diminished carbon emissions. The findings corroborate the Environmental Kuznets Curve (EKC) hypothesis, indicating that following a specific threshold of economic growth, carbon emissions decline. The study underscores the challenges confronting South Asian economies, such as rapid population growth and industrial expansion, which exacerbate carbon emissions. The study concludes by emphasizing the importance of incorporating renewable energy sources, improving human capital, and implementing environmentally sustainable policies in the region to achieve long-term economic growth and environmental sustainability.*

Key Words: Renewable Energy, Human Capital, Carbon Emissions, Economic Growth

Introduction

South Asian countries, such as India, Pakistan, Sri Lanka, Bhutan, Nepal, Afghanistan, and the Maldives, are progressively embracing renewable energy sources, including solar, wind, hydroelectric, and biomass. These nations, situated in various climatic zones, possess abundant access to these resources, rendering them an optimal site for implementing renewable energy systems. The swift expansion of population and economic progress has resulted in a substantial rise in energy demand, requiring a transition to sustainable energy sources to diminish reliance on non-renewable fuels and satisfy escalating energy needs (Shrestha et al., 2022).

South Asian nations are collaborating to establish policies for sustainable energy security and economic prosperity. The imperative transition from coal-based energy production to low-carbon technologies is underscored, as renewable resources such as wind and solar power are inexhaustibly replenished and not prone to depletion. Sustainable energy sources enhance GDP and improve overall well-being by generating new employment opportunities and fostering business growth. Expanding renewable energy infrastructure fosters economic advancement while reducing carbon emissions. IRENA forecasts a 1.1% increase in global GDP and a 3.7% enhancement in human welfare by 2030, contingent upon the widespread adoption of renewable energy (Islam & Ali, 2024).

Developing nations in South Asia, home to a substantial segment of the global impoverished populace, are concurrently pursuing economic growth. Despite their per capita GDP remaining inferior to that of middle- and low-income nations globally, there are encouraging signs of growth. Nepal attained a significant annual GDP growth rate of 7.9% in 2017, exceeding that of other regional nations. India and

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Pakistan have demonstrated substantial economic growth, with 6.68% and 5.70%, respectively. Sri Lanka registered the lowest GDP growth rate at 3.30%. To foster prosperity and improve living conditions, it is essential to sustain and augment economic growth in these nations, particularly in regions with elevated poverty levels (Rockström et al., 2017). Socio-economic factors substantially influence economic growth, including population growth, energy consumption, trade liberalization, infrastructure advancement, financial sector development, corruption prevalence, governance quality, and policy efficacy. The literature reveals conflicting results concerning the influence of specific factors on economic growth, attributed to differing methodologies, unique country characteristics, variations in sample sizes, and omitted variable bias.

Human capital is a pivotal determinant of sustained and rapid economic growth in numerous South Asian nations (Škare & Lacmanović, 2015). This is accomplished by enhancing knowledge and skills, advancing education and training, and elevating the quality of life. The factors driving economic growth, including consumer spending, investment in human capital, and employment rates, are directly interconnected. Numerous South Asian nations have significantly progressed, resulting in rapid economic expansion. Human capital is crucial for rapid growth and development, generating competitive advantages for nations that offer superior work and lifestyle conditions (Teixeira & Queirós, 2016).

Superior human capital in the health, science, management, and education sectors is crucial for fostering a stable growth environment. Studies indicate that human capital is a significant catalyst for economic growth, influencing both the level and the growth rate (Teixeira & Queirós, 2016) posited that the accumulation of human capital and innovation affects the output growth rate. asserted that technological advancements heighten the demand for skilled labourers who have undergone training programs (Coulombe & Tremblay, 2009).

Literature Review

Rehman et al. (2020) examined the causal relationship between renewable and non-renewable energy consumption with economic growth in the Asia-Pacific Economic Cooperation (APEC) region from 1990 to 2015. Their study found that all two types of energy did stimulate economic activities and that the degree of openness of the economy positively affected economic growth. Similarly, Balcilar et al. (2018) examined the dynamic relationship between renewable energy and GDP in the G-7 countries from 1960 to 2015. Agan and Balcilar (2023) rendered the task of risk understanding the economic growth, availability of renewable sources of energy, and environmental resources to explain the surge of carbon dioxide pollution in five selected EU countries from 1985 to 2016, uncovering the results of the research conducted. They revealed that while electricity consumption, the availability of natural resources, and energy modernization promoted the environment, the augmentation of internal trade, economic growth, and electricity consumption did increase CO_2 emissions. Apergis and Payne (2010a) found a positive uptake of CO_2 emissions concerning GDP and imports, while exports had a negative relationship (Farhani et al., 2014).

Eregha et al. (2022) detected a relationship between GDP and renewable energy in ten Central and Eastern European Nations from 1990 through 2014. (Shahbaz et al., 2016) tried to evaluate the association between economic growth and renewable energy consumption in Pakistan by utilizing the rolling window technique and autoregressive distributed lag framework. Apergis and Payne (2010b) found a unidirectional causality that goes from economic growth to renewable energy use from 1992 to 2007 in thirteen countries in the Eurasian region, including bidirectional nexus for national economies growth and renewable resources energy employment within shorter and longer period implications. It is widely accepted that using renewable energy contributes to reducing CO_2 emissions while reaping the benefits of economic regression expansion; in this, the abuse of the power of such renewable energy sources may also contaminate the environment. The health subsidy is negatively influenced by renewable energy and health expenditure in South Asian countries (Khan et al., 2020).

Radmehr et al. (2021) confirmed positive spatial correlations between GDP growth, carbon dioxide emission, and renewable energy consumption in the countries of the European Union between 1995 and 2014. They found that there is a one-way causation in moving from economic development to renewable energy, which can help design optimal environmental and energy policies for decision-makers (Radmehr et al., 2024). Rehman et al. (2020) analyzed the impacts of renewable energy consumption, electricity use, agriculture, and carbon dioxide emissions in SAARC countries. It is concluded that India is the biggest emitter of CO_2 among SAARC countries, and energy consumption from renewable sources reduces emissions and helps achieve ISO14001 certification.

In their study, Shahbaz et al. (2016) examined the relationship of GDP, energy use, and CO2 emissions using the annual series from Portugal from 1971-2011. Both GDP and energy consumption were shown to increase CO2 emissions, while" financial deepening" helped mitigate the emissions. They also found that CO2 emissions were Granger caused by economic growth and financial development (Shahbaz et al., 2016). Etokakpan et al., 2020) set out to re-examine the relationship between electricity consumption, economic growth, and carbon dioxide emissions flows in the BRICS countries. The findings supported Russia's feedback hypothesis, while South Africa was more consistent with the conservation hypothesis. However, there was no evidence of Granger causality between economic growth and CO2 emissions for India and China. As for the short-run results, (Menegaki, 2018) reported the presence of a bi-directional relationship between output and carbon emissions, as well as between renewables and carbon emissions. Apergis et al. (2023) found that consumption of discovered CO2 emissions positively affects the utilization of renewable energy.

The contribution of human capital towards environmental protection is of great importance and has attracted considerable interest. Adikari et al. (2023) on the contrary found a significant and negative relationship between this variable of carbon emissions and human capital. This implies that education spending improves human capital, which will eventually translate to lower CO2 emission levels and lower deterioration of the environment. Likewise, (Gnangoin et al., 2022). It is clear that people’s capital has a significant impact on curbing the negative effects of non-renewable energy utilization on the quality of the environment (Wen et al., 2022). Arshad et al. (2024) explored through citation relationships between human capital, globalization, and CO2 emissions in developing countries using 78 country-level data covering the period of 1990 to 2016. It was hypothesized that human capital would be linked to CO2 emissions, where more peoples' capital levels would lead to reduced CO2 emissions in all regions analyzed.

Khan and Hou (2021) studied the relationship between CO_2 emissions and fiscal decentralization by using a panel data set from seven member countries of the OECD and concluded that fiscal decentralization has favorable effects on the environment, geospatial variations, and spatial effects on geodata institutional quality, and building human capital are likely to sustain. However, Lin et al. (2021) researched the interactions between economic growth, CO_2 emissions, and R&D human capital within the regions of China and claimed that the development of human capital focused on research and new product development would decrease CO_2 emissions, which will turn increase the ability of the country to protect the environment. Wang and Xu (2021) used the ARDL approach to investigate the interrelationships between internet usage, human capital, and CO_2 emissions in countries with different levels of economic growth and their implications for severe global climate change.

Data Sources and Methodology

This study examined the data from six South Asian economies: Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. However, Afghanistan and Maldives were not included in the analysis due to the unavailability of data. The data set was obtained from Pakistan's economic survey from 1990 to 2021. In South Asia, several developing countries like India, Pakistan, Sri Lanka, Bhutan, Nepal, Afghanistan, and Maldives are looking for renewable energy sources such as solar, wind, hydro, and biomass. Geographically, South Asian countries are in a region of different climatic conditions, providing easy access to various renewable energy sources. The core variables of the study include CO2 emission, Human Capital, Gross Domestic Product, and Renewable energy.

Empirical Model- Specific form of FMOLS Model

Contemplation of CO2, GDP, and Human capital

Reduced Form Model

$$CO2 = f(GDP, GDP(Square))$$

$$CO2_{1t} = \alpha_{11} + \sum_{i=1}^{\rho_1} \beta_{11t}\, GDP_{1t-1} + \sum_{i=1}^{\rho_1} \delta_{11t}\, GDP^2{}_{1t-1} + \varepsilon_{11t}$$

Estimation Form Model

$$CO2 = f(\, GDP, GDP^2, GDP, CO2(t-1), LFPR, GFCF, HC, URB, INDG, RENE, TRAD)$$

$$CO2_{it} = \alpha_{11} + \sum_{i=1}^{\rho_1} \beta_{11t}\, GDP_{it} + \sum_{i=1}^{\rho_1} \delta_{11t}\, GDP^2{}_{it} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, CO2_{it-1} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, GDP_{it-1} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, LFPR_{it} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, GFCF_{it}$$
$$+ \sum_{i=1}^{\rho_1} \varphi_{11t}\, HC_{it} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, POPG_{it} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, INDG_{it} + \sum_{i=1}^{\rho_1} \varphi_{11t}\, RENE_{it} + + \sum_{i=1}^{\rho_1} \varphi_{11t}\, TRAD_{it} + \varepsilon_{it}$$

Where,
CO2 are the carbon omissions, GDP is the gross domestic product, HC is human capital, RENE is renewable energy, GFCF is gross fixed capital formation, POPG is the Population growth, INDG is industrial growth and TRAD is the trade openness.

Several studies have attempted to investigate the relationship between carbon emissions and human capital, but there are still no conclusive results for South Asia's economies to date. This study contributes to the existing literature by virtue of placing human capital, which is a social variable, in the framework of EKC. The next phase of the development of renewable energy sources has changed the structure of consumption of energy resources due to the growth of human capital and growing ecological consciousness. There are a lot of studies that explain that a higher share of renewable energy consumption reduces carbon emissions from industries (Cowan et al., 2014). This caused the expansion of international trade, aggravating the movement of commodities and increasing cross-border economic activities together with the movement and spread of new goods and innovations. Consequently, a number of studies have shown that trade liberalization has a significant effect on the environment (Balcilar et al., 2023)

The data for this dynamic panel regression analysis was FMOLS regressed, which assumes the dependent variable of an individual is a dynamic one in that part of its value is taken from its value in the previous period (Baum et al., 2011; Huang et al., 2019). Because emission levels are fixed for a certain duration of time, the amount of emissions during the current year is determined by the amount released in the previous year. So, in this study, it is hypothesized that the endogenous variable, which is the lagged logarithm of carbon emissions, has been treated as one of the determinants for the emission model.

Table 1

Descriptive statistics

Variable	Abbreviation	Mean	Std. Dev.
CO2 emission	CO2	0.193636	0.142659
Labor force participation rate	LFPR	60.95416	11.18477
Gross Fixed capital formation	GFCF	27.64089	11.81441
Human Capital	HC	47.17778	10.69595
Gross Domestic Product	GDP	5.169996	2.911434
Renewable energy consumption	RENE	63.41409	20.84597
Population growth	POPG	1.503803	0.973786
Industry	IND	25.89789	7.312546
Trade openness	TRAD	50.21276	24.2031

Source: Author’s calculations using STATA 14.

Table 2

Correlation analysis

	CO2	GDP	LFPR	GFCF	HCI	POPG	INDG	RENE
GDP	0.0534							
LFPR	-0.4514	-0.0169						
GFCF	0.009	0.219	0.1282					
HCI	-0.2197	-0.0038	-0.1079	0.1666				
POPG	0.1972	0.0441	-0.1731	-0.2645	-0.4524			
INDG	0.1145	0.2834	-0.1171	0.7534	0.2061	-0.1619		
RENE	-0.3463	-0.0237	0.4128	0.3348	-0.2064	-0.1299	0.0498	
TRAD	-0.3333	0.1739	0.1352	0.6797	0.1841	-0.35	0.4431	0.5617

Source: Author's calculations using STATA 14.

Table 3

Panel cointegration test

Method	Alternative Hypothesis: Common AR coef. (within dimension)		Weighted	
	t.Stat	Prob.	t-Stat	Prob.
Panel V- stat	-6.5271	1	-5.4287	1
Panel rho-stat	-7.8744	0	-6.1627	0
Panel PP-stat	-17.686	0	-14.127	0
Panel ADF-stat	-63.757	0	-5.0963	0
	Alternative Hypothesis: Individual AR coef. (between dimensions)			
	t-Stat	Prob.	t.Stat	Prob.
Group rho-stat	-4.9093	0		
Group PP-stat	-14.941	0		
Group ADF-stat	-7.4011	0		

Source: Author's calculations using STATA 14.

Long-run results

Contemplation of CO2, GDP, and Human capital

Table 4

Empirical model 1: FMOLS model results

	beta	t-stat	beta	t-stat
GDP	-0.01*	1.71	6.14***	14.82
GDPSQ	0.00	1.01	-3.97***	-10.95
CO2_L1			0.22***	11.54
GDP_L1			0.01***	8.06
LFPR			0.08***	14.05
GFCF			0.01***	8.46
HCI			-0.03***	-14.67
POPG			0.01	0.78
INDG			0.06**	2.41
RENE			-0.11***	-36.74
TRAD			0.002	-1.21
Constant	-0.04***	-17.94	-0.01***	-5.93

Source: Author's calculations using STATA 14.

Note: *** p<0.01, ** p<0.05, * p<0.1

The regression results help measure the relationship between carbon emission (CO2)and the economic and social characteristics of South Asian countries. High GDP per capita contributes to the rapid growth of

CO_2 emissions, as evidenced by the Positive coefficient (6.14) given for GDP. The available literature, including (Apergis & Payne, 2010b; Balcilar et al. 2018; Baum et al., 2011; Shrestha et al., 2022), has shown that the relationship between carbon emissions and different economic and social parameters in South Asian economies is much more complex and multi-directional. According to the other World Development Report available for the South Asian region, increases in GDP in South Asian countries, contrary to the same in Brazil, China, and Indonesia, do not exacerbate CO_2 levels. This finding goes against the traditional EKC hypothesis, which suggests that emissions decrease at higher income growth levels after a certain point (Agan & Balcilar, 2023; Wen et al., 2022).

The regression coefficient for the lagged term of CO_2 (CO2_L1) is 0.22, which means that there is a lag of carbon emissions, suggesting that any level of carbon emissions, once achieved, will be hard to change in the future, thus underpinning the need to take measures for a long time in the protection of the environment. In line with what was established above and through negative coefficients of lagged terms in carbon emissions, such as the lagged term for CO_2 here, such persistence in emissions of pollution was earlier discovered by Shahbaz (2013) that such pollution is habitual with stringing that present emissions are more likely to incur upwards because of history pathways and accumulation to how the environment is treated. Economically speaking, the value of 0.08 means a direct link between the Labour Force Participation Rate (LFPR) and carbon emissions: the higher the rate of the LFPR – the higher the carbon emissions; this increase is related to higher levels of economic activities and energy usage to the extent of increased level of the workforce participation. The coefficient of 0.01 indicates a positive association between GFCF and carbon emissions, where a high GFCF is associated with high carbon emissions. Still, it stresses the need to include green construction concepts when building infrastructure.

Regarding the HCI, the evaluation shows -0.03, meaning that human capital increases surprisingly and emits less carbon. With an increase in human capital, there is likely to be a decrease in carbon emissions. This finding resonates with that of Shahbaz (2013). It should be negative in the context of South Asia because the higher the human capital index, the lower the emissions, suggesting that climate change-friendly policies are more likely to be adopted where there is investment in the education and skill development of the populace. The coefficient for Population Growth (POPG) was found to be 0.01, which means with the increase in population growth, there will be an increase in carbon emissions. The coefficient of 0.06 indicates a positive relationship between industrial growth (INDG) and carbon emissions—the introduction of low-emission technologies and the application of stringent industrial process regulations.

The variable "Renewable Energy Consumption (RENE)" has a significant impact on carbon emissions with a negative coefficient value of -0.11. This is expected based on the finding that renewable energy would reduce the production of carbon emissions in the economy. The Trade Openness (TRAD) coefficient, taking a value of -0.002, explains an inverse relationship between trade openness and carbon emissions, which may suggest that as economies open more, the carbon emissions get reduced. The Labour Force Participation Rate, Gross Fixed Capital Formation, and Population Growth, all with positive coefficients in South Asia, also have trends in countries like Indonesia and Malaysia. For instance, increased contribution to the labor force, high gross capital formation, and increasing population have positive correlations with high CO_2 emissions (Shahbaz, 2013; Begum, 2015), which in turn bring out the problems facing South Asian economies in the quest for economic growth with environmental protection, especially during industrialization and population growth phases which suggests that globalization has potential for facilitating division of ecologically negative works and shoddy technologies for production. The results would show how economic relations, human resources, and the environment are related in South Asia.

Table 5

Diagnostics - model 1

Regression diagnostics	Null Hypothesis	Estimated values	P value
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	Ho: Constant variance	chi2(1) = 46.90	Prob > chi2 =0.9871

Regression diagnostics	Null Hypothesis	Estimated values	P value
Ramsey RESET test	Ho: The model has no omitted variables	F (3, 170) = 27.48	Prob > F = 1.9832
Breusch-Godfrey LM test for autocorrelation	H0: no serial correlation	chi2(1) = 63.56	Prob = 5.3331

Source: Author's calculations using STATA 14.

The table presents regression diagnostic tests to assess the assumptions and performance of the regression model. Breusch-Pagan / Cook-Weisberg Test for Heteroskedasticity with a high p-value (0.9871) suggests no significant evidence to reject the null hypothesis. Hence, the assumption of constant variance is not violated, indicating homoskedasticity in the model. Ramsey RESET Test for omitted variables indicates that the p-value of 1.9832 is greater than the significance level, indicating no significant evidence to reject the null hypothesis. This suggests that the model does not have omitted variables, as indicated by the RESET test. Breusch-Godfrey LM Test for Autocorrelation rejects the null hypothesis and makes a conclusive determination about no autocorrelation in this context.

Conclusion and Policy Recommendation

This study's key findings emphasize the interplay among GDP, carbon dioxide emissions, renewable energy utilization, and human capital development in South Asian nations. We demonstrate that economic growth leads to an increase in carbon footprint metrics, but there is potential to counteract this negative environmental impact by increasing investments in renewable energy and human capital. Moreover, various findings corroborate the Environmental Kuznets Curve (EKC) hypothesis, indicating that despite economic growth, the relationship between carbon emissions and growth peaks before emissions subsequently decline. This suggests that we can implement sustainable strategies to eliminate the correlation between economic growth and the imperative of environmental conservation. Furthermore, the results validate the understanding of the second aspect—fuel consumption—where human capital plays a pivotal role in a nation's reduction of carbon emissions by leveraging a better-educated workforce in eco-friendly practices and technology utilization. Nevertheless, industrial expansion continues to pose environmental hazards because of its association with elevated emission levels. Therefore, all efforts should focus on mitigating the environmental issues arising from industrialization while simultaneously fostering regional development.

South Asian countries must enact policy measures to guarantee sufficient economic growth while safeguarding the environment. Initially, policymakers should incorporate renewable energy policies to encourage the adoption of cleaner energy sources through tax incentives, subsidies, or regulatory relaxation. The renewable energy sector will expand, diminishing reliance on non-renewable energy sources and consequently lowering carbon emissions. Moreover, investing in human resources is crucial; enhancing the education system and vocational training programs focused on environmental issues will cultivate a workforce adept at embracing green energy. Industrialization of the economy and the advancement of industries are essential; politicians should mandate the integration of energy-efficient technologies in industrial operations.

References

Adikari, A. P., Liu, H., Dissanayake, D., & Ranagalage, M. (2023). Human capital and carbon emissions: The way forward reducing environmental degradation. *Sustainability*, *15*(4), 2926. https://doi.org/10.3390/su15042926

Agan, B., & Balcilar, M. (2023). Unraveling the green growth matrix: Exploring the impact of green technology, climate change adaptation, and macroeconomic factors on sustainable development. *Sustainability*, *15*(11), 8530. https://doi.org/10.20944/preprints202305.0243.v1

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. https://doi.org/10.1016/j.enpol.2009.09.002

Apergis, N., Kuziboev, B., Abdullaev, I., & Rajabov, A. (2023). Investigating the association among CO2 emissions, renewable and non-renewable energy consumption in Uzbekistan: an ARDL approach. *Environmental Science and Pollution Research International*, *30*(14), 39666–39679. https://doi.org/10.1007/s11356-022-25023-z

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and growth in Eurasia. *Energy Economics*, *32*(6), 1392-1397. https://doi.org/10.1016/j.eneco.2010.06.001

Arshad, Z., Madaleno, M., Lillebø, A. I., & Vieira, H. (2024). Digitalization's contribution towards sustainable development and climate change mitigation: An empirical evidence from EU economies. *Heliyon*, *10*(13), e33451. https://doi.org/10.1016/j.heliyon.2024.e33451

Balcilar, M., Gupta, R., & Jooste, C. (2018). Renewable energy consumption and economic growth nexus: Evidence from a bootstrap rolling window approach. *Renewable and Sustainable Energy Reviews*, *68*, 679-690.

Balcilar, M., Ozdemir, Z. A., Ozdemir, H., & Shahbaz, M. (2018). The renewable energy consumption and growth in the G-7 countries: Evidence from historical decomposition method. *Renewable Energy*, *126*, 594-604. https://doi.org/10.1016/j.renene.2018.03.066

Baum, M. A., & Lake, D. A. (2003). The political economy of growth: Democracy and human capital. *American Journal of Political Science*, *47*(2), 333-347. https://doi.org/10.2307/3186142

Begum, R. A., Sohag, K., Abdullah, S. M., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594-601. https://doi.org/10.1016/j.rser.2014.07.205

Coulombe, S., & Tremblay, J.-F. (2009). Education, Productivity and Economic Growth: A Selective Review of the Evidence. *International productivity monitor*, 18, 3-24. https://ideas.repec.org/a/sls/ipmsls/v18y20091.html

Cowan, W. N., Chang, T., Inglesi-Lotz, R., & Gupta, R. (2014). The nexus of electricity consumption, economic growth and CO2 emissions in the BRICS countries. *Energy Policy*, *66*, 359-368. https://doi.org/10.1016/j.enpol.2013.10.081

Eregha, P. B., Aworinde, O. B., & Vo, X. V. (2022). Modeling twin deficit hypothesis with oil price volatility in African oil-producing countries. *Resources Policy*, 75(102512), 102512. https://doi.org/10.1016/j.resourpol.2021.102512

Eshchanov, B., Abdurazzakova, D., Yuldashev, O., Salahodjaev, R., Ahrorov, F., Komilov, A., & Eshchanov, R. (2021). Is there a link between cognitive abilities and renewable energy adoption: Evidence from Uzbekistan using micro data. *Renewable and Sustainable Energy Reviews*, *141*(110819), 110819. https://doi.org/10.1016/j.rser.2021.110819

Etokakpan, M. U., Osundina, O. A., Bekun, F. V., & Sarkodie, S. A. (2020). Rethinking electricity consumption and economic growth nexus in Turkey: environmental pros and cons. *Environmental Science and Pollution Research International*, 27(31), 39222–39240. https://doi.org/10.1007/s11356-020-09612-4

Farhani, S., Chaibi, A., & Rault, C. (2014). CO2 emissions, output, energy consumption, and trade in Tunisia. *Economic Modelling*, *38*, 426-434. https://doi.org/10.1016/j.econmod.2014.01.025

Gnangoin, T. Y., Kassi, D. F., Edjoukou, A. J.-R., Kongrong, O., & Yuqing, D. (2022). Renewable energy, non-renewable energy, economic growth and CO2 emissions in the newly emerging market economies: The moderating role of human capital. *Frontiers in Environmental Science*, *10, 1-15*. https://doi.org/10.3389/fenvs.2022.1017721

Huang, G., Li, Z., Li, X., Liang, S., Yang, K., Wang, D., & Zhang, Y. (2019). Estimating surface solar irradiance from satellites: Past, present, and future perspectives. *Remote Sensing of Environment*, *233*(111371), 111371. https://doi.org/10.1016/j.rse.2019.111371

Islam, M. T., & Ali, A. (2024). Sustainable green energy transition in Saudi Arabia: Characterizing policy framework, interrelations and future research directions. *Next Energy*, *5*(100161), 100161. https://doi.org/10.1016/j.nxener.2024.100161

Khan, I., & Hou, F. (2021). The impact of Socio-economic and environmental sustainability on CO2 emissions: A novel framework for thirty IEA countries. *Social Indicators Research*, *155*(3), 1045–1076. https://doi.org/10.1007/s11205-021-02629-3

Khan, S. A. R., Zhang, Y., Kumar, A., Zavadskas, E., & Streimikiene, D. (2020). Measuring the impact of renewable energy, public health expenditure, logistics, and environmental performance on sustainable economic growth. *Sustainable Development*, *28*(4), 833–843. https://doi.org/10.1002/sd.2034

Lin, X., Zhao, Y., Ahmad, M., Ahmed, Z., Rjoub, H., & Adebayo, T. S. (2021). Linking innovative human capital, economic growth, and CO2 emissions: An empirical study based on Chinese provincial panel data. *International Journal of Environmental Research and Public Health*, *18*(16), 8503. https://doi.org/10.3390/ijerph18168503

Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics*, *33*(2), 257–263. https://doi.org/10.1016/j.eneco.2010.10.004

Radmehr, R., Henneberry, S. R., & Shayanmehr, S. (2021). Renewable energy consumption, CO2 emissions, and economic growth nexus: A simultaneity spatial modeling analysis of EU countries. *Structural Change and Economic Dynamics*, 57, 13–27. https://doi.org/10.1016/j.strueco.2021.01.006

Radmehr, R., Shayanmehr, S., Baba, E. A., Samour, A., & Adebayo, T. S. (2024). Spatial spillover effects of green technology innovation and renewable energy on ecological sustainability: New evidence and analysis. *Sustainable Development*, *32*(3), 1743–1761. https://doi.org/10.1002/sd.2738

Rehman, A., Ma, H., Irfan, M., Ahmad, M., & Traore, O. (2020). Investigating the influence of international tourism in Pakistan and its linkage to economic growth: Evidence from ARDL approach. *SAGE Open*, *10*(2), 215824402093252. https://doi.org/10.1177/2158244020932525

Rehman, E., Ikram, M., Feng, M. T., & Rehman, S. (2020). Sectoral-based CO2 emissions of Pakistan: A novel grey relation analysis (GRA) approach. *Environmental Science and Pollution Research*, *27*(23), 29118-29129. https://doi.org/10.1007/s11356-020-09237-7

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., DeClerck, F., Shah, M., Steduto, P., De Fraiture, C., Hatibu, N., Unver, O., Bird, J., Sibanda, L., & Smith, J. (2016). Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio*, *46*(1), 4-17. https://doi.org/10.1007/s13280-016-0793-6

Shahbaz, M., Hussain Shahzad, S. J., & Jammazi, R. (2016). *Nexus between US energy sources and economic activity: Time-frequency and bootstrap rolling window causality analysis.* https://mpra.ub.uni-muenchen.de/68724/

Shahbaz, M., Jam, F. A., Bibi, S., & Loganathan, N. (2015). Multivariate Granger causality between co2 emissions, energy intensity and economic growth in Portugal: Evidence from cointegration and causality analysis. *Technological and Economic Development of Economy*, *22*(1), 47–74. https://doi.org/10.3846/20294913.2014.989932

Shahbaz, M., Mahalik, M. K., Shah, S. H., & Sato, J. R. (2016). Time-varying analysis of CO2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. *Energy Policy*, *98*, 33–48. https://doi.org/10.1016/j.enpol.2016.08.011

Shrestha, A., Mustafa, A. A., Htike, M. M., You, V., & Kakinaka, M. (2022). Evolution of energy mix in emerging countries: Modern renewable energy, traditional renewable energy, and non-renewable energy. *Renewable Energy*, *199*, 419–432. https://doi.org/10.1016/j.renene.2022.09.018

Škare, M., & Lacmanović, S. (2015). Human capital and economic growth: a review essay. *Amfiteatru Economic Journal*, *17*(39), 735-760. http://www.amfiteatrueconomic.ro/temp/Article_2422.pdf

Teixeira, A. A. C., & Queirós, A. S. S. (2016). Economic growth, human capital and structural change: A dynamic panel data analysis. *Research Policy*, *45*(8), 1636–1648. https://doi.org/10.1016/j.respol.2016.04.006

Wang, J., & Xu, Y. (2021). Internet usage, human capital and CO2 emissions: A global perspective. *Sustainability*, *13*(15), 8268. https://doi.org/10.3390/su13158268

Wen, Y., Haseeb, M., Safdar, N., Yasmin, F., Timsal, S., & Li, Z. (2022). Does degree of stringency matter? Revisiting the pollution haven hypothesis in BRICS countries. *Frontiers in Environmental Science*, *10*. https://doi.org/10.3389/fenvs.2022.949007