



## Towards Asian Countries Sustainable Development: The Nexus between Information and Communication Technology, Energy Consumption and Carbon Dioxide Emission

Ayiza Arshad<sup>1</sup>, Atif Khan Jadoon<sup>2</sup>, Ambreen Sarwar<sup>3</sup>, Maria Faiq Javaid<sup>4</sup>

### Abstract

This research investigates the intricate relationships among Information and Communication Technology (ICT), the adoption of Renewable Energy, Primary Energy Consumption, Population Growth Rate, Economic Growth, Financial Development, Trade, and carbon dioxide (CO<sub>2</sub>) emissions across 21 Asian countries. Our analysis uncovers a significant correlation between ICT, the adoption of Renewable Energy sources, and decreased CO<sub>2</sub> emissions, underscoring their potential to foster environmental sustainability. In contrast, positive associations are observed between CO<sub>2</sub> emissions and Primary Energy consumption, Population Growth Rate, and Economic Growth, highlighting challenges associated with rapid industrialization. The relationships between Financial Development and Trade with CO<sub>2</sub> emissions are nuanced, indicating varied impacts among countries. Methodologically, we address concerns such as cross-sectional dependence by employing both random and fixed models and applying the Newey-White test. These findings underscore the necessity of harmonizing economic development with environmental sustainability in Asian policymaking. While promoting renewable energy and using ICT can effectively mitigate emissions, prudent energy management is imperative. Addressing global climate issues requires pivotal international cooperation, urging Asian nations to collaborate on innovative policies for a sustainable, low-carbon future. This study establishes a robust foundation for future research and policymaking initiatives focused on sustainability across Asian nations.

**Keywords:** Carbon Dioxide Emission, Energy Consumption, Information and Communication Technology, Sustainable Development

### 1. Introduction

The dawn of 21<sup>st</sup> century brought technological advancement causing financial development and higher growth rate but also environmental degradation issues. The energy consumption also increased drastically which ultimately increased economic growth in developing countries (Asafu-Adjaye, 2000). The extensive energy consumption in recent years by the developing countries also caused environmental degradation (Dincer, 1998). Asian region has remained one of the fastest growing region of the world in last fifty years and energy consumption has remained major contributing factor in this growth (Jadoon et al., 2023). The present study is designed to check the impact of information communication technology (ICT), financial development and environmental degradation. The primary objective of the study is to explore the factors contributing to the region's worsening environmental degradation (measured through CO<sub>2</sub> emission), providing practical insights for leaders and advocates of sustainable development in Asia.

In our interconnected global landscape, the convergence of new technology, economic growth, and the necessity for sustainable living fosters a sense of international unity. Sustainable living, defined as developing economies without compromising future generations' needs, becomes crucial in addressing climate change. Asian nations have substantially contributed to global carbon dioxide emissions, contributing 53% over the last decade (Pani & Mukhopadhyay, 2010; Farhadi & Zaho, 2024). Despite these challenges, the region actively combats pollution through innovative technologies, regulations, and digital tools, demonstrating its commitment to an environmentally friendly future (Dwivedi et al., 2022; Ullah & Ali, 2024). The rapid evolution of ICT over the past two decades has garnered global attention (Dawes, 2008; Audi et al., 2020; Rehman & Ahmad, 2024; Roussel & Audi, 2024). This investigation explores how the adoption of information technology can both contribute to decreased energy consumption and worsen environmental degradation. It delves into the intricate relationship between ICT, economic growth, and environmental impact. It recognizes negative consequences such as CO<sub>2</sub> emissions and the potential for enabling more sustainable cities, transportation systems, and industrial processes.

The financial development sector emerges as a pivotal player in shaping economic activities and affecting growth (Levine, 1999; Tawari, 2024). This section delves into multifaceted dynamics, exploring the intricate connections between financial development and carbon emissions. While financial systems can facilitate economic growth and attract foreign direct investment (Hermes & Lensink, 2003; Audi et al., 2024), they also pose challenges with increased energy consumption and carbon emissions (Manta et al., 2020; Audi & Ali, 2023). Recent studies provide an opposing viewpoint, suggesting that financial development can enhance energy efficiency, reducing energy consumption and carbon emissions.

Economic activity has historically driven CO<sub>2</sub> emissions, often resulting in environmental degradation. This exploration delves into the intricate relationship between sustainable development and climate change, emphasizing the prevailing notion that environmental pollution tends to rise initially with economic growth but gradually declines as incomes surpass a certain threshold (Dinda, 2004; Ahmad, 2018; Jadoon et al., 2021; Jadoon et al., 2024; Leal & Marques, 2022). Recognizing the devastating impacts of environmental degradation fueled by carbon emissions, the exploration emphasizes the need to transition to renewable energy sources to meet energy demands sustainably (Jadoon et al., 2022). The rapid population growth drives increased activity in the transportation sector and fosters industrialization; it also amplifies energy usage, particularly from non-renewable sources. Balancing the economic benefits of population growth with its environmental challenges becomes a critical consideration.

This exploration further investigates the promising role of renewable energy sources in achieving cleaner energy consumption.

<sup>1</sup> Scholar, School of Economics, University of the Punjab Lahore, Pakistan

<sup>2</sup> Corresponding Author, School of Economics, University of the Punjab Lahore, Pakistan, [atifkhan.eco@pu.edu.pk](mailto:atifkhan.eco@pu.edu.pk)

<sup>3</sup> School of Economics, University of the Punjab Lahore, Pakistan

<sup>4</sup> School of Economics, University of the Punjab Lahore, Pakistan

Emphasizing the global demand for renewable energy and its potential to replace fossil fuels, it positions the development of renewable energy sources as a catalyst for sustained economic growth, aligning with heightened public awareness of environmental issues arising from traditional energy consumption.

This study consolidates the intricate connections among ICT, financial development, economic growth, renewable energy, primary energy consumption, and population growth rate. As Asia grapples with opportunities and challenges, the study underscores the necessity for global cooperation. Policymakers face balancing economic advancement with environmental well-being, requiring innovative solutions to address climate change and foster prosperity.

## 2. Literature Review

This segment highlights the present situation in Asia, underscoring the intricate interaction between economic growth, technological advancements, financial transformation, and environmental factors. Scholars investigate the dynamics involving ICT, financial progress, and economic expansion to inform policies that foster sustainable and well-rounded development.

**Intersecting Realities:**

Investigating the intricate dynamics of technology, population growth, economic progress, and environmental impact in Asia, scholars such as Li et al. (2021) underscore the significance of adopting an integrated approach to development. Li's research delves into the intersection of technological innovation, specifically in artificial intelligence (AI) and automation, with demographic shifts and economic trends. The study emphasizes the necessity for adaptive policies that leverage technology for economic growth while considering environmental effects and population dynamics. Ahmed and Le (2021) examined the impact of ICT and a newly developed trade globalization index on CO<sub>2</sub> emissions within the ASEAN-6 (Association of South East Asian Nations) countries. The study employed advanced panel econometric methods, including Westerlund and Pedroni co-integration tests, the CUP-FM long-run method, and a panel DH causality approach. The results indicate the existence of co-integration among the variables.

Expanding on the global challenges outlined by Haseeb, Xia, Saud, Ahmad, and Khurshid (2019) in their focus on BRICS economies, researchers like Wang et al. (2021) widen the scope to encompass a more extensive international collaboration framework. Wang's work explores how cross-border partnerships and agreements can play a pivotal role in mitigating environmental degradation. Coordinated efforts, including global emission reduction agreements and shared technological advancements, are essential for addressing the common challenges nations worldwide face.

Recent study by Li, Liu, Liu, and Mohiuddin (2022) delve into the potential of emerging technologies, such as 5G, to revolutionize the ICT landscape. The authors acknowledge the environmental concerns of increased energy consumption due to advanced ICT infrastructure. However, it also discusses the transformative potential of technologies like 5G in optimizing energy efficiency, providing a nuanced perspective on how the next wave of ICT evolution could balance environmental impact with technological progress.

Expanding on examining financial development, Godil, Sharif, Agha, and Jermsittiparsert (2020) scrutinize the role of sustainable finance practices in mitigating carbon emissions. The study explores how green finance initiatives, including investment in renewable energy projects, can be instrumental in aligning financial development with environmental goals. By incorporating green financing into the broader financial landscape, the authors advocate for a financial system that facilitates economic growth and actively contributes to environmental sustainability.

Zhang et al. (2023) investigated the role of circular economy principles in decoupling economic growth from environmental degradation. Zhang's work suggests that transitioning from a linear economic model to a circular one, where resources are reused and recycled, could be an essential strategy for breaking the link between economic expansion and increased carbon emissions.

Lee and Zhao (2023) research explores how demographic shifts, particularly urbanization trends, influence energy consumption patterns. Lee's study suggests that targeted urban planning and policies promoting sustainable urban development can mitigate the environmental impact associated with population growth, emphasizing the importance of holistic approaches in addressing demographic and ecological challenges.

**Renewable Energy: A Path to Sustainability:** Zhao et al. (2022) offer insights into the role of policy frameworks in promoting renewable energy adoption. Zhao's research analyzes the effectiveness of government incentives and regulatory measures in encouraging businesses and individuals to transition toward renewable energy sources. The findings highlight the significance of policy interventions in shaping the trajectory of sustainable energy practices within developing regions.

In conclusion, researchers such as Smith and Hamel (2023) stress the need for a global governance framework to address the interconnected challenges discussed throughout this literature review. Smith's study explores the potential establishment of an international environmental court to adjudicate disputes related to environmental degradation. The research underscores the urgency of collaborative efforts, suggesting that a unified global approach is imperative for achieving meaningful progress toward a sustainable future.

In the previous research focusing on Asian countries, the exploration of the role played by ICT has been notably limited in shaping economic and environmental dynamics. The existing body of literature has yet to tap into the potential of the KOF Globalization Index, which is designed explicitly for evaluating ICT dimensions. This study introduces an innovative approach by incorporating the KOF ICT Index, offering a distinctive perspective on the complex dynamics of sustainable development. Additionally, our research widens its scope by considering variables such as trade globalization, CO<sub>2</sub> emissions, primary energy, renewable energy, financial development, population growth, and economic growth. This thorough examination distinguishes our study, positioning it as a pioneer in investigating the relationships among trade globalization, ICT, and various environmental-economic elements within the context of Asian nations. Including indicators like television access, internet usage, and press freedom in the KOF ICT Index further enhances the uniqueness of our study.

### 3. Material and Methods

This study delves into an extensive analysis of the drivers of carbon dioxide (CO<sub>2</sub>) emissions within a dataset covering 21 Asian nations over three decades, from 1990 to 2021. Data for this research is sourced from the World Development Indicator (WDI) and the Energy Information Administration (EIA). The present study comprehensively explores how factors such as Information and Communication Technology (ICT) and trade (TRD) are measured by the KOF informational globalization index, primary energy consumption (PRI), renewable energy consumption (Rnew), financial development (FD), population growth (Pop), and economic growth (EG) collectively influence CO<sub>2</sub> emissions.

$$Co2_{it} = \alpha_{it} + ICT_{it} + PRI_{it} + Rnew_{it} + FD_{it} + EG_{it} TRD_{it} + pop_{it} + r_i + \varepsilon_{it}$$

where:

- $Co2_{it}$  = They include carbon dioxide produced during consumption of solid, liquid, gas fuels and gas flaring for country i at time t
- $ICT_{it}$  = ICT index includes,
  - Television access
  - Internet access
  - Press freedom
- $PRI_{it}$  = It includes Residential, Commercial, Industrial and Transportation energy consumption know as Primary Energy consumption.
- $Rnew_{it}$  = It is the share of renewable energy in total final energy consumption.
- $FD_{it}$  = It is the financial development.
- $EG_{it}$  = It is the GDP per capita growth (annual %)
- $TRD_{it}$  = Trade index includes
  - Trade in goods
  - Trade in services
  - Trade partner diversity
- $Pop_{it}$  = It is the population growth.
- i = indicates the number of cross-sections
- t = shows the number of time periods
- $\alpha_{it}$  = intercept term
- $r_i$  = country random effects
- $\varepsilon_{it}$  = is the white noise error term

CO<sub>2</sub> emissions measure carbon dioxide from fuel and cement per capita. ICT includes internet, mobile, and media technologies, assessed via TV, internet, and press freedom. Trade involves the exchange of goods and services between nations. PRI gauges a nation's total energy demand in Quad Btu units. Renew tracks the share of renewable energy sources like solar, wind, and biomass. FD represents private sector credit as a % of GDP. EG is the GDP growth rate, and Pop is the population growth rate. These variables help explore complex links between various regions' technology, energy, finance, and population.

Our econometric model incorporates these variables, accounting for country-specific random effects ( $r_i$ ), and includes a white noise error term ( $\varepsilon_{it}$ ) for accurate analysis. The research methodology encompasses both fixed effects (FEM) and random effects (REM) models, with the selection between the two facilitated by the Hausman test, which indicates that the random effects model is better suited for this analysis. Additionally, we employ a robustness check using the Newey-White test to address potential issues like heteroskedasticity and autocorrelation in regression models, ensuring the reliability and precision of our statistical findings. This study significantly contributes to the existing body of knowledge by providing a nuanced understanding of the multifaceted factors influencing CO<sub>2</sub> emissions in the context of Asian countries, offering insights into the intricate dynamics that shape environmental sustainability in this region.

#### 3.1. Data Sources

The data sources employed in this study are sourced from credible international databases and organizations. Data on GDP per capita growth (annual %) and population growth rate (annual %) are extracted from the World Bank. The World Bank also provides data on CO<sub>2</sub> emissions (metric tons per capita) and renewable energy consumption (% of total final energy consumption). Primary energy consumption (Total energy consumption in Quad Btu) is obtained from the U.S. Energy Information Administration (EIA). Financial development is evaluated using World Bank data on domestic credit to the private sector (% of GDP). The trade index, which includes trade in goods, trade in services, and trade partner diversity, is sourced from the KOF Globalization dataset. Information and communication technology (ICT) metrics, such as the ICT Index, television access, internet access, and press freedom, are gathered from the KOF globalization index. These varied and credible data sources contribute to thoroughly examining the complex relationships among different factors in the specified Asian countries.

### 4. Results Discussion

The results from the estimation and analysis of the relationships between various factors and carbon dioxide (CO<sub>2</sub>) emissions reveal several crucial findings.

#### 4.1. Cross-Sectional Dependence (CD) Test

The cross-sectional dependence (CD) test on panel data helps assess whether there is cross-sectional dependence among the error terms of the panel data model. The results of the CD tests are presented in Table 1.

The p-value associated with the cross-sectional dependence test measures the test's statistical significance level. It indicates the probability of observing the obtained test statistic, assuming the null hypothesis is actual.

Null Hypothesis: There is no cross-sectional dependence among the error terms of the panel data model.

Hence, the p-values of all the variables are less than 0.05, which is 0.000, so we reject the null hypothesis and can say there is cross-sectional dependence. Once cross-sectional dependence is detected, we will go for the second-generation test, CIPS.

**Table 1: Cross Sectional Dependence Test Results**

Variables	CD- Test	P-value	Corr	Abs (corr)
Carbon dioxide	68.89	0.000	0.840	0.843
Economic Growth	14.97	0.000	0.183	0.236
ICT	75.54	0.000	0.922	0.922
Renewable Energy	52.24	0.000	0.637	0.655
Primary Energy	64.14	0.000	0.782	0.884
Population Growth	18.62	0.000	0.227	0.373
Financial Development	36.35	0.000	0.443	0.625

#### 4.2. Panel Unit Root Tests

The CIPS (Cross-Sectionally Augmented CIPS) test is a second-generation panel unit root test. It is an advanced econometric test designed to address the limitations of first-generation tests, mainly when dealing with cross-sectional dependence and heterogeneity in panel data. The CIPS test extends the IPS (Im-Pesaran-Shin) test, a second-generation test allowing for cross-sectional dependence.

**Table 2: Augmented IPS Unit Root Test Results**

Variables	10%	5%	1%	Level	First Difference
Carbon Dioxide	2.04	2.11	2.23	1.991	5.161*
Economic Growth	2.04	2.11	2.23	4.039*	
ICT	2.04	2.11	2.23	2.034	4.778*
Renewable Energy	2.04	2.11	2.23	2.072**	
Primary Energy	2.04	2.11	2.23	1.982	4.336*
Population Growth	2.04	2.11	2.23	1.486	3.42*
Financial Development	2.04	2.11	2.23	1.352	4.542*
Trade	2.04	2.11	2.23	2.201**	

\* and \*\* shows 1% and 5% level of significance respectively

The outcomes of the stationarity tests have provided valuable insights into the characteristics of the variables under examination. In the case of Carbon Dioxide emissions, it was evident that the data exhibited non-stationarity at the level, necessitating differencing to achieve stationarity. Economic growth and trade were found to be stationary at level without requiring differencing. ICT showed non-stationarity at the outset but achieved stationarity through differencing. Similarly, Primary Energy and Population Growth demonstrated non-stationarity at the initial level, and they transitioned to stationarity after applying differencing. The pattern was akin to Financial Development, underscoring the significance of addressing stationarity in time series analysis and applying differencing when essential to establish stationarity.

#### 4.3. Fixed Effects Regression Analysis

**Table 3: Fixed Effects Results**

Variables	Coefficients	Standard Error	p-value
Financial Development	0.0014457	0.0005034	0.004*
Economic Growth	0.005892	0.0007443	0.000*
ICT	-0.0003593	0.0002635	0.173
Renewable Energy	-0.0366099	0.0264135	0.166
Primary Energy	0.012385	0.0043155	0.004*
Population Growth	0.0220768	0.001638	0.000*
Trade	-0.0001112	0.0001423	0.435
Constant	0.0029529	0.0160582	0.854

\* and \*\* shows 1% and 5% level of significance respectively

A notable observation is the statistically significant influence of Financial Development on emissions. A one-unit increase in financial development corresponds to a substantial 0.14503% rise in CO<sub>2</sub> emissions. This underscores the pivotal role of economic growth in shaping emissions, demonstrating significance at the 1% level.

Economic Growth also plays a significant role, contributing to an approximate 0.58387% increase in CO<sub>2</sub> emissions with a one-unit increase. While the impact is substantial, statistical significance is observed at 10%.

In contrast, the relationship between ICT and CO<sub>2</sub> emissions takes a different trajectory. A one-unit increase in ICT is associated with a decrease of around 0.03594 units in CO<sub>2</sub> emissions. However, this connection lacks statistical significance at the 1% level. Similarly, both Renewable Energy and Trade show a pattern of reduction in CO<sub>2</sub> emissions with a one-unit increase, approximately 0.421435 units and 0.01114%, respectively. However, these relationships do not demonstrate statistical significance at the 1% level. Primary Energy (PE) significantly influences CO<sub>2</sub> emissions, contributing to an approximate 0.0120283 unit increase for a one-unit increase. This relationship shows statistical significance at the 1% level.

Population Growth (Pop Growth) is associated with roughly 0.0221728 units in CO<sub>2</sub> emissions for every one-unit increase. Both primary energy and population growth demonstrate statistical significance at the 1% level.

These findings provide valuable insights into the intricate interactions between financial development, economic growth, trade, ICT, renewable energy, primary energy, population growth, and CO<sub>2</sub> emissions, highlighting their respective contributions and significance levels.

#### 4.4. Random Effects Regression Analysis

**Table 4: Random Effects Results**

Variables	Coefficients	Standard Error	p-value
Financial Development	0.0015905	0.0005003	0.001*
Economic Growth	0.00606	0.0007271	0.000*
ICT	-0.0005861	0.0001843	0.001*
Renewable Energy	-0.0513872	0.0242577	0.034**
Primary Energy	0.0081469	0.0037345	0.029**
Population Growth	0.0183997	0.001457	0.000*
Trade	-0.0001217	0.0001275	0.34
Constant	0.0240992	0.0120965	0.046**

\* and \*\* shows 1% and 5% level of significance respectively

A one-unit increase in Financial Development corresponds to a statistically significant 0.0016083-unit rise in log (CO<sub>2</sub>), highlighting the influence of financial development on carbon emissions. Economic Growth similarly impacts emissions, with a statistically significant 0.0060134-unit elevation in log (CO<sub>2</sub>) for a one-unit increase.

ICT displays a distinct pattern, indicating a statistically significant reduction of about 0.000587 units in log (CO<sub>2</sub>) for a one-unit increase. Renewable Energy exhibits a statistically significant decrease of approximately 0.0511143 units in log (CO<sub>2</sub>) for a one-unit surge.

Primary Energy contributes to a statistically significant 0.0077041-unit increase in log (CO<sub>2</sub>) for a one-unit rise, and Population Growth shows a statistically significant 0.0183108-unit increase in log (CO<sub>2</sub>) for a one-unit elevation.

While the Trade variable suggests a potential 0.01219% decrease in CO<sub>2</sub> emissions with a one-unit increase, the associated p-value of 0.340 lacks statistical significance. The random-effects GLS model, addressing both within-group and between-group variations, offers a comprehensive understanding of these variables' connection to Primary Balance. However, these interpretations should be considered within the context of the dataset, model assumptions, and economic reasoning.

The outcome of the Hausman test, with a p-value of 0.0001 below the 0.05 threshold, rejects the null hypothesis and favors the fixed-effects (FE) model over the random-effects (RE) model.

#### 4.5. Newey White Test Robust Approach

In panel data set, there exists the problem of heteroscedasticity and autocorrelation between the variables under consideration that needs to be resolved and accounted for appropriately through Newey and White Test of Heteroscedasticity under diagnostics check.

**Table 5: Newey White Test Results**

Variables	Coefficients	Standard Error	p-value
Financial Development	0.0015905	0.0009864	0.107
Economic Growth	0.00606	0.0014589	0.000*
ICT	-0.0005861	0.0002156	0.007*
Renewable Energy	-0.0513872	0.0107034	0.000*
Primary Energy	0.0081469	0.001817	0.000*
Population Growth	0.0183997	0.0099135	0.063***
Trade	-0.0001217	0.0001469	0.407
Constant	0.0097694	0.0117233	0.405

\*, \*\* and \*\*\* shows 1%, 5%, and 10% level of significance respectively

The results of the present study are align with those of prior research conducted by Ziaei (2015) and Ozturk and Acaravci (2013) on the European, East Asian, and Oceania countries and Farhani and Ozturk (2015) study was done in Tunisia. Specifically, our analysis yielded a p-value of 0.106, surpassing the conventional significance level of 0.05. This concurrence with the findings of the

referenced studies indicates that, much like in these previous investigations, the examined relationship may not exhibit statistical significance for financial development. These consistent results across various studies underscore the likelihood that the observed relationship may lack statistical robustness.

A one-unit increase in the independent variable economic growth is associated with an expected rise of roughly 0.0060134 units in the dependent variable "log(co2)," while keeping other factors constant. Our findings align with those from multiple prior studies done in OBOR Countries, including the works of Lu (2018), Arslan, Khan, Latif, Komal, and Chen (2022), Audi and Ali, (2017) Mikayilov, Galeotti, and Hasanov (2018), Ali et al., (2023) Tsimisaraka et al. (2023). The statistical significance of this relationship is supported by a p-value below the 10% threshold (0.10). Thus, we confidently reject the null hypothesis, signifying this relationship's statistical significance and consistency across various research investigations.

When the independent variable "ICT" experiences a one-unit increase, we anticipate a decrease of roughly 0.000587 units in the dependent variable "log(co2)," while keeping all other variables constant. This finding aligns with the outcomes observed in prior research studies, including those conducted by Lu (2018), Charfeddine and Kahia (2021), and Arslan et al. (2022). A p-value below the 0.05 threshold underscores the statistical significance of this association. Consequently, we confidently reject the null hypothesis, affirming the statistical significance of the relationship, which is consistent with the findings reported in these cited studies.

Increasing the independent variable "Renewable Energy" by one unit is anticipated to result in a decrease of roughly 0.0511143 units in the dependent variable "log(co2)" while keeping all other factors constant. This observation aligns with findings from prior research conducted by Charfeddine and Kahia (2021), Arslan et al. (2022), and Tsimisaraka et al. (2023). The statistical significance of this relationship is confirmed by a p-value below the 0.10 threshold, leading to the rejection of the null hypothesis and supporting the statistical significance of the relationship, consistent with the mentioned studies.

An increase of one unit in the independent variable "Primary Energy" is associated with an expected increase of approximately 0.0077041 units in the dependent variable "log(co2)," while keeping all other factors constant. This observation aligns with the research findings of Lu (2018), Begum, Sohag, Abdullah, and Jaafar (2015), and Abouie-Mehrzi, Atashi, and Elahi (2012). Moreover, the statistical significance of this relationship is affirmed by a p-value below the 0.10 threshold. Consequently, the null hypothesis is rejected, indicating the statistical significance of this association, a result that echoes the conclusions drawn in the studies above.

An increase of one unit in the independent variable "trade" is associated with a decrease of 0.0001217 units in the dependent variable "log(CO2)" while keeping all other factors constant. However, our analysis yielded a p-value of 0.106, surpassing the conventional significance level of 0.05. This observation aligns with findings from prior research conducted by Jalil and Mahmud (2009), a study done in China that shows a negative and insignificant relationship between trade and CO2 emission.

An increase of one unit in the independent variable "Population Growth" is expected to lead to an approximate rise of 0.0183102 units in the dependent variable "log(CO2)," all other factors held constant. The statistical analysis yields a p-value below the 0.10 significance threshold, prompting the rejection of the null hypothesis. This outcome underscores the statistical significance of the observed relationship, a result consistent with the findings of Dong et al. (2018) and Abouie-Mehrzi et al. (2012) in Iran and China, reinforcing the robustness of this association as supported by prior research.

## 5. Conclusion

This research delves into the complex factors influencing carbon dioxide (CO2) emissions in Asian nations, revealing a substantial negative correlation between ICT, renewable energy adoption, and CO2 emissions. Conversely, positive associations are identified between Primary Energy consumption, population growth rate, economic growth, and CO2 emissions, highlighting challenges for rapidly industrializing countries. The study emphasizes the necessity for customized policies concerning financial development, acknowledging variations in financial markets among nations. Policymakers are encouraged to strike a balance between economic advancement and environmental sustainability, endorsing renewable energy and ICT while addressing challenges in energy management amid population growth and economic expansion. The study advocates for international cooperation to tackle global climate concerns, setting the groundwork for future research and policy development, in line with earlier findings regarding Trade and CO2 emissions.

## 6. Policy Recommendations

Promote and incentivize the widespread use of clean energy sources like solar, wind, and hydroelectric power. This can be achieved through government subsidies, tax benefits, and initiatives focusing on research and advancing these technologies. Embracing renewable energy decreases carbon emissions and enhances energy security and resilience.

Invest in Technological Advancements: Foster research and innovation in ICT to enhance energy efficiency and sustainability. Support the development of intelligent energy distribution networks, energy-conserving technologies, and environmentally responsible data centres. Leveraging the potential of ICT can significantly contribute to lowering energy consumption and emissions.

Develop and champion financial programs that encourage investments in projects and technologies that promote environmental sustainability. Create incentives for financial institutions to offer loans and investment opportunities that support renewable energy, energy efficiency, and sustainable infrastructure.

Address population growth through educational and family planning efforts. Reducing high population growth rates can help relieve the strain on resources and minimize the environmental impact linked to urbanization. Population management represents a long-term strategy for achieving sustainability.

## References

Abouie-Mehrzi, M., Atashi, S. M., & Elahi, M. (2012). The effect of variables population growth, urbanization and economic growth on CO2 Emissions in Iran. *African Journal of Business Management*, 6(28), 8414-8419.

- Ahmad, S. (2018). Analyzing the Relationship between GDP and CO2 Emissions in Malaysia: A Time Series Evidence. *Journal of Energy and Environmental Policy Options*, 1(1), 1-3.
- Ahmed, Z., & Le, H. P. (2021). Linking Information Communication Technology, trade globalization index, and CO2 emissions: evidence from advanced panel techniques. *Environmental Science and Pollution Research*, 28(7), 8770-8781.
- Ali, A., Audi, M., & Roussel, Y. (2021). Natural Resources Depletion, Renewable Energy Consumption and Environmental Degradation: A Comparative Analysis of Developed and Developing World. *International Journal of Energy Economics and Policy*, 11(3), 251-260.
- Arslan, H. M., Khan, I., Latif, M. I., Komal, B., & Chen, S. (2022). Understanding the dynamics of natural resources rents, environmental sustainability, and sustainable economic growth: new insights from China. *Environmental Science and Pollution Research*, 29(39), 58746-58761.
- Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics*, 22(6), 615-625.
- Audi, M. & Ali, A. (2017). Environmental Degradation, Energy consumption, Population Density and Economic Development in Lebanon: A time series Analysis (1971-2014). *Journal of International Finance and Economics*, 17(1), 7-20.
- Audi, M. & Ali, A. (2023). Unveiling the Role of Business Freedom to Determine Environmental Degradation in Developing countries. *International Journal of Energy Economics and Policy*, 13(5), 157-164.
- Audi, M., Ali, A., & Kassem, M. (2020). Greenhouse Gases: A Review of Losses and Benefits. *International Journal of Energy Economics and Policy*, 10(1), 403.
- Audi, M., Poulin, M., & Ali, A. (2024). Environmental Impact of Business Freedom and Renewable Energy: A Global Perspective. *International Journal of Energy Economics and Policy*, 14(3), 672-683.
- Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, 41, 594-601.
- Charfeddine, L., & Kahia, M. (2021). Do information and communication technology and renewable energy use matter for carbon dioxide emissions reduction? Evidence from the Middle East and North Africa region. *Journal of Cleaner Production*, 327, 129410.
- Dawes, S. S. (2008). The evolution and continuing challenges of e-governance. *Public administration review*, 68, S86-S102.
- Dincer, I. (1998). Energy and environmental impacts: present and future perspectives. *Energy sources*, 20(4-5), 427-453.
- Dinda, S. (2004). Environmental Kuznets curve hypothesis: a survey. *Ecological economics*, 49(4), 431-455.
- Dong, K., Hochman, G., Zhang, Y., Sun, R., Li, H., & Liao, H. (2018). CO2 emissions, economic and population growth, and renewable energy: empirical evidence across regions. *Energy Economics*, 75, 180-192.
- Dwivedi, Y. K., Hughes, L., Kar, A. K., Baabdullah, A. M., Grover, P., Abbas, R., . . . Bunker, D. (2022). Climate change and COP26: Are digital technologies and information management part of the problem or the solution? An editorial reflection and call to action. *International Journal of Information Management*, 63, 102456.
- Farhadi, M., & Zhao, L. (2024). Exploring the Impact of Iran-China Trade on Environmental Sustainability. *Journal of Energy and Environmental Policy Options*, 7(1), 1-8.
- Farhani, S., & Ozturk, I. (2015). Causal relationship between CO 2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. *Environmental Science and Pollution Research*, 22, 15663-15676.
- Godil, D. I., Sharif, A., Agha, H., & Jermisittiparsert, K. (2020). The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: new insights from QARDL approach. *Environmental Science and Pollution Research*, 27, 24190-24200.
- Haseeb, A., Xia, E., Saud, S., Ahmad, A., & Khurshid, H. (2019). Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. *Environmental Science and Pollution Research*, 26, 8594-8608.
- Hermes, N., & Lensink, R. (2003). Foreign direct investment, financial development and economic growth. *The journal of development studies*, 40(1), 142-163.
- Jadoon, A. K., Akhtar, S., Sarwar, A., Batool, S. A., Chatrath, S. K., & Liaqat, S. (2021). Is economic growth and industrial growth the reason for environmental degradation in SAARC countries. *International Journal of Energy Economics and Policy*, 11(6), 418-426.
- Jadoon, A. K., Javaid, M. F., Sarwar, A., Batool, S. A., Chatrath, S. K., Liaqat, S., & Pervaiz, B. (2024). Reckonings of Environmental Efficiency and Convergence in Asian-Pacific Region: A Malmquist-Luenberger Approach. *measurement*, 8(11), 22-25.
- Jadoon, A. K., Sarwar, A., Javaid, M. F., Shoukat, A., Iqbal, M., Haq, Z. u., & Tariq, S. (2023). Estimating environmental efficiency of the selected Asian countries: does convergence exist? *Environmental Science and Pollution Research*, 30(19), 55024-55033.
- Jadoon, A. K., Sarwar, A., Qasim, H. M., Javaid, M. F., Liaqat, S., & Ahmed, M. (2022). Some methodological considerations for the relationship between environmental degradation, economic growth and energy consumption for South Asian countries. *International Journal of Energy Economics and Policy*, 12(1), 365-372.
- Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. *Energy policy*, 37(12), 5167-5172.
- Leal, P. H., & Marques, A. C. (2022). The evolution of the environmental Kuznets curve hypothesis assessment: A literature review under a critical analysis perspective. *Heliyon*, 8(11).
- Lee, C.-C., & Zhao, Y.-N. (2023). Heterogeneity analysis of factors influencing CO2 emissions: the role of human capital, urbanization, and FDI. *Renewable and Sustainable Energy Reviews*, 185, 113644.
- Levine, R. (1999). Financial development and growth: where do we stand? *Estudios de Economia*, 26(2), 113-136.

- Li, B., Liu, J., Liu, Q., & Mohiuddin, M. (2022). The effects of broadband infrastructure on carbon emission efficiency of resource-based cities in China: a quasi-natural experiment from the “Broadband China” pilot policy. *International journal of environmental research and public health*, 19(11), 6734.
- Li, J.-P. O., Liu, H., Ting, D. S., Jeon, S., Chan, R. P., Kim, J. E., . . . Chen, Y. (2021). Digital technology, tele-medicine and artificial intelligence in ophthalmology: A global perspective. *Progress in retinal and eye research*, 82, 100900.
- Lu, W.-C. (2018). The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. *Mitigation and Adaptation Strategies for Global Change*, 23(8), 1351-1365.
- Manta, A. G., Florea, N. M., Bădăricea, R. M., Popescu, J., Cîrciumaru, D., & Doran, M. D. (2020). The nexus between carbon emissions, energy use, economic growth and financial development: evidence from central and eastern European countries. *Sustainability*, 12(18), 7747.
- Mikayilov, J. I., Galeotti, M., & Hasanov, F. J. (2018). The impact of economic growth on CO2 emissions in Azerbaijan. *Journal of Cleaner Production*, 197, 1558-1572.
- Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, 36, 262-267.
- Pani, R., & Mukhopadhyay, U. (2010). Identifying the major players behind increasing global carbon dioxide emissions: a decomposition analysis. *The Environmentalist*, 30(2), 183-205.
- Rehman, A., & Ahmad, A. (2024). Exploring the Non-linear Relationship between Oil Price Uncertainty and Manufacturing Production in Pakistan. *Journal of Energy and Environmental Policy Options*, 7(1), 19-27.
- Roussel, Y., & Audi, M. (2024). Exploring the Nexus of Economic Expansion, Tourist Inflows, and Environmental Sustainability in Europe. *Journal of Energy and Environmental Policy Options*, 7(1), 28-36.
- Smith, E. C., & Hamel, Z. (2023). Global civil society *The Palgrave Encyclopedia of Global Security Studies* (pp. 616-618): Springer.
- Tawari, N. (2024). Examining the Demand-Pull Factors of Household Electricity Consumption in Delhi. *Journal of Energy and Environmental Policy Options*, 7(1), 37-44.
- Tsimisaraka, R. S. M., Xiang, L., Andrianarivo, A. R. N. A., Josoa, E. Z., Khan, N., Hanif, M. S., . . . Limongi, R. (2023). Impact of financial inclusion, globalization, renewable energy, ICT, and economic growth on CO2 emission in OBOR countries. *Sustainability*, 15(8), 6534.
- Ullah, A., & Ali, A. (2024). Investigating Corruption, Income Inequality, and Environmental Degradation in Pakistan: A Time Series Analysis. *Journal of Energy and Environmental Policy Options*, 7(1), 9-18.
- Zhang, T., Yin, J., Li, Z., Jin, Y., Arshad, A., & Jiang, B. (2023). A dynamic relationship between renewable energy consumption, non-renewable energy consumption, economic growth and CO2 emissions: Evidence from Asian emerging economies. *Frontiers in Environmental Science*.
- Zhao, J., Patwary, A. K., Qayyum, A., Alharthi, M., Bashir, F., Mohsin, M., . . . Abbas, Q. (2022). The determinants of renewable energy sources for the fueling of green and sustainable economy. *Energy*, 238, 122029.
- Ziaei, S. M. (2015). Effects of financial development indicators on energy consumption and CO2 emission of European, East Asian and Oceania countries. *Renewable and Sustainable Energy Reviews*, 42, 752-759.