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Governance, Renewable Energy, and Urbanization: Drivers of Environmental Outcomes in Asia

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Abstract

Environmental damage has become a pressing concern for researchers and policymakers worldwide, receiving significant attention in global discussions. Among the various contributors to environmental degradation, the emission of greenhouse gases, particularly carbon dioxide, stands out as a primary driver. CO_2 emissions arise predominantly from the burning of fossil fuels for energy, industrial processes, and deforestation, making them a central focus in efforts to combat climate change. The accumulation of GHGs in the atmosphere intensifies the greenhouse effect, leading to global warming, rising sea levels, and disruptions in weather patterns. This research examines the impact of corruption on carbon emissions in six ASEAN countries, incorporating indicators such as economic growth, renewable energy usage, and urbanization. Economic growth, while crucial for development, often leads to increased energy consumption and industrial activities, resulting in higher carbon emissions. Conversely, renewable energy adoption can mitigate these emissions by replacing fossil fuels with cleaner energy sources. Urbanization, a common feature of ASEAN countries, presents a dual challenge: while it drives economic development, it also increases energy demand and emissions, especially in the absence of sustainable urban planning. By analyzing the interplay between these factors, the research aims to provide insights into the role of governance in shaping environmental outcomes. The findings are expected to guide policymakers in designing strategies to reduce carbon emissions, enhance renewable energy adoption, and address the challenges posed by corruption in achieving sustainable development goals. The research findings reveal the presence of an Environmental Kuznets Curve in the studied ASEAN countries, characterized by an inverted U-shaped relationship between economic growth and carbon emissions. This suggests that at lower levels of economic development, emissions increase with growth, but beyond a certain income threshold, emissions begin to decline as economies adopt cleaner technologies and stronger environmental policies. The analysis shows that renewable energy has a significant negative impact on carbon emissions, highlighting its critical role in mitigating environmental degradation. Conversely, urbanization positively influences emissions, indicating that unplanned urban growth leads to increased energy consumption and pollution. Promoting sustained and inclusive economic growth while prioritizing investments in renewable energy is vital to reducing emissions. Urbanization must be managed with sustainable urban planning and infrastructure to minimize its environmental footprint.

Keywords: Carbon Emissions, Corruption, Renewable Energy, Urbanization

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1. INTRODUCTION

Environmental damage has been a critical topic of concern among researchers for decades and has emerged as a central focus in global discussions on sustainability (Nuță et al., 2024; Audi, 2024; Rafiq et al., 2023; Kakar et al., 2024). A particularly alarming type of environmental damage stems from the emission of greenhouse gases, including carbon dioxide, methane, and nitrous oxide (Senturk, 2023; Yılmaz & Şahin, 2023; Zhang et al., 2023; Ahmad et al., 2024; Audi et al., 2024; Mubiinzi et al., 2024; Voumik et al., 2023; Rahman & Sultana, 2024). These gases significantly contribute to the greenhouse effect, intensifying global warming and climate change. CO_2 emissions primarily result from the burning of fossil fuels for energy and transportation, as well as deforestation and industrial activities. Methane, a more potent GHG in terms of its warming potential, is released during agricultural activities, livestock rearing, and the decomposition of organic waste in landfills. Nitrous oxide, often associated with agricultural practices involving synthetic fertilizers, adds another layer of complexity to the issue. The rising concentration of these GHGs in the atmosphere has far-reaching consequences, including extreme weather events, rising sea levels, biodiversity loss, and disruptions to ecosystems. Addressing these emissions requires coordinated global efforts, including the adoption of renewable energy, the development of sustainable agricultural practices, and the enforcement of stringent environmental regulations. The growing focus on these issues highlights the urgency of transitioning to a low-carbon, sustainable future to mitigate environmental damage and protect the planet for future generations (Mahmood, 2019; Nathaniel et al., 2020; Zaheer & Nasir, 2020; Bakht, 2020; Habibullah, 2020; Abbasi et al., 2020; Huang et al., 2022; Islam et al., 2022; Hussain & Khan, 2022; Chien et al., 2022; Liddle, 2022; Ali et al., 2022; Patiño

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et al., 2020; Rossi, 2023; Kibritcioglu, 2023; Iqbal & Noor, 2023). Cohen et al. (2018) highlight that the growing volume of gas emissions has emerged as a significant global challenge in recent years. The escalation in greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide, has intensified environmental degradation and exacerbated the effects of climate change. This surge is largely attributed to industrialization, deforestation, agricultural practices, and the reliance on fossil fuels for energy (Ali & Audi, 2016; Shahbaz et al., 2016; Audi & Ali, 2017; Gorus & Groeneveld, 2018; Audi & Ali, 2018; Khan & Hassan, 2019; Desiree, 2019; Emodi, 2019). The study underscores the urgent need for effective mitigation strategies to address this pressing issue. It emphasizes the importance of transitioning to renewable energy sources, implementing energy-efficient technologies, and adopting sustainable practices in agriculture and industry. Furthermore, the research advocates for robust international cooperation and policy frameworks to curb emissions and achieve long-term environmental sustainability. Cohen et al.'s findings serve as a critical reminder of the consequences of unchecked emissions and the necessity of collective action to mitigate their impact.

Dong et al. (2018) highlighted a dramatic rise in global carbon dioxide (CO_2) emissions over the past 25 years, illustrating the escalating environmental challenges associated with industrial and economic growth. According to their study, global CO_2 emissions increased from 21,571.7 million metric tons in 1990 to 33,472.0 million metric tons in 2014, marking a staggering 55.1% rise within a relatively short timeframe of 25 years. This sharp increase underscores the growing reliance on fossil fuels for energy, transportation, and industrial processes during this period, particularly in rapidly developing economies. The data serves as a critical indicator of the urgent need for effective global climate policies and a transition toward renewable energy sources. The findings emphasize the necessity of coordinated international efforts to address this trend and mitigate the environmental consequences of rising greenhouse gas emissions. According to a report by British Petroleum (2017), carbon dioxide (CO_2) emissions have been rising at an average rate of approximately 1.8% per year. This continuous increase has significantly contributed to abnormal climate changes, including a notable rise in global temperatures, increased forest fires, severe flooding, and widespread damage to ecosystems (Keshavarzian & Tabatabaienasab, 2022). Climate change is a global crisis that transcends national borders, affecting all nations and individuals alike. The impacts of climate change are increasingly evident and experienced worldwide, as emphasized by Nathaniel and Khan (2020). The consequences of climate change extend beyond immediate effects, posing long-term challenges to ecosystems, economies, and human well-being. Addressing these complex and multifaceted environmental problems requires urgent and collaborative action at local, national, and international levels. Ignoring or underestimating the gravity of climate change could exacerbate its impacts, making it imperative to prioritize sustainable practices and policies to mitigate its effects and secure a stable future for generations to come.

The relationship between economic growth and environmental damage is a topic of ongoing debate among policymakers (Gorus & Groeneveld, 2018; Audi & Ali, 2018; Khan & Hassan, 2019; Desiree, 2019; Emodi, 2019; Mahmood, 2019; Nathaniel et al., 2020; Zaheer & Nasir, 2020; Bakht, 2020; Habibullah, 2020; Abbasi et al., 2020; Huang et al., 2022; Islam et al., 2022; Hussain & Khan, 2022; Chien et al., 2022; Liddle, 2022; Ali et al., 2022; Patiño et al., 2020; Rossi, 2023). As highlighted by Puntoon et al. (2022), economic expansion and its negative impact on the environment are often seen as interconnected, with growth frequently being accompanied by increased resource consumption and pollution. This creates a challenging dilemma for nations seeking to balance economic development with environmental preservation. Efforts to mitigate environmental damage, such as adopting sustainable practices or transitioning to cleaner energy sources, can sometimes slow economic growth in the short term, as they often require significant investments and structural adjustments. Consequently, many countries tend to prioritize immediate economic welfare over environmental concerns, leading to trade-offs that sacrifice ecological sustainability for developmental goals. This tension underscores the need for innovative strategies and policies that promote sustainable development, enabling countries to achieve economic growth while minimizing environmental degradation. Emphasizing green technologies, energy efficiency, and sustainable resource management can help reconcile this trade-off, offering pathways for long-term economic prosperity and environmental health.

The reliance on fossil fuels continues to grow, particularly in developing countries, where their affordability and accessibility make them a preferred energy source. However, this dependence poses significant environmental concerns, as fossil fuels are a major contributor to greenhouse gas emissions. These emissions exacerbate climate change and environmental degradation, highlighting the urgent need to transition to cleaner energy alternatives. Promoting the use of renewable energy sources such as wind energy, geothermal energy, and nuclear energy is critical to mitigating emissions and fostering sustainable development. These alternatives offer significant environmental benefits by reducing carbon footprints and minimizing reliance on non-renewable resources. Despite their potential, the adoption of these technologies remains limited, primarily due to their high upfront costs and infrastructure requirements (Karim et al., 2022; Ahmad et al., 2024; Audi et al., 2024; Mubiinzi et al., 2024; Voumik et al., 2023; Rahman & Sultana, 2024; Nuţă et al., 2024). Addressing these barriers requires substantial investment in research, innovation, and financial incentives to make renewable energy technologies more affordable and accessible. Furthermore, fostering international cooperation and policy frameworks can accelerate the global transition to cleaner energy systems, ensuring a more sustainable and environmentally friendly energy future.

Environmental damage is influenced not only by economic factors but also by demographic changes, with urbanization being a key contributor. In developing countries, urbanization is on the rise as people migrate to cities in search of improved living conditions and access to essential amenities such as electricity, food, transportation, and education (Akalin et al., 2021). This influx of people into urban areas often leads to increased energy consumption, waste generation, and resource demand, placing significant pressure on local ecosystems. The rapid expansion

of urban centers can result in deforestation, loss of biodiversity, and heightened greenhouse gas emissions due to transportation and industrial activities. Additionally, unplanned urban growth can exacerbate air and water pollution, creating challenges for sustainable urban development. Addressing these issues requires comprehensive urban planning, the adoption of green technologies, and policies that encourage resource efficiency. Efforts to mitigate the environmental impact of urbanization should focus on promoting sustainable urban infrastructure, improving public transportation, and integrating renewable energy solutions. By balancing the needs of growing urban populations with environmental sustainability, countries can work towards mitigating the ecological consequences of urbanization while enhancing the quality of life for their citizens. Corruption, a pervasive issue in social and political systems, has often been underexplored in previous research. As a dangerous phenomenon, it poses significant challenges globally and has garnered widespread concern. Corruption is prevalent in both developed and developing countries (Avis et al., 2018 Ahmad et al., 2024; Audi et al., 2024; Mubiinzi et al., 2024; Voumik et al., 2023; Rahman & Sultana, 2024; Nuţă et al., 2024). However, its impact is more pronounced in the latter due to weaker and less efficient governmental institutions. Developing nations often struggle with limited regulatory capacity, inadequate enforcement mechanisms, and a lack of transparency, which make them particularly vulnerable to corruption (López & Mitra, 2000). The consequences of corruption are far-reaching, undermining economic growth, distorting resource allocation, and eroding public trust in institutions. Its presence hampers development efforts and disproportionately affects marginalized populations by exacerbating inequality and diverting resources away from essential public services.

Addressing corruption requires a multifaceted approach, including strengthening institutional frameworks, enhancing transparency and accountability, and fostering a culture of integrity through education and awareness. Collaborative efforts between governments, international organizations, and civil society are essential to combating corruption effectively and ensuring sustainable development. Corruption, a pervasive issue in social and political systems, has often been underexplored in previous research. As a dangerous phenomenon, it poses significant challenges globally and has garnered widespread concern. Corruption is prevalent in both developed and developing countries (Avis et al., 2018); however, its impact is more pronounced in the latter due to weaker and less efficient governmental institutions. Developing nations often struggle with limited regulatory capacity, inadequate enforcement mechanisms, and a lack of transparency, which make them particularly vulnerable to corruption (López & Mitra, 2000). The consequences of corruption are far-reaching, undermining economic growth, distorting resource allocation, and eroding public trust in institutions. Its presence hampers development efforts and disproportionately affects marginalized populations by exacerbating inequality and diverting resources away from essential public services. Addressing corruption requires a multifaceted approach, including strengthening institutional frameworks, enhancing transparency and accountability, and fostering a culture of integrity through education and awareness. Collaborative efforts between governments, international organizations, and civil society are essential to combating corruption effectively and ensuring sustainable development.

Environmental damage has become a compelling subject of study for researchers, as it directly impacts the long-term survival of humanity. The more extensive the environmental degradation, the greater the risks posed to human health, safety, and overall well-being in the future. While much attention has been devoted to factors such as economic growth and energy consumption, one critical yet underexplored driver of environmental damage is corruption. Corruption undermines the enforcement of environmental regulations, allowing exploitative practices such as illegal logging, unregulated industrial activities, and overexploitation of natural resources to persist. It also diverts funds intended for environmental conservation and sustainable development into private hands, further aggravating ecological degradation. In many cases, corruption distorts policy priorities, favoring short-term economic gains over long-term environmental sustainability. Given its profound influence, addressing corruption is crucial to mitigating environmental damage. This requires strengthening institutional accountability, promoting transparency in governance, and ensuring the strict enforcement of environmental laws. By integrating anti-corruption measures into environmental policies, governments and organizations can create a more robust framework for protecting ecosystems and securing a sustainable future for humanity.

2. LITERATURE REVIEW

Economic growth is widely recognized as a primary driver of carbon emissions, particularly in developing countries with low and middle-income status, where the pursuit of high economic growth often comes at the cost of increased carbon emissions (Li et al., 2023). The relationship between economic growth and carbon dioxide emissions is frequently examined within the framework of the Environmental Kuznets Curve (EKC), a concept popularized by Dinda (2004). The EKC suggests two possible trajectories of the relationship between economic growth and environmental degradation. The first trajectory is the inverted U-shaped curve, where environmental degradation initially increases with economic growth but decreases after reaching a certain income threshold, as economies adopt cleaner technologies and stronger environmental regulations. Empirical support for this pattern has been provided by studies such as Liu et al. (2021), Muhammad and Long (2021), Ren et al. (2021), and Karim et al. (2022). The second trajectory is the U-shaped curve, where pollution levels decrease during early stages of economic development but rise again in later stages as growth accelerates and resource consumption intensifies. This pattern has been confirmed by research conducted by Sekrafi and Sghaier (2018), Arminen and Menegaki (2019), Ahmad et al. (2021), and Lv and Gao (2021).

These contrasting findings reflect the complexity of the relationship between economic growth and environmental quality, influenced by factors such as policy frameworks, energy sources, technological advancements, and the stage of economic development. Understanding these dynamics is critical for developing tailored strategies that balance economic growth with

environmental sustainability, particularly for developing countries striving to mitigate the adverse impacts of carbon emissions. Energy plays a fundamental role in driving economic activities, but reliance on non-environmentally friendly energy sources leads to significant carbon dioxide (CO_2) pollution, contributing to climate change and environmental degradation. This underscores the critical need for alternative energy solutions, such as renewable energy, to address these challenges sustainably. Renewable energy sources, including solar, wind, and hydroelectric power, offer a viable path to reducing carbon emissions while meeting growing energy demands. Empirical evidence consistently highlights the environmental benefits of renewable energy. For instance, Yang et al. (2022) demonstrated that increased investment in renewable energy significantly mitigates pollution in 13 countries that prioritize this sector. Their findings reinforce the idea that transitioning to renewable energy not only helps reduce CO_2 emissions but also fosters long-term environmental sustainability. Promoting renewable energy requires concerted efforts, including policy incentives, financial support for green technology, and international cooperation to enhance accessibility and affordability. By investing in renewable energy infrastructure and innovation, countries can achieve a dual objective of economic growth and environmental protection, paving the way for a more sustainable future.

Similarly, Li et al. (2023) conducted a comprehensive study involving 130 countries and found that renewable energy significantly reduces carbon emissions, with the effect being particularly pronounced in low and middle-income countries. These nations, often heavily reliant on fossil fuels for economic development, stand to benefit greatly from adopting renewable energy technologies, both in terms of reducing their carbon footprints and achieving sustainable growth. The study highlights the transformative potential of renewable energy in mitigating environmental damage, especially in regions where energy demand is rapidly increasing. By transitioning to cleaner energy sources, low and middle-income countries can address pressing pollution concerns while fostering economic resilience and energy independence. The findings emphasize the importance of targeted investments and policy support to make renewable energy accessible and scalable in these economies, contributing to global efforts to combat climate change.

Moreover, Bozatli and Akca (2023) explored the relationship between renewable energy and carbon emissions in OECD countries, finding that renewable energy, along with carbon taxes, plays a pivotal role in reducing emissions. Their study highlights the importance of combining policy instruments, such as taxation, with investments in renewable energy to achieve substantial environmental improvements. Similarly, Zhu et al. (2023) analyzed 51 developing and developed countries and reached similar conclusions, emphasizing the dual role of renewable energy and regulatory measures in mitigating carbon emissions across diverse economic contexts. In the case of E-7 countries, Saqib et al. (2022) employed advanced econometric techniques, including the Augmented Mean Group (AMG) and Cross-Sectionally Augmented ARDL (CS-ARDL) methods, to investigate the impact of renewable energy. Their findings reveal that renewable energy consumption has both short- and long-term effects on reducing carbon emissions, highlighting its sustained impact on environmental quality. Voumik et al. (2023) provided country-specific evidence from Kenya, showing that renewable energy consumption had a significant negative effect on carbon emissions, further underscoring its efficacy in lowering pollution levels. Additionally, Liu et al. (2021) focused on China and found that renewable energy consumption effectively reduces carbon intensity, reinforcing the argument for its widespread adoption. These studies collectively underscore the critical role of renewable energy in addressing carbon emissions globally, while also highlighting the need for tailored approaches and complementary policies to maximize its environmental benefits across different regions and income levels.

Numerous studies have investigated the relationship between urbanization and carbon dioxide (CO_2) emissions, yielding varying results across different regions and contexts. Lv and Gao (2021) demonstrated that urbanization has a positive impact on carbon emissions in China, attributing this to increased energy consumption, industrialization, and transportation demands in urban areas. Similarly, Sinha et al. (2019), using the Generalized Method of Moments (GMM), examined N-11 and BRICS countries and concluded that urbanization significantly contributes to higher carbon emissions in these rapidly developing economies. Akhbari and Nejati (2019) employed Fixed Effects Model (FEM) estimates to analyze the effects of urbanization on pollution across both developed and developing countries. Their findings indicated that urban population growth substantially drives pollution levels, largely due to higher energy demands and waste generation in urban centers. Conversely, other studies have reported divergent results. For instance, Arminen and Menegaki (2019) and Akalin et al. (2021) found no significant relationship between urbanization and carbon emissions, suggesting that the environmental impact of urbanization may depend on factors such as urban planning, energy efficiency, and infrastructure development. These contrasting findings highlight the complexity of the urbanization-emissions nexus, emphasizing the need for region-specific analyses and policies. While urbanization often leads to increased emissions, sustainable urban development practices, including improved public transportation, energy-efficient buildings, and green spaces, can mitigate its environmental impact.

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3. METHODOLOGY

Moreover, Bozatli and Akca (2023) explored the relationship between renewable energy and carbon emissions in OECD countries, finding that renewable energy, along with carbon taxes, plays a pivotal role in reducing emissions. Their study highlights the importance of combining policy instruments, such as taxation, with investments in renewable energy to achieve substantial environmental improvements. Similarly, Zhu et al. (2023) analyzed 51 developing and developed countries and reached similar conclusions, emphasizing the dual role of renewable energy and regulatory measures in mitigating carbon emissions across diverse economic contexts. In the case of E-7 countries, Saqib et al. (2022) employed advanced econometric techniques, including the Augmented Mean Group (AMG) and Cross-Sectionally Augmented ARDL (CS-ARDL) methods, to investigate the impact of renewable energy. Their findings reveal that renewable energy consumption has both short- and long-term effects on reducing carbon emissions, highlighting its sustained impact on environmental quality. Voumik et al. (2023) provided country-specific evidence from Kenya, showing that renewable energy consumption had a significant negative effect on carbon emissions, further underscoring its efficacy in lowering pollution levels. Additionally, Liu et al. (2021) focused on China and found that renewable energy consumption effectively reduces carbon intensity, reinforcing the argument for its widespread adoption. These studies collectively underscore the critical role of renewable energy in addressing carbon emissions globally, while also highlighting the need for tailored approaches and complementary policies to maximize its environmental benefits across different regions and income levels.

$$CO_{2it} = f\,(GDP_{it}, GDP^2_{it}, REN_{it}, URB_{it}, CC_{it})$$

Where *i* is region, *t* is year, CO_2 is carbon dioxide emissions, *GDP* is economic growth, *GDPSQ* is quadratic economic growth, *REN* is renewable energy consumption, *URB* is urban population, *CC* is corruption control. The data of selected variables have been taken from the World Bank.

We have utilized a traditional panel approach called a static panel. This approach involves three models: The Common Effect Model, FEM, and Random Effect Model (Kurniadi et al., 2021). The best model was selected after testing these three models using the Chow test, Hausman test, and Lagrange Multiplier (LM) test.

4. RESULTS AND DISCUSSIONS

This table 1 summarizes the descriptive statistics for the variables used in the analysis, providing insights into their distribution, variability, and normality. The statistics include the mean, maximum, minimum, standard deviation, and the Jarque-Bera (JB) test for normality, with significance levels denoted by one, two, and three asterisks for 10%, 5%, and 1% levels respectively. The CO2 variable, measuring carbon dioxide emissions, has a mean value of 11.170, with a range from 6.659 to 13.337. The standard deviation of 1.178 indicates moderate variability around the mean. The Jarque-Bera test statistic of 46.479 is highly significant, suggesting that the distribution of CO2 emissions is not normal. The GDP variable, representing gross domestic product, has a mean of 8.492, with values ranging from 6.681 to 11.024. Its standard deviation of 1.158 reflects similar variability to CO2. The Jarque-Bera test statistic of 17.287 is also significant, indicating a departure from normality in the GDP distribution. The RENEW variable, which measures renewable energy, has a mean of 27.360 and exhibits substantial variability, with values ranging from 0.330 to 86.548 and a standard deviation of 23.757. The Jarque-Bera test statistic of 14.170 is significant, confirming non-normality in the distribution of renewable energy data.

The URBAN variable, reflecting urbanization, has a mean value of 16.583 and ranges from 13.713 to 18.836, with a standard deviation of 1.409. The Jarque-Bera test statistic of 8.098 is significant at the 5% level, suggesting some deviation from

normality. The COC variable, representing control of corruption, has a mean value of −0.048, with values spanning from −1.331 to 2.301. The standard deviation of 1.067 indicates moderate dispersion. The Jarque-Bera test statistic of 37.618 is highly significant, indicating a non-normal distribution for this variable. Overall, the descriptive statistics reveal substantial variability across the variables, with all showing significant departures from normality based on the Jarque-Bera test. These findings highlight the importance of considering non-normality and potential transformations in further statistical analyses to ensure robust results.

Table 1: Descriptive Statistics

Variables	Mean	Max	Min	SD	JB
CO_2	11.170	13.337	6.659	1.178	46.479***
GDP	8.492	11.024	6.681	1.158	17.287***
RENEW	27.360	86.548	0.330	23.757	14.170***
URBAN	16.583	18.836	13.713	1.409	8.098**
COC	−0.048	2.301	−1.331	1.067	37.618***

This table 2 presents the results of the best model testing, including the Chow test, Hausman test, and LM test. The Chow test produces a Chi-square statistic of 210.64 with a p-value of 0.000, indicating a strong rejection of the null hypothesis and suggesting that the pooled model is not appropriate. This result highlights the need for a more complex model, such as fixed or random effects, to account for differences across cross-sectional units. The Hausman test yields a Chi-square statistic of 174.227 with a p-value of 0.000, also rejecting the null hypothesis. This result favors the fixed effects model over the random effects model, as it implies that individual effects are correlated with the explanatory variables, making the fixed effects model more suitable for the analysis. No results are available for the LM test, which is typically used to evaluate the suitability of a random effects model compared to a pooled model. Its absence may suggest that it was either not conducted or not necessary, given the clear preference for fixed effects based on the Hausman test. These findings collectively point to the fixed effects model as the most appropriate choice, ensuring that unobserved heterogeneity is accounted for and that the results are robust.

Table 2: Best model testing

Testing	Chi-square stat	P-value
Chow	210.64***	0.000
Hausman	174.227***	0.000
LM	–	–

This table 3 presents the fixed effects model estimates, including coefficients, standard errors, t-values, and p-values for the variables in the analysis. The results provide insights into the relationships between the dependent variable and the explanatory variables. The constant term has a coefficient of −5.145 with a t-value of −4.196 and a p-value of 0.000, indicating a statistically significant negative baseline effect when all explanatory variables are held constant. GDP has a positive and significant effect, with a coefficient of 2.030, a t-value of 5.944, and a p-value of 0.000. This suggests that GDP positively influences the dependent variable in the fixed effects model. GDP squared shows a negative and significant relationship, with a coefficient of −0.091, a t-value of −6.034, and a p-value of 0.000. This indicates a nonlinear relationship, where the positive effect of GDP diminishes as GDP increases, consistent with an inverted-U shape.

The renewable energy variable has a significant negative effect, with a coefficient of −0.027, a t-value of −8.438, and a p-value of 0.000. This suggests that increased reliance on renewable energy sources is associated with a decrease in the dependent variable. Urbanization exhibits a positive and significant effect, with a coefficient of 0.410, a t-value of 3.278, and a p-value of 0.001, implying that urbanization positively impacts the dependent variable. The control of corruption variable has a negative and significant effect, with a coefficient of −0.135, a t-value of −2.014, and a p-value of 0.046. This suggests that better control of corruption is associated with a reduction in the dependent variable. Overall, these results highlight the significance of GDP, its squared term, renewable energy, urbanization, and control of corruption in explaining the variation in the dependent variable. The negative quadratic term for GDP suggests a nonlinear effect, while the results for renewable energy and control of corruption underline the importance of environmental and institutional factors in shaping the outcomes.

Table 3: FEM model estimates

Variables	Coefficients	S.Error	T-value	P-value
C	−5.145	1.290	−4.196	0.000
GDP	2.030	0.341	5.944	0.000
GDP^2	−0.091	0.015	−6.034	0.000
RENEW	−0.027	0.003	−8.438	0.000
URBAN	0.410	0.125	3.278	0.001
COC	−0.135	0.067	−2.014	0.046

The study highlights the significant role of corruption control in reducing carbon dioxide emissions. The corruption control variable, with a coefficient of −0.135-0.135−0.135 and a P-value of 0.0170.0170.017, demonstrates that a one-unit improvement in corruption control leads to a 0.135%0.135\%0.135% reduction in carbon emissions. This finding aligns with the results of several previous studies, including those by Shinra et al. (2019), Khan and Rana (2021), Muhammad and Long (2021), Lv and Gao (2021), Liu et al. (2021), Liu and Dong (2021), and Karim et al. (2022). These studies collectively emphasize the effectiveness of enhanced governance and institutional reforms in mitigating environmental damage. However, the results differ from those of Akalin et al. (2021), Arminen and Menegaki (2019), and Leal and Marques (2021), which found no significant relationship between corruption control and carbon emissions. These contrasting findings may be attributed to differences in methodological approaches, regional contexts, or the time periods analyzed. The evidence from this study underscores the importance of addressing corruption as a means of achieving environmental sustainability. Strengthening governance systems and implementing robust anti-corruption measures can play a crucial role in reducing carbon emissions, particularly in regions where corruption undermines environmental regulations and sustainable practices.

5. CONCLUSIONS

The primary aim of this study is to investigate the relationship between corruption control and environmental damage, with a focus on carbon dioxide emissions. The analysis also incorporates other influential factors, including economic growth, renewable energy consumption, and urbanization, to provide a comprehensive understanding of their combined effects on environmental outcomes. Using panel data and employing the fixed effects model estimation technique, the study selected the best model based on the results of Chow and Hausman tests. The fixed effects model estimates reveal nuanced findings. Economic growth exhibits a positive impact on environmental damage during the initial stages of development, suggesting increased carbon dioxide emissions as economies expand. However, as growth progresses, the quadratic term indicates a decline in emissions, supporting the Environmental Kuznets Curve hypothesis, where economic growth eventually contributes to environmental improvement. The results further show that renewable energy consumption plays a significant role in reducing carbon dioxide emissions, emphasizing its importance as a sustainable energy source. Conversely, urbanization is associated with increased emissions, reflecting the challenges posed by higher energy demands, transportation needs, and industrial activities in urban areas. Crucially, the study finds that corruption control effectively reduces carbon dioxide emissions. This underscores the importance of governance and institutional quality in addressing environmental challenges. By improving corruption control, governments can enhance regulatory enforcement, promote sustainable practices, and mitigate environmental damage. These findings provide valuable insights for policymakers, suggesting that targeted efforts in renewable energy promotion, urban planning, and anti-corruption measures can collectively advance environmental sustainability. Governments must implement optimal strategies to boost economic growth while ensuring environmental sustainability.

High economic growth provides opportunities for improving living standards and advancing technological development. However, this growth must be achieved in a manner that minimizes environmental damage. ASEAN countries, in particular, need to prioritize the transition from fossil fuels to renewable energy sources. Fossil fuels are a primary contributor to carbon emissions and environmental degradation, making the adoption of cleaner, environmentally friendly energy alternatives essential for sustainable development. Urbanization is another critical issue that requires attention to curb rising carbon emissions. The migration of populations to urban areas in pursuit of better job opportunities, improved amenities, and access to essential services increases energy consumption and environmental stress. Addressing urbanization challenges through sustainable urban planning, energy-efficient infrastructure, and green transportation systems can mitigate its environmental impact. By integrating renewable energy into their energy mix, implementing policies that promote sustainable urban development, and fostering economic growth that aligns with environmental objectives, ASEAN countries can effectively balance development and ecological conservation. These measures will ensure a healthier, more sustainable future for the region. To reduce the adverse environmental impacts of urbanization, governments should focus on creating more job opportunities in rural areas and ensuring the availability of essential utilities in both urban and rural regions. This can help to alleviate the pressure on cities by offering viable alternatives for people to live and work in rural areas, thus reducing the migration to urban centers. Providing infrastructure such as reliable energy, clean water, and access to healthcare and education in rural areas can improve the quality of life and contribute to more balanced regional development. Corruption is another significant challenge that has a detrimental effect on the environment and economic stability. It undermines the effectiveness of government policies, diverts public resources, and leads to inefficient management of environmental and economic resources. Therefore, it is essential for governments to implement and strictly enforce anti-corruption measures. Failure to address corruption results in wasted resources, hinders sustainable development, and exacerbates inequality. Furthermore, corruption can lead to poor governance, lack of accountability, and lower education standards, all of which have long-term negative consequences for both the economy and the environment. By focusing on reducing urbanization pressures, promoting rural development, and tackling corruption, governments can foster a more sustainable and equitable path to economic growth, environmental protection, and social well-being. These efforts will not only mitigate environmental damage but also enhance the overall quality of life for citizens, promoting long-term prosperity.

REFERENCES

Abbasi, M. A., Parveen, S., Khan, S., & Kamal, M. A. (2020). Urbanization and energy consumption effects on carbon dioxide emissions: evidence from Asian-8 countries using panel data analysis. *Environmental Science and Pollution Research*, *27*(15), 18029-18043.

Ahmad, M., Ali, S., & Khan, U. U. (2024). Empowering Asia's Sustainable Future: Unraveling Renewable Energy Dynamics with Trade, Carbon Emission, Governance, and Innovative Interactions. *Renewable Energy*, 120716.

Ahmad, M., Işık, C., Jabeen, G., Ali, T., Ozturk, I., & Atchike, D.W. (2021). Heterogeneous links among urban concentration, non-renewable energy use intensity, economic development, and environmental emissions across regional development levels. *Science of the Total Environment, 765*, 144527.

Akalin, G., Erdogan, S., & Sarkodie, S.A. (2021). Do dependence on fossil fuels and corruption spur ecological footprint? *Environmental Impact Assessment Review, 90*, 106641.

Akhbari, R., & Nejati, M. (2019). The effect of corruption on carbon emissions in developed and developing countries: Empirical investigation of a claim. *Heliyon, 5*(9), e02516.

Ali, A., & Audi, M. (2016). The Impact of Income Inequality, Environmental Degradation and Globalization on Life Expectancy in Pakistan: An Empirical Analysis. *International Journal of Economics and Empirical Research (IJEER)*, *4*(4), 182-193.

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.

Ali, A., Audi, M., Bibi, C., & Roussel, Y. (2021). The Impact of Gender Inequality and Environmental Degradation on Human Well-being in the Case of Pakistan: A Time Series Analysis. *International Journal of Economics and Financial Issues*, *11*(2), 92-99.

Ali, A., Audi, M., Senturk, I., & Roussel, Y. (2022). Do sectoral growth promote CO2 emissions in Pakistan?: time series analysis in presence of structural break. *International Journal of Energy Economics and Policy*, *12*(2), 410-425.

Ali, A., Sumaira, S., Siddique, H. M. A., & Ashiq, S. (2023). *Impact of Economic Growth, Energy Consumption and Urbanization on Carbon Dioxide Emissions in the Kingdom of Saudi Arabia*. University Library of Munich, Germany.

Arminen, H., & Menegaki, A.N. (2019). Corruption, climate and the energy-environment-growth nexus. *Energy Economics, 80*, 621-634.

Audi, M. (2024). The Role of Urbanization and Trade in Driving Carbon Emissions in Asia. *Journal of Energy and Environmental Policy Options*, *7*(3), 23-34.

Audi, M., & Ali, A. (2017). *Environmental Degradation, Energy consumption, Population Density and Economic Development in Lebanon: A time series Analysis (1971-2014)*. University Library of Munich, Germany.

Audi, M., & Ali, A. (2018). *Determinants of Environmental Degradation under the Perspective of Globalization: A Panel Analysis of Selected MENA Nations*. University Library of Munich, Germany.

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., 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.

Avis, E., Ferraz, C., & Finan, F. (2018). Do government audits reduce corruption? Estimating the impacts of exposing corrupt politicians. *Journal of Political Economy, 126*(5), 1912-1964.

Bakht, Z. (2020). The Nexus between Economic Growth, Energy Consumption, and Environmental Pollution in Bangladesh. *Journal of Energy and Environmental Policy Options*, *3*(1), 1-8.

Bozatli, O., & Akca, H. (2023). The effects of environmental taxes, renewable energy consumption and environmental technology on the ecological footprint: Evidence from advanced panel data analysis. *Journal of Environmental Management, 345*, 118857.

British Petroleum (BP). (2017). *BP Energy Outlook 2017 Edition.*

Chien, F., Hsu, C. C., Ozturk, I., Sharif, A., & Sadiq, M. (2022). The role of renewable energy and urbanization towards greenhouse gas emission in top Asian countries: Evidence from advance panel estimations. *Renewable Energy*, *186*, 207-216.

Cohen, G., Jalles, J.T., Loungani, P., & Marto, R. (2018). The long-run decoupling of emissions and output: Evidence from the largest emitters. *Energy Policy, 118*, 58-68.

Desiree, B. (2019). Dynamic Analysis of Energy Consumption and Environmental Impact on GDP in Sub-Saharan Africa. *Journal of Energy and Environmental Policy Options*, *2*(1), 18-26.

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.

Emodi, S. A. (2019). Analyzing the Nexus between Energy Consumption, CO2 Emissions, and Economic Growth in Nigeria. *Journal of Energy and Environmental Policy Options*, *2*(3), 84-94.

Gorus, S., & Groeneveld, R. (2018). Vietnam's Development Trajectory: Threshold Cointegration and Causality Analysis of Energy Consumption and Economic Growth. *Journal of Energy and Environmental Policy Options*, *1*(2), 28-35.

Habibullah, M. (2020). Understanding Energy Consumption Dynamics in Malaysia: An Empirical Analysis. *Journal of Energy and Environmental Policy Options*, *3*(1), 9-19.

Huang, Y., Ahmad, M., & Ali, S. (2022). The impact of trade, environmental degradation and governance on renewable energy consumption: Evidence from selected ASEAN countries. *Renewable energy*, *197*, 1144-1150.

Hussain, M., & Khan, A. R. (2022). The Impact of Economic Growth, Energy Consumption, and Trade Openness on Carbon Emissions in Pakistan. *Journal of Energy and Environmental Policy Options*, *5*(3), 1-6.

Iqbal, Z., & Noor, M. (2023). The Impact of Energy Consumption on Economic Growth in Selected Emerging Economies. *Journal of Energy and Environmental Policy Options*, *6*(2), 29-35.

Islam, M. M., Irfan, M., Shahbaz, M., & Vo, X. V. (2022). Renewable and non-renewable energy consumption in Bangladesh: The relative influencing profiles of economic factors, urbanization, physical infrastructure and institutional quality. *Renewable Energy*, *184*, 1130-1149.

Kakar, A., Khan, A., & Khan, A. (2024). Analyzing the role of governance, ICT, and urbanization on environment in South Asian countries. *Journal of the Knowledge Economy*, *15*(1), 2682-2703.

Karim, S., Appiah, M., Naeem, M.A., Lucey, B.M., & Li, M. (2022). Modelling the role of institutional quality on carbon emissions in Sub-Saharan African countries. *Renewable Energy*, *198*, 213-221.

Keshavarzian, M., & Tabatabaienasab, Z. (2022). The effects of electricity consumption on CO2 emissions in Iran. *Technology and Economics of Smart Grids and Sustainable Energy*, *7*(1), 1-8.

Khan, M. N., & Hassan, T. (2019). Balancing Economic Growth and Environmental Sustainability through Energy Consumption in Pakistan. *Journal of Energy and Environmental Policy Options*, *2*(4), 109-116.

Khan, M., & Rana, A.T. (2021). Institutional quality and CO2 emission-output relations: The case of Asian countries. *Journal of Environmental Management*, *279*, 111569.

Kibritcioglu, A. (2023). Financial Development and Energy Consumption Dynamics in Turkey. *Journal of Energy and Environmental Policy Options*, *6*(2), 1-8.

Kurniadi, A.P., Aimon, H., & Amar, S. (2021). Determinants of biofuels production and consumption, green economic growth and environmental degradation in six Asia Pacific countries: A simultaneous panel model approach. *International Journal of Energy Economics and Policy*, *11*(5), 460-471.

Leal, P.H., & Marques, A.C. (2021). The environmental impacts of globalisation and corruption: Evidence from a set of African countries. *Environmental Science and Policy*, *115*, 116-124.

Lei, L., Ozturk, I., Murshed, M., Abrorov, S., Alvarado, R., & Mahmood, H. (2023). Environmental innovations, energy innovations, governance, and environmental sustainability: Evidence from South and Southeast Asian countries. *Resources Policy*, *82*, 103556.

López, R., & Mitra, S. (2000). Corruption, pollution, and the Kuznets environment curve. *Journal of Environmental Economics and Management*, *40*(2), 137-150.

Lv, Z., & Gao, Z. (2021). The effect of corruption on environmental performance: Does spatial dependence play a role? *Economic Systems*, *45*(2), 100773.

Mahmood, H. (2019). Exploring the Dynamics Nexus of Energy Consumption, Economic Growth, Capital Stock, and Labor Force. *Journal of Energy and Environmental Policy Options*, *2*(3), 78-83.

Muhammad, S., & Long, X. (2021). Rule of law and CO2 emissions: A comparative analysis across 65 belt and road initiative (BRI) countries. *Journal of Cleaner Production*, *279*, 123539.

Nathaniel, S., & Khan, S. A. R. (2020). The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries. *Journal of cleaner production*, *272*, 122709.

Nathaniel, S., & Khan, S.A.R. (2020). The nexus between urbanization, renewable energy, trade, and ecological footprint in ASEAN countries. *Journal of Cleaner Production*, *272*, 122709.

Nathaniel, S., Nwodo, O., Sharma, G., & Shah, M. (2020). Renewable energy, urbanization, and ecological footprint linkage in CIVETS. *Environmental Science and Pollution Research*, *27*, 19616-19629.

Nuţă, F. M., Sharafat, A., Abban, O. J., Khan, I., Irfan, M., Nuţă, A. C., ... & Asghar, M. (2024). The relationship among urbanization, economic growth, renewable energy consumption, and environmental degradation: A comparative view of European and Asian emerging economies. *Gondwana Research*, *128*, 325-339.

Puntoon, W., Tarkhamtham, P., & Tansuchat, R. (2022). The impacts of economic growth, industrial production, and energy consumption on CO2 emissions: A case study of leading CO2 emitting countries. *Energy Reports*, *8*, 414-419.

Rafiq, M. A., Rauf, A., Shakir, S., Abbas, A. M. A., Sun, H., & Abid, S. (2023). Exploring the Intertwined Nexus between Globalization, Energy Usage, Economic Complexity, and Environmental Quality in Emerging Asian Economies: A Pathway Towards a Greener Future. *Environmental Science and Pollution Research*, *30*(45), 100431-100449.

Rahman, M. M., & Sultana, N. (2024). Nexus of Human Development and Environmental Quality in Low-Income and developing countries: do renewable energy and good Governance Matter? *Sustainability*, *16*(13), 5382.

Rossi, S. (2023). Exploring the Relationship between Economic Growth, Energy Consumption, Trade Openness, and Carbon Dioxide Emissions: A Case Study of Italy. *Journal of Energy and Environmental Policy Options*, *6*(3), 19-24.

Saqib, N., Usman, M., Radulescu, M., Sinisi, C.I., Secara, C.G., & Tolea, C. (2022). Revisiting EKC hypothesis in context of renewable energy, human development and moderating role of technological innovations in E-7 countries. *Frontiers in Environmental Science*, *10*, 1077658.

Sekrafi, H., & Sghaier, A. (2018). The effect of corruption on carbon dioxide emissions and energy consumption in Tunisia. *PSU Research Review*, *2*(1), 81-95.

Senturk, I. (2023). The Impact of Financial Development and Energy Prices on Turkey's Energy Consumption. *Journal of Energy and Environmental Policy Options*, *6*(1), 24-29.

Shahbaz, M., Ozturk, I., & Ali, A. (2016). Does financial development lower environmental quality in Saudi Arabia? Fresh evidence from linear and non-linear specifications. *International Journal of Economics and Empirical Research (IJEER)*, *4*(7), 376-392.

Sinha, A., Gupta, M., Shahbaz, M., & Sengupta, T. (2019). Impact of corruption in public sector on environmental quality: Implications for sustainability in BRICS and next 11 countries. *Journal of Cleaner Production*, *232*, 1379-1393.

Voumik, L. C., Mimi, M. B., & Raihan, A. (2023). Nexus between urbanization, industrialization, natural resources rent, and anthropogenic carbon emissions in South Asia: CS-ARDL approach. *Anthropocene Science*, *2*(1), 48-61.

Voumik, L.C., Ridwan, M., Rahman, H., & Raihan, A. (2023). An investigation into the primary causes of carbon dioxide releases in Kenya: Does renewable energy matter to reduce carbon emission? *Renewable Energy Focus*, *2023*, 100491.

Yang, Z., Zhang, M., Liu, L., & Zhou, D. (2022). Can renewable energy investment reduce carbon dioxide emissions? Evidence from scale and structure. *Energy Economics*, *112*, 106181.

Zaheer, A., & Nasir, W. (2020). Exploring the Relationship Between Economic Freedom and Energy Consumption in Pakistan. *Journal of Energy and Environmental Policy Options*, *3*(2), 56-64.

Zhang, L., Khan, Z., Abbas, S., & Ahamed, H. (2023). The roles of renewable energy, globalization, population expansion and deliberative democracy on Sustainable Development in South Asia. *Environmental Science and Pollution Research*, *30*(38), 88775-88788.

Zhu, Y., Taylor, D., & Wang, Z. (2023). The role of environmental taxes on carbon emissions in countries aiming for net-zero carbon emissions: Does renewable energy consumption matter? *Renewable Energy*, *218*, 119239.