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Nexus of Population, Energy Consumption, and Environmental Pollution: The Case of Cambodia

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Abstract

This paper investigates the intricate relationship between Cambodia's population dynamics, energy consumption patterns, and carbon dioxide emissions. The paper uses the ARDL and fixed and random panel data methods. The data was collected at the Word Bank from 2000 to 2022. The paper draws upon a comprehensive analysis of demographic trends, energy landscapes, and historical emission data. The study explores the interconnections and impacts of these factors. The paper scrutinizes government policies and initiatives to manage this nexus, evaluating their efficacy and addressing challenges. The research aims to provide insights into sustainable strategies applicable to Cambodia by examining international case studies and best practices. Ultimately, the findings contribute to the discourse on fostering a harmonious balance between population growth, energy sustainability, and carbon emissions reduction for Cambodia's socio-economic and environmental well-being.

Keywords: *carbon dioxide emissions, energy consumption, environmental pollution, population.*

1. Introduction

In an era marked by unprecedented global population growth and the escalating challenges posed by climate change, the intricate interplay between demographic dynamics, energy consumption patterns, and carbon dioxide emissions has emerged as a focal point of scholarly inquiry. This study delves into this complex nexus with a particular focus on the Kingdom of Cambodia, a nation undergoing transformative changes in population, energy demand, and environmental impact (Adebayo, Pata, & Akadiri, 2022; Adebayo & Samour, 2023; Aftab et al., 2021).

Cambodia, situated in Southeast Asia, exhibits a distinctive socio-economic landscape shaped by historical events, rapid urbanization, and evolving energy needs. As the population burgeons and urbanizes, there is a corresponding surge in energy consumption, primarily fueled by industrialization and increased urban lifestyles. This issue, in turn, raises concerns about escalating carbon dioxide emissions and their ramifications for the nation's environment and sustainability (Aghasafari, Aminizadeh, Karbasi, & Calisti, 2021; Al Afif, Ayed, & Maaitah, 2023; Alvarez-Herranz, Balsalobre-Lorente, Shahbaz, & Cantos, 2017; Alvarez et al., 2022).

Against this backdrop, our research aims to unravel the multifaceted connections between Cambodia's population dynamics, energy consumption patterns, and carbon emissions.

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By scrutinizing historical trends, government policies, and international best practices, we seek to offer a nuanced understanding of the challenges and opportunities entwined within this nexus. Furthermore, the study endeavors to contribute actionable insights that may inform sustainable development strategies for Cambodia and, potentially, other nations facing similar socio-environmental complexities (An et al., 2023; Andersen et al., 2010; Balsalobre-Lorente, Contente dos Santos Parente, Leitão, & Cantos-Cantos, 2023).

As we embark on this exploration, it is our aspiration that the findings presented herein will not only enrich the academic discourse but also provide pragmatic guidance for policymakers and stakeholders committed to steering Cambodia towards a resilient and sustainable future (Balsalobre-Lorente, Ibáñez-Luzón, Usman, & Shahbaz, 2022; Balsalobre-Lorente, Nur, Topaloglu, & Evcimen, 2023; Balsalobre-Lorente, Shahbaz, Murshed, & Nuta, 2023; Balsalobre-Lorente, Shahbaz, Roubaud, & Farhani, 2018).

This study contains 06 sections: Section 1- introduction; Section 2- literature reviews; Section 3- methodologies; Section 4- results and discussions; Section 5- conclusion; and Section 6- limitations and future study.

2. Literature reviews:

As the global community grapples with the complexities of sustainable development, a growing body of literature has emerged to explore the intricate relationships between population dynamics, energy consumption, and carbon dioxide (CO2) emissions. Understanding these interconnections is essential for formulating effective solutions and strategies to improve rapid population growth and climate change challenges. This section reviews key themes and findings in the existing literature, focusing on both global perspectives and specific insights relevant to Cambodia (Banerjee, 2022; Bassey Enya, James, & Friday Bassey, 2022; Borg, Kits, Junttila, & Uddin, 2022).

Global Perspectives- scholars such as (Bui Minh & Bui Van, 2023; Can, Balsalobre-Lorente, Adedoyin, & Mercan, 2023; Can, Dogan, & Saboori, 2020; Cao, Yan, & Tang, 2022; C. Chen, Pinar, & Stengos, 2022) have conducted comprehensive reviews of global trends, emphasizing the direct correlation between population size and energy demand. Their work underscores the importance of considering demographic factors in designing sustainable energy policies. Additionally, (Y. Chen, 2022; Chu, Doğan, Abakah, Ghosh, & Albeni, 2023; Chu, Doğan, Dung, Ghosh, & Alnafrah, 2023; Dai, Ahmed, Sinha, Pata, & Alvarado, 2023; W. Dai et al., 2023; Doğan, Balsalobre-Lorente, & Nasir, 2020) explores the role of population growth in exacerbating carbon emissions, providing a foundation for understanding the broader implications of demographic changes on climate change.

Developing Country Contexts- studies specific to developing countries, including (Doğan, Chu, Ghosh, Diep Truong, & Balsalobre-Lorente, 2022; Doğan, Driha, Balsalobre Lorente, & Shahzad, 2021; Doğan, Ghosh, Hoang, & Chu, 2022; Dogan, Madaleno, Tiwari, & Hammoudeh, 2020; Doğan, Rao, Ferraz, Sharma, & Shahzadi, 2023; Doğan, Shahbaz, Bashir, Abbas, & Ghosh, 2023; Esmaeili, Balsalobre Lorente, & Anwar, 2023; Feng, Xiao, Zhou, & Ni, 2023), shed light on the unique challenges faced by nations undergoing rapid urbanization and industrialization. These works emphasize the need for tailored solutions considering socio-economic contexts, highlighting the significance of a localized approach to address population-related energy demands and associated carbon emissions.

Insights from Southeast Asia- transitioning to a regional focus, research by (Sahoo & Goswami, 2024; Samour, Adebayo, Agyekum, Khan, & Kamel, 2023; Saqib & Usman, 2023; Sarwar, Shahzad, Chang, & Tang, 2019; Shahbaz, Balsalobre-Lorente, & Sinha, 2019; Shahzad, 2020; Shahzad, Fareed, Shahzad, & Shahzad, 2021) and (Fernandes & Ferrão, 2023; Ganesan, Kor, Pattinson, & Rondeau, 2020; Ghasemi, Rajabi, & Aghakhani, 2023; Ghosh, Adebayo, Abbas, Doğan, & Sarkodie, 2023; Giang, Trung,

Yoshida, Xuan, & Que, 2019; Han, Zhe, & Liu, 2023) provides valuable insights into the dynamics of population, energy, and emissions in Southeast Asia. While these studies offer a broader regional perspective, they set the stage for examining the Cambodian case, recognizing the specificities that differentiate Cambodia from its neighbors.

Research Gaps and Relevance to Cambodia- despite the wealth of literature addressing the nexus globally and within similar regional contexts, there still needs to be a noticeable gap in understanding Cambodia's specific challenges and opportunities. This research seeks to bridge this gap by conducting a nuanced analysis of Cambodia's population dynamics, energy consumption patterns, and carbon emissions, thereby contributing to the growing reviews of knowledge that orms sustainable development strategies tailored to the Cambodian context (Hoa, Xuan, & Phuong Thu, 2023; Jahanger et al., 2023; Johnathon, Agalgaonkar, Planiden, & Kennedy, 2023; Joo, Shawl, & Makina, 2022; Kartal, Pata, Kılıç Depren, & Depren, 2023).

In synthesizing these insights, our literature review lays the groundwork for a focused investigation into the nexus of population, energy consumption, and carbon dioxide emissions in Cambodia (Kartal, Samour, Adebayo, & Kılıç Depren, 2023; Keh, Tan, Tang, Sim, & Lee, 2023; H. Khan, Weili, Bibi, Sumaira, & Khan, 2022; M. K. Khan, Khan, & Rehan, 2020; M. K. Khan, Teng, & Khan, 2019).

3. Methodologies:

Research Design- adopts a mixed-methods approach to comprehensively explore the interconnections between population dynamics, energy consumption, and carbon dioxide emissions in Cambodia (M. K. Khan, Teng, Khan, & Khan, 2019; Kocoglu, Jahanger, Awan, Barak, & Balsalobre-Lorente, 2023; Lan, Li, & Wang, 2022; Le, Nguyen, & Phan, 2022; Leitão, 2021).

Utilize quantitative methods for data analysis, including statistical modeling of demographic trends, energy consumption patterns, and emissions data (Leitão, Dos Santos Parente, Balsalobre-Lorente, & Cantos Cantos, 2023; Leitão, Koengkan, & Fuinhas, 2022; D. Li & Ge, 2023; S. Li, Samour, Irfan, & Ali, 2023; Lu, Zhao, & Lin, 2023).

Employ qualitative methods like interviews and content analysis to capture nuanced insights into government policies, public perceptions, and stakeholder perspectives.

Data Collection- Demographic Data: Gather historical population data from reputable sources, including national statistics, census reports, and demographic surveys.

Analyze population growth rates, urbanization trends, and distribution patterns.

Energy Consumption Data: Acquire data on energy consumption from diverse sources, including government energy reports, utility records, and industry data.

Categorize energy consumption by sector (industrial, residential, commercial) and energy sources (fossil fuels, renewable energy).

Carbon Dioxide Emissions Data: Collect historical CO2 emissions data from official reports, environmental agencies, and international databases. Identify primary sources of emissions, considering sectors like transportation, industry, and deforestation (Martí-Ballester, 2022; Melane-Lavado & Álvarez-Herranz, 2020; Nguyen Thi Ngoc, 2016; Nguyen & Nguyen, 2021; Overland, Juraev, & Vakulchuk, 2022; Pata, Erdogan, & Ozkan, 2023).

Figure 1 presents the diagram of the paper as follows:

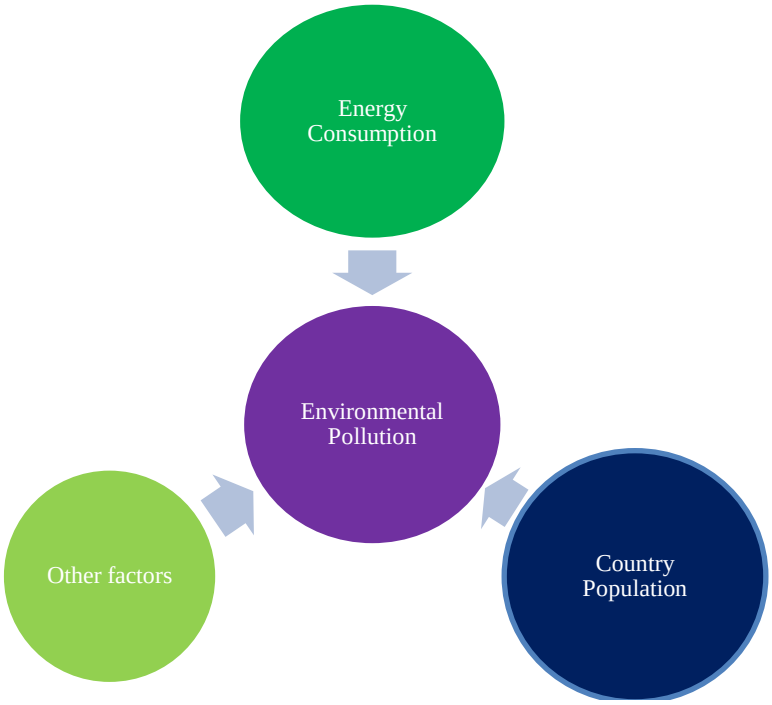

Figure 1. Nexus of energy consumption, country population regarding environmental pollution

(Source: Compiled by authors)

The authors assume that the functions of environmental pollution as equation (1), such as:

$$EP = A\,EC^{a}POP^{b} + e_{i,t} \quad (1)$$

Alternatively, the study can be logarithm on both sides as equation (2):

$$Ln(EP_{i,t}) = A + aLn(EC_{i,t}) + bLn(POP_{i,t}) + e_{i,t} \quad (2)$$

To test this function to forecast the change in environmental pollution (EP), the authors calculated the elasticity of EP to energy consumption (EC) as equation (3):

$$E_{EC} = EP'_{EC}\,EC/EP = Aa\,EC^{a-1}POP^{b}EC/\,AEC^{a}POP^{b} \quad (3)$$

Hence, $E_{EC} = a$

To test this function to forecast the change in environmental pollution (EP), the authors calculated the elasticity of EP to POP as equation (4):

$$E_{POP} = EP'_{POP}\,POP/EP = AbEC^{a}POP^{b-1}POP/\,AEC^{a}POP^{b} \quad (4)$$

Hence, $E_{POP} = b$

The author uses regression analysis, the study can see in the equation (5), such as

$$Ln(EP_{i,t}) = A + aLn(EC_{i,t}) + bLn(POP_{i,t}) + e_{i,t} \quad (5)$$

The study model used the detailed function in the following section.

The function EP = function (EC, POP,…) was used, in which the dependent and independent variables were the following:

EP: the dependent variable of environmental pollution or carbon dioxide emissions (CO2), which is measured by million tons;

EC: the independent variable is Cambodia's energy consumption per capita, measured by KWh.

POP: the independent variable is the country population, estimated by persons.

Data will be sourced from the General Statistics Office of Cambodia, the World Bank, and other reputable sources. Initial summary statistics and correlations will be presented. Data visualization techniques like heat maps and scatter plots will be employed.

The manuscript has the hypothesis in the research as follows:

H_1: Energy consumption positively affects environmental pollution.

H_2: Population positively affects environmental pollution.

The independent variable is presented in Table 1 as follows:

Table 1. The independent and dependent variables used in the paper

Variable	Concept	Relationship
EC	Energy consumption	+
POP	Country population	+

(Sources: compiled by author)

The definition and symbol +/- in Table 1 mean that energy consumption positively affects environmental pollution, and population positively affects environmental pollution.

Table 2 presents the independent variables and dependent variables in the model.

Table 2. The variables related to the dependent variables of the regression model

Variables	Observation	Mean	Standard Deviation	Minimum	Maximum
Year	23	2011	6.7	2000	2022
CO2 million tons	23	7.72087	6.269822	1.975	22.679
Energy consumption (Khw per capita)	23	216.2333	201.3661	38.78258	588.5499
Country population (millions person)	23	14.54783	1.478285	12.12	17.2

(Source: compiled by authors)

This paper uses the VECM- Vector Error Correction Model to analyze short- and long-term dynamics. The VECM approach is chosen for its capacity to handle non-stationary

time series data that may be integrated. It differentiates between short-term deviations from equilibrium and long-term equilibrium relationships. Granger causality tests are applied post-VECM to establish the direction of causality between variables. Granger causality tests to determine directional relationships among variables. We categorized data based on the World Bank and General Statistics Office indicators from 2000 to 2022, such as the following:

Cambodia's energy consumption from Cambodia's Office of Statistics is kWh per capita.

Cambodia's population from Cambodia's Office of Statistics and the World Bank is a person.

There were 23 observations compiled as data that were collected in Cambodia in the period from 2000 to 2022.

The dependent variable EP was environmental pollution or carbon dioxide emissions, with a mean of 7.72087 million tons, a lowest value of 1.975 million tons in 2000, and a highest weight of 22.679 million tons in 2022.

Figure 2 presents the environmental pollution or carbon dioxide emissions- CO2 for the period 2000 to 2022 as follows:

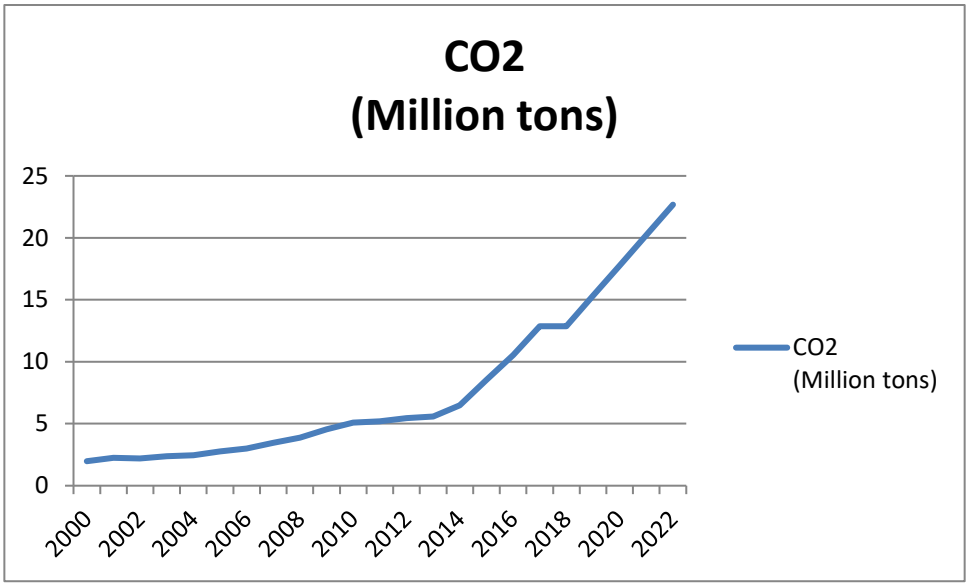

Figure 2. The environmental pollution in Cambodia from 2000 to 2022

(Source: Compiled by authors)

The Independent variable EC was the energy consumption of Cambodia, with a mean of 216 kWh per capita, a lowest of 38.78 kWh in 2000, and a highest of 588.55 kWh per capita in 2022. Figure 3 presents the energy consumption for Cambodia from 2000 to 2022 as follows:

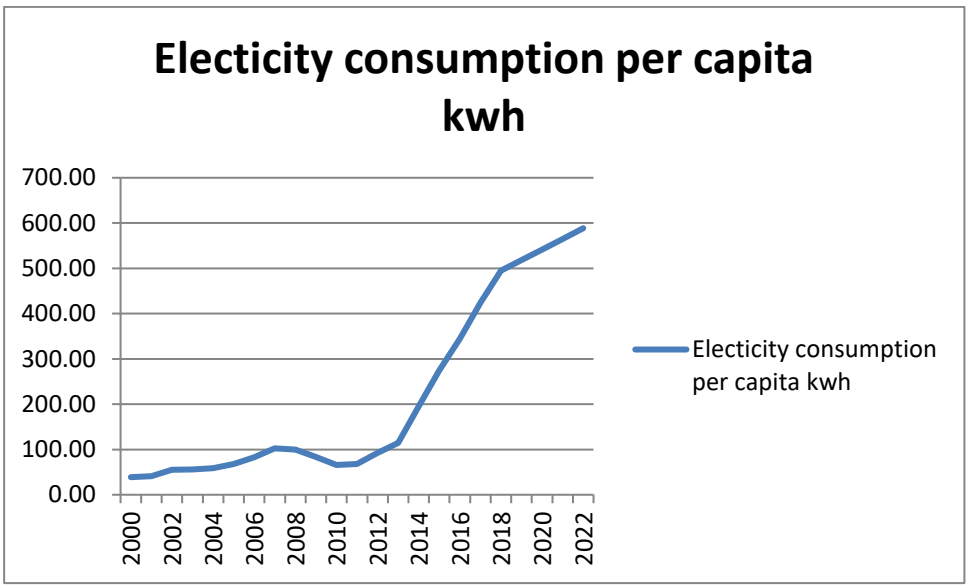

Figure 3. The energy consumption in Cambodia from 2000 to 2022

(Source: Compiled by authors)

The Independent variable POP was the population of Cambodia, with a mean of 14.55 million persons, a lowest of 12.12 million persons in 2000, and a highest of 17.2 million persons in 2022.

Figure 4 presents the population in Cambodia from 2000 to 2022 as follows:

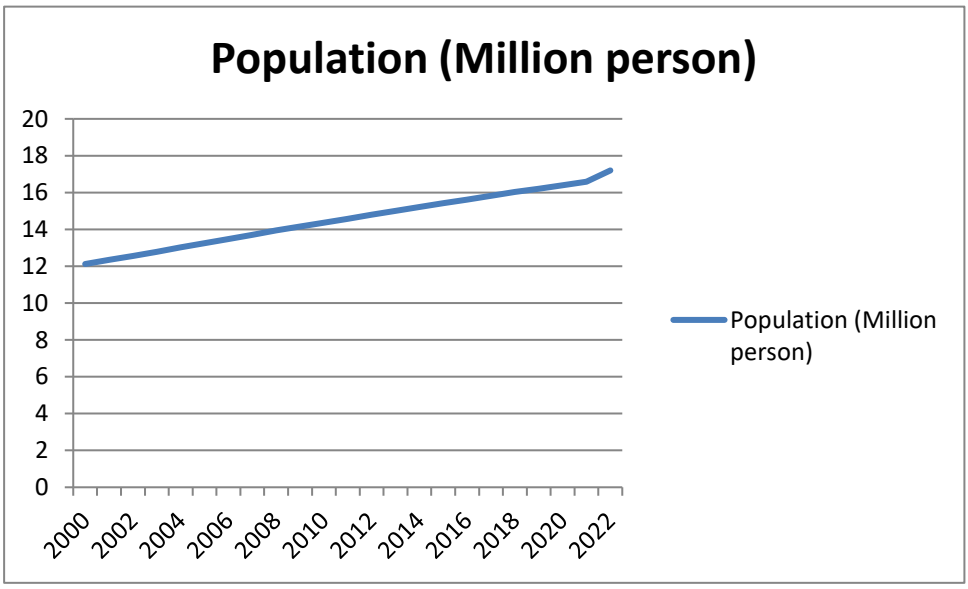

Figure 4. The people in Cambodia from 2000 to 2022

(Source: Compiled by authors)

4. Results and Discussions

4.1. Results

Table 3. The regression analysis model uses fixed and random panel data methods of energy consumption (EC), country population (POP), and environmental pollution (EP) for the period from 2000 to 2022 in Cambodia.

Source	SS	Df	MS	Number of obs	= 23	
Model	13.1191099	2	6.55955497	Prob > F	= 0.0000	
Residual	0.31788949	20	0.015894475	R-squared	= 0.9763	
				Adj R-squared	= 0.9740	
Total	13.4369994	22	0.610772702	Root MSE	= 0.12607	
Ln Environmental pollution	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]	
Ln energy consumption	0.3066732***	0.077936	3.93	0.001	0.1441015	0.4692448
Ln Country population	4.809577***	0.725353	6.63	0.0000	3.296517	6.322636
_Cons	-12.62191***	1.585747	-7.96	0.0000	-15.92972	-9.314096

*** represent 1% significance, respectively

(Source: computed by Stata 16.0 software)

Table 3 displays the regression analysis results of energy consumption (EC), country population (POP), and environmental pollution (EP) for the period from 2000 to 2022 in Cambodia. According to the adjusted R-squared value of 0.9740, environmental pollution can be explained by 97.40% of the independent variable change.

The nexus of energy consumption and environmental pollution is demonstrated by the P-value of 0.001. Hence, hypothesis 1 is accepted. The elasticity of environmental pollution to energy consumption is 0.3. According to these findings, environmental pollution will rise by 0.3% if Cambodia's energy consumption increases by 1%. The empirical results show that Cambodia’s energy consumption significantly affects environmental pollution. The greater the energy consumption, the worse the environmental pollution. It means Cambodian citizens consume more non-energy, such as coal and fossil fuels, which destroys the environment.

Table 3 also displays the regression analysis results for environmental pollution (EP) and population in Cambodia (POP). The relationship between population and environmental pollution is shown by the P-value of 0.000. Hence, the hypothesis 2 is accepted. The elasticity of environmental pollution to the population is 4.8. The empirical results show a positive nexus between population and environmental pollution. If the population is up by

1%, environmental pollution is up by 4.8%. It means Cambodian citizens significantly help to promote environmental pollution.

The empirical results show a significantly positive nexus of Cambodia's population and carbon dioxide emissions or environmental pollution. The results of this paper show that environmental pollution has dramatically affected Cambodia's population. Nowadays, Cambodian citizens should care about significant sustainable development, and everybody should care about decreasing environmental pollution.

Based on the regression above, the articles have the function in equation (6) as follows:

$$\text{Ln EP} = -12.62 + 0.30 \text{ Ln EC} + 4.80 \text{ Ln POP} \quad (6)$$

Equation (6) shows that if EC=0 and POP=0, the environmental pollution in Cambodia is -12.62 million tons. This equation also shows the slope of EP to EC= 0.30, the slope of EP to POP= 4.80;

These results help to compute the elasticity. Hence, the results show that if Cambodia's energy consumption is up by 1%, then the environmental pollution is up by 0.30%; if the population is up by 1%, then the environmental pollution is up by 4.80%;

Table 4 illustrates the correlation coefficients for the independent variables within the model. The observed correlation coefficients between these variables are minimal, and the variance inflation factor (VIF) remains below 5 for all variables. This low VIF signifies an absence of multicollinearity within the model.

Table 4. The correlation of the independence variables in the model

	Energy consumption	Country Population
Energy consumption	1	
Country Population	1.2	1

(Sources: compiled by author)

Policy Documents and Stakeholder Perspectives: Review relevant government policies, energy plans, and environmental regulations addressing the nexus.

Conduct interviews with policymakers, experts, and representatives from non-governmental organizations to gain qualitative insights.

Data Analysis- employs statistical tools to analyze demographic trends, energy consumption patterns, and carbon emissions over time.

Use regression analysis to identify correlations between population growth, energy use, and emissions.

Apply qualitative analysis techniques like thematic coding to extract key themes from interviews and policy documents.

Case Study Approach- selects specific regions or cities within Cambodia for in-depth case studies to capture regional variations in population dynamics, energy profiles, and emissions. Compare and contrast findings to better understand localized challenges and opportunities.

Ethical Considerations- ensure the confidentiality and anonymity of interview participants.

Obtain necessary ethical approvals for research involving human subjects and adhere to established ethical guidelines throughout the study.

By integrating quantitative and qualitative methods, this research aims to provide a comprehensive and nuanced analysis of the nexus of population, energy consumption, and carbon dioxide emissions in Cambodia. The triangulation of data sources and methodologies enhances the robustness of the study's findings and contributes valuable insights for informed policy recommendations.

4.2. Discussions:

Population Dynamics and Energy Consumption- interpret the observed correlations between population growth and energy demand in Cambodia, considering how demographic trends contribute to increased energy needs.

Compare findings with global and regional patterns discussed in the literature review, highlighting similarities and differences.

Carbon Dioxide Emissions and Environmental Impacts- analyze the identified sources of carbon dioxide emissions in Cambodia, emphasizing their environmental repercussions.

Discuss the implications of emissions on climate change and local ecosystems, drawing connections to international climate commitments.

Policy Effectiveness and Challenges- evaluate the impact of existing government policies on population management, energy sustainability, and emissions reduction in Cambodia.

Address any discrepancies between policy intentions and practical outcomes, identifying potential challenges and areas for improvement.

Socio-Economic Consequences- examine the socio-economic consequences of the nexus, exploring how population-related energy demands and emissions influence communities, livelihoods, and income distribution.

Consider the potential disparities in the distribution of benefits and burdens across different demographic groups.

Comparative Analysis with International Best Practices- compares the Cambodian case with successful international strategies outlined in the literature review.

Discuss the feasibility of implementing similar approaches in Cambodia, considering cultural, economic, and institutional differences.

Recommendations for Sustainable Development- Based on the study's findings, propose targeted recommendations for policymakers. Emphasize the importance of integrated strategies that balance population management, energy efficiency, and emissions reduction.

Limitations and Future Research Directions- acknowledge the study's limitations, such as data constraints or methodological considerations. The paper suggests avenues for future research to address gaps in understanding and refine strategies for sustainable development.

Conclusion- summarizes vital insights from the discussion, emphasizing the broader implications for Cambodia's sustainable development.

Reinforce the significance of a holistic approach to managing the nexus of population, energy consumption, and carbon dioxide emissions.

This section aims to contribute actionable insights for policymakers and stakeholders invested in fostering sustainable development in Cambodia by synthesizing research findings with existing knowledge in a comprehensive discussion.

5. Conclusion:

In conclusion, this study delves into the intricate nexus of Cambodia's population dynamics, energy consumption, and carbon dioxide emissions, offering valuable insights into the challenges and opportunities inherent in the nation's sustainable development journey.

Our analysis reveals a pronounced correlation between population growth and increased energy demand, particularly in the context of rapid urbanization and industrialization. The ensuing surge in carbon dioxide emissions poses substantial environmental challenges, necessitating a nuanced and integrated approach to balance socio-economic development with environmental sustainability.

Existing government policies aimed at addressing this nexus demonstrate varying degrees of effectiveness. While some initiatives align with global best practices, discrepancies between policy intentions and on-the-ground outcomes persist. Policymakers must revisit and refine existing strategies, considering the unique socio-economic landscape of Cambodia.

The socio-economic consequences of this nexus are significant, affecting communities, livelihoods, and income distribution. Vulnerable demographic groups may disproportionately bear increased energy costs and environmental degradation burdens. As such, any future policy interventions must prioritize equity and social inclusivity.

Drawing on international best practices, we recommend a multifaceted approach encompassing population management, enhanced energy efficiency, and targeted emissions reduction strategies. Collaboration between governmental bodies, non-governmental organizations, and the private sector is crucial for successfully implementing such measures.

While this study provides valuable insights, it has limitations. Data constraints and the dynamic nature of socio-economic factors present challenges that merit further investigation. Future research endeavors should address these limitations and explore emerging trends, ensuring the continued relevance of strategies proposed in this study.

In conclusion, Cambodia's population, energy consumption, and carbon dioxide emissions nexus require a holistic and adaptive approach. Cambodia can navigate this nexus towards a resilient and sustainable future by integrating sustainable development practices and fostering a harmonious balance between demographic dynamics and environmental preservation. The findings of this study contribute to the ongoing discourse on sustainable development and provide a foundation for informed decision-making in the Cambodian context and beyond.

6. Limitations and Future Study:

Limitations- while this paper has provided valuable insights into the nexus of population, energy consumption, and carbon dioxide emissions in Cambodia, it is essential to acknowledge certain limitations that may influence the interpretation and generalization of findings:

Data Constraints- the availability and accuracy of data, especially in developing contexts, are posed challenges. Incomplete or outdated data may influence the precision of our analyses (Pata & Ertugrul, 2023; Pata, Kartal, Dam, & Kaya, 2023; Pata & Samour, 2023; Payne, Truong, Chu, Doğan, & Ghosh, 2023).

Methodological Considerations:

Using a mixed-methods approach while enriching the study introduces inherent complexities. The integration of quantitative and qualitative data requires careful interpretation and potential subjectivity.

Policy Dynamics- The evolving nature and dynamic implementation of governmental policies may result in variations between policy intentions and real-world outcomes. The study's snapshot may only capture part of the spectrum of policy impacts.

Socio-Economic Variables- while efforts were made to consider socio-economic factors, the study may need to comprehensively account for the factors influencing population dynamics, energy consumption, and emissions.

Regional Variations- the study's focus on national-level trends may overlook regional variations within Cambodia. Future research could explore localized nuances to provide a more granular understanding.

Future Study Directions- building on the insights gained from this study, future research endeavors can explore the following avenues further to refine our understanding of the nexus in Cambodia:

Longitudinal Studies- conducting longitudinal studies can offer a more dynamic perspective on the evolution of population dynamics, energy consumption, and emissions over time, allowing for a more robust analysis of trends and patterns.

Scenario Modeling- employing scenario modeling techniques can help predict future trajectories based on different demographic and policy scenarios, providing valuable insights for proactive decision-making.

Community-level Analyses- investigating the nexus at the community or regional level can unveil localized challenges and opportunities. This approach would enable the development of targeted interventions catering to specific socio-economic contexts.

Technological Innovations- assessing the impact of emerging technologies and innovations on energy consumption and emissions can provide forward-looking insights. This issue includes adopting renewable energy sources, advancements in energy efficiency, and integrating intelligent technologies.

Social Equity Studies- future studies should delve deeper into the socio-economic consequences of the nexus, explicitly examining how different demographic groups are affected. This issue can inform policies that prioritize social equity and inclusivity.

Comparative Analyses- conducting comparative analyses with other countries facing similar challenges can offer valuable benchmarks and identify transferable best practices.

By addressing these limitations and exploring these future study directions, researchers can contribute to a more nuanced and comprehensive understanding of the nexus of population, energy consumption, and carbon dioxide emissions, fostering sustainable development in Cambodia (Phan, Stachuletz, & Nguyen, 2022; Rahman & Alam, 2022; Raihan, 2023; Raihan & Tuspekova, 2022a, 2022b; Ram, Gulagi, Aghahosseini, Bogdanov, & Breyer, 2022).

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