The Impact of Urban Energy Poverty on Environmental Degradation: An Environmental Pollution Perspective.

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KEYWORDS

Pollution, Urbanization, CO2, Energy Poverty, Economic Growth

ABSTRACT

This paper investigates the impact of urban energy poverty on environmental degradation from an environmental pollution perspective. Environmental degradation has been an issue of global concern for several years due to its alarming impact on the Earth's landscape, which prompted significant apprehension among environmental stakeholders. Energy poverty research rarely explores urban areas. This research investigates the unique contribution of urban energy poverty to environmental degradation. Annual panel data of South from 1991 to 2021 was used to estimate the influence of urban energy poverty on environmental pollution. The ARDL-PMG, FMOLS, and DOLS test methodologies are employed for analysis. Results showed that a 1% increase in urban energy poverty corresponds to a 0.32% increase in environmental pollution. Another significant finding is that Economic growth is a primary driver of pollution. The study revealed a positive relationship between urban energy poverty and environmental pollution, suggesting economic growth alone does not mitigate environmental degradation. Renewable energy consumption is crucial for environmental sustainability. Moreover, South Asian countries should set targets to eliminate energy poverty and encourage using clean energy by increasing their energy budget.

1. Introduction

The world's environment has significantly deteriorated in the last two decades, leading to severe weather conditions and environmental disasters. Governments are under pressure to address environmental concerns while maintaining economic growth. Human actions such as industrialization, population growth, economic expansion, urbanization, and extensive use of fossil fuels are believed to be responsible for ecosystem deterioration. CO_2 is a significant contributor to climate change and environmental decline. Environmental stakeholders have spurred academics to delve into the issue of environmental degradation and propose viable solutions (Osuntuyi & Lean, 2022). Environmental Kuznets Curve (EKC) theory (Grossman & Krueger, 1991) has been instrumental in establishing a correlation between environmental degradation and economic growth. It posits that environmental deterioration intensifies during the initial stages of economic growth and subsides after a certain threshold.

Energy poverty is a pressing problem in the global South, especially in South Asia. It is a significant concern because of the fast urbanization and projected increase in urban population by 2040 (Pan et al., 2022). With 152 million people lacking access to energy and 900 million deprived of clean energy for cooking, addressing urban energy poverty is crucial and urgent. Governments worldwide are supporting efforts to reduce urban energy poverty, which includes enhancing energy technology and increasing the utilization of clean energy. The International Energy Agency (IEA) reports that renewable energy has grown since 2000, accounting for 11% of total energy consumption in 2018. This shift is aimed at eradicating energy poverty by replacing conventional fuels like firewood and coal (Lin & Wang, 2020), which currently dominate the energy supply, causing high consumption costs for low-income groups (Johnson & Keith, 2004).

As energy becomes more widespread, it is essential to consider whether using clean energy may help to mitigate CO_2 emissions. Regional disparities in energy can be attributed to variances in nonrenewable energy resources, renewable energy infrastructure building, and economic aggregates among nations. Further research is needed to understand the diverse effects of urban energy poverty on environmental pollution and the factors contributing to regional differences. Hence, this research comprehensively investigates the connections between environmental pollution and Urban energy poverty, employing a dataset comprising five South Asian countries from 1991 to 2021, thereby ensuring a comprehensive study.

As a result, this study offers two critical contributions to current research on the relationship between urban energy poverty and environmental pollution. Firstly, while previous studies have primarily focused on the fundamental impacts of energy poverty, such as welfare, health, and education, there has been limited exploration of the relationship between urban energy poverty and carbon emissions reduction. The present research represents the initial attempt to empirically test the effects of urban energy poverty on environmental pollution. The results of this test can effectively determine how the current rise in urban energy, primarily focused on thermal energy generation, mitigates the effects of environmental pollution. Moreover, the findings of this study can provide national policymakers with crucial information to formulate relevant policies and measures to reduce climate change from the perspective of Urban energy consumption, thereby making the research highly relevant to policy formulation.

Secondly, the primary strategy to eradicate urban energy poverty is popularizing and adopting clean energy. South Asia now uses a variety of energy sources, but not much research has looked at how they affect environmental pollution. To do this, this study investigates the diversity between different energy production types of environmental pollution and the underlying causes of the variety based on identifying the existing situation of urban energy generation types in South Asia. In addition to optimizing and adjusting the energy source structure and increasing the progress of urban energy poverty elimination, this study offers readers a comprehensive reference to assist them in understanding the individual environmental pollution consequences of current production types.

The current research is organized as follows: The second section reviews the literature on energy poverty, and the third section provides the methodology and data. The fourth section presents the estimations of the data analysis, and the final section summarizes the entire research.

2. Literature Review

The Environmental Kuznets Curve theory suggests that economic growth increases environmental degradation, persisting until a threshold is reached, then diminishes, but its validity remains uncertain, with some studies supporting it (Sirag et al., 2018; Wang & Zhang, 2020), while others lack substantial proof (Ehigiamusoe & Lean, 2019). Empirical studies show a link between energy consumption and pollution levels, and increasing consumption leads to higher levels. Renewable energy sources are suggested as a solution (Destek & Aslan, 2020). Energy poverty significantly impacts environmental pollutants and hinders shared prosperity and sustainable economic growth due to progressive industrialization and Urbanization (Bardazzi et al., 2021). The research evaluates the environmental and socioeconomic effects of energy poverty. Boardman (2010) and Hills (2011) highlight the energy industry's limited supply, causing energy poverty. This refers to the inability of the current system to meet fundamental energy demands (Churchill & Smyth, 2020), such as maintaining home warmth.

Energy poverty is measured by affordability and accessibility (Wang et al., 2015), with various studies using dual-factor approaches (Rafi et al., 2021). However, no standardized approach exists, necessitating further research to evaluate this issue comprehensively. Various indicators are used, but no standardized approach exists (Dong et al., 2021). Studies show a link between economic growth, energy poverty, financial inclusion, and income inequality (Koomson & Danquah, 2021). Reducing energy poverty is crucial, but some suggest a long-term decoupling link between eliminating poverty and reducing CO2 emissions (Bilgili and colleagues, 2022). Increased clean energy usage may slow climate change, with carbon emissions being a leading cause (Liu et al., 2023).

A few studies explored the relationship between energy poverty and the environment. Notably, urban energy poverty's effects on global South Asia's environmental pollution seem less explored. How the increasing urban energy poverty situation helps to mitigate environmental deterioration needs further investigation. Therefore, this study fills the literature gap by analyzing urbanization's effects on environmental pollution in South Asian countries. It reveals that urbanization contributes to pollution, with the population shifting from rural areas. The study also compares renewable and non-renewable energy consumption to find the best solution for mitigating pollution.

This study can benefit policymakers by helping them understand urban population challenges in accessing reliable energy services, aiding in policy development for poverty alleviation and CO2 emissions reduction, and promoting sustainable urban growth strategies in Asian countries. Comparative analysis of energy sources in South Asian countries can help formulate policies prioritizing renewables, reducing fossil fuel reliance, and mitigating climate change.

Overall, the proposed study can provide policymakers in Asian countries with evidence-based insights and recommendations for addressing pressing issues related to urban energy poverty, urbanization, renewable and non-renewable energy sources, and environmental pollution. By integrating findings from this research into policy formulation and decision-making processes, policymakers can work towards creating more sustainable, equitable, and resilient environments for South Asian countries. Additionally, our study employs accurate research methods and provides valuable insights contributing to the existing literature.

3. Methodology and the Data Source

3.1 Model specification

The impact of Urban energy poverty on environmental pollution is examined in this study. We also use the EKC hypothesis model to investigate environmental pollution and urban energy poverty. The basic EKC model is shown below,

$$CO2_{it} = f(UEP_{it}, GDP_{it}, GDP2_{it} R\,E_{\ it}, NRE_{it}, URB_{it}) \qquad (1)$$

Subscript i denotes the five South Asian nations chosen for the data, and t indicates the time. The functional relationship between urban EP and carbon emissions is shown by f(·). CO2 represents a nation's carbon emissions, whereas UEP represents urban energy poverty. The symbols UEP, GDP, RE, NRE, and URB stand for urban energy poverty, renewable and nonrenewable energy consumption, economic growth, and the evolution of urbanization, respectively. The paper justifies the selection of variables for the econometric models, which are chosen based on their relevance to the research gap and their potential to provide insights into the relationship between urban energy poverty and environmental pollution. These variables are crucial in understanding the complex dynamics of urban energy poverty and its impact on the environment. Further, urban areas have a larger population than their natural resources, leading to energy depletion and having a direct environmental impact. The choice of urban energy poverty and urbanization effects on the environment in a single model context is based on authentic studies for South Asia, providing a comprehensive understanding of the issue.

Hence, for the long and short-run effects, the following PMG-ARDL is the appropriate equation (2)

$$\Delta lnCO2_t = \lambda_0 + \lambda_1 lnUEP_{t-1} + \lambda_2 lnGDP_{t-1} + \lambda_3 lnGDP2_{t-1} + \lambda_4 lnRE_{t-1} + \lambda_5 lnNRE_{t-1} + \lambda_6 lnURB_{t-1} + \sum_{i=1}^{l} \Phi_{1i}\, \Delta lnCO2_{t-i} + \sum_{i=0}^{m} \Phi_{2i}\, \Delta lnUEP_{t-i} + \sum_{i=0}^{n} \Phi_{3i}\, \Delta lnPGDP_{t-i} + \sum_{i=0}^{p} \Phi_{4i}\, \Delta lnGDP2_{t-i} + \sum_{i=0}^{p} \Phi_{5i}\, \Delta lnRE_{t-i} + \sum_{i=0}^{p} \Phi_{6i}\, \Delta lnNRE_{t-i} + \sum_{i=0}^{q} \Phi_{7i}\, \Delta lnURB_{t-i} + \in_{it} \qquad (2)$$

Equation (2) illustrates the total number of nations. the dependent variable (lnCO2), the explanatory variables (InUEP, lnPGDP, lnRE, lnNRE, and lnURB), and the group-specific impact $\in_{it}$. A short-run connections coefficient is repressed by $\Phi_{1i}, \Phi_{2i}, \ldots \ldots, \Phi_{7i}$, whereas $\lambda_1, \lambda_{2,} \ldots \ldots, \lambda_6$ represent the long-run links between variables.

3.2 Estimation strategy

The empirical analysis starts with estimating the unit root. The Im, Pesaran, Shin (IPS), and augmented Dickey-Fuller (ADF) panel unit root tests were used. Further, the Westerlund (2008) test examined the long-term relationships among variables. Moreover, the Pooled Mean Group (PMG) estimate approach is used to investigate relationships among variables. The PMG approach assumes homogeneity in long-term dynamics while allowing for variation in short-run parameters across different countries (Chudik & Pesaran, 2013). Unlike dynamic OLS (DOLS) approaches and fully modified least squares (FMOLS), this method focuses on the error correction term, which represents the adjustment of short-run and long-run dynamics (Osuntuyi & Lean, 2023). ARDL models will be applied when the variables have a mixed order of integration: I (0) or I (1). FMOLS and DOLS will be used because they have leads and lags of the difference's independent variables for the serial correlation and endogeneity problems. They lead to efficient and remarkably consistent long-run estimates.

This study tests whether urban energy poverty contributes to decreased environmental pollution using a panel dataset of South Asian countries. The time duration from 1991 to 2021 is based on data availability. Table 1 represents the measurements of the variables and the sources of data that are used.

Table 1. Description of variables and sources of data

Variables	Measurement	Source
Environmental pollution (CO2 Emissions)	Metric tons of CO2	WDI (2022)
Urban Energy Poverty (UPE)	Total urban population without energy access	WDI (2022)
Economic Growth (GDP)	Annual GDP growth.	WDI (2022)
Renewable Energy Consumption (RE)	Renewable energy percentage in energy.	WDI (2022)

Nonrenewable Energy Consumption (NRE)	Nonrenewable energy percentage in energy.	WDI (2022)
Urbanization (URB)	Population in urban areas.	WDI (2022)

4. Empirical Findings and Discussion

The descriptive statistics summary shows the variables' variations in Table 2. After organizing the data, a descriptive statistical analysis was performed on selected variables to enhance comprehension of how urban energy poverty affects environmental pollution. The findings are presented in Table 2.

Table 2. Descriptive Statistics

	lnCO2	**lnUEP**	**lnGDP**	**lnRN**	**lnNRN**	**lnURB**
Mean	0.955	4.494	1.542	4.051	6.815	4.051
Std. dev.	0.890	0.096	0.537	0.287	2.323	0.350
Min	0.500	4.061	2.119	3.424	1.230	3.424
Max	-3.005	4.605	2.213	4.555	7.608	4.555

Based on the findings from the descriptive statistical analysis presented in Table 2, the mean value of UEP is 4.494, with a minimum value of 4.061 and a maximum value of 4.605. The pollution intensity is also reported at -0.955 because the carbon emission in South Asia is 1.34 mt. The prominence of nonrenewable energy consumption is notable, with a value of 6.815 compared to renewable energy consumption at 4.051. Furthermore, the sample's nonrenewable energy consumption standard deviations exhibit significant variation compared to other variables, indicating diverse energy consumption patterns. These findings highlight the need for strategic interventions to promote sustainable energy practices and address environmental challenges within the South Asian regions.

Table 3 displays the outcomes of the unit root test, which shows that some of the variables in this table are stationary at their first difference; some are stable at the level.

Table 3 Results of Panel Stationarity

	ADF- Fisher Chi-square	**Lm, Pesaran and Shin Test**
Level		
Variables		
lnCO2	24.040***	-2.295**
lnUEP	28.712***	-3.130***
lnGDP	791.645***	-25.315***
lnRE	3.986*	2.113
lnNRE	16.210*	-1.364
lnURB	17.645*	-1.213
First Difference		
lnCO2	61.497***	-7.236***
lnUEP	104.055***	-10.788***
lnGDP	790.737***	-33.625**
lnRE	57.235***	-7.049***
lnNRE	64.227*	-7.332***
lnURB	50.790**	-6.002*

Furthermore, The Westerlund cointegration test results are displayed in Table 4. The cointegration relationship between the variables is visible. These findings provide us with reasonable justification for choosing the PMG approach.

Table 4. Panel Cointegration Test Results

Dependent Variable	**lnCO2**
Model With Urban Energy Poverty	**-2.7118*** **

Table 5 provides the results of PMG, FMOLS, and DOLS techniques. According to PMG results, a significant positive link with a coefficient of 0.599 is found between UEP and CO2; in other words, a 1% increase in UEP can result in a 0.599 % increase in CO2 emissions. In another context, eliminating urban energy poverty by granting everyone access to energy is feasible for the CO2 mitigation plan. The sign, significance, and size of the results from each estimating approach are comparatively similar. From the analysis, it can be deduced that as the number of urban people without access to energy rises, there is a possibility of putting into use the nonrenewable energy sources that are inefficient and detrimental to the environment in the sense that they contribute to higher CO2 emissions. This brings out the need to combat energy poverty in the urban setting to reduce environmental pollution. Analyzing these findings, one can state that the measures elaborated in this work have pertinent implications for policymakers and urban planners, preserving and developing the problem of sustainable energy in urban environments.

Further, the results imply that GDP has a significant positive effect on CO2 emissions. The results suggest that growth in economic activity will increase the damage to South Asia's natural ecosystem. This means that with an increase in a country's Gross Domestic Product (GDP), there is a proportionate increase in Carbon Dioxide emissions. Higher GDP is always attained with increased industrialized activity, energy consumption, and transportation, leading to enhanced atmospheric carbon dioxide emissions. This, therefore, means that while economic growth is a prerequisite for development, it comes with some detrimental effects on the sustainability of the environment through augmentation of the emission of greenhouse gases.
These discoveries augmented the accumulation of studies on the relationship between economic growth and the environment (Ehigiamusoe et al., 2022). The mutually beneficial status of economic development and protecting the environment has become an effective tool for worldwide competitiveness, which is more challenging for governments due to the promotion of carbon neutrality and the broad strengthening of the sustainable economy.

South Asian cities represent relatively high urban population density and continuing environmental stress. This occasion makes places congested; there is no proper sanitation and disposal provision, and traffic congestion promotes pollution. In the urban areas, there is high energy demand, which results in the use of fossil fuels, hence high CO2 emission and air pollution. Current energy poverty is another problem that significantly contributes to the degradation of the environment in many cities of South Asia, as most use coal and other non-renewable energy sources. The negative impacts of urbanization in South Asia are attributed to rapid and uncontrolled urbanization, high urban population mass, industries, energy consumption, poor waste disposal, reduced green space, and transport challenges. These factors are major environmental issues that sustainable urban planning and policies must consider.

Additionally, the initiative effectively ensures that the existing energy poverty will be reduced. Governments have progressively taken measures to replace coal with immaculate energy and slowly with natural gas to reduce environmental pollution. Additionally, the initiative effectively ensures that the existing energy poverty will be reduced. More precisely, Natural gas generates 23.4% of total energy, while renewable energy share is only 11.7%. This demonstrates that natural gas and coal are the primary driving forces behind the evolution of the contemporary worldwide electricity industry. Carbon emissions from coal and fossil fuels are the greatest among all energy sources (Lin & Xu, 2020).

The variables' short-term coefficients are significant, except for urban energy poverty and urbanization. In the short term, economic growth and renewable and nonrenewable energy consumption significantly impact South Asia's environment, as shown by the results. The results indicate that 96% will be adjusted annually to reach a long-term equilibrium.

Table 5. The Impacts of Urban Energy Poverty on Environmental Pollution

	(1)	**(2)**	**(3)**
	PMG	**FMOLS**	**DOLS**
Long Run			
lnUEP	0.599 (4.941***)	1.651 (3.247***)	0.954(3.208***)
lnGDP	0.062 (8.100***)	0.094 (2.776**)	0.102(2.248*)
lnGDP2	0.104 (8.842***)	0.143 (1.640)	0.145 (1.688)
lnRE	-1.241(-17.820***)	-1.864(-5.076***)	-0.788(-3.319***)
lnNRE	0.003 (5.335***)	0.018 (2.633**)	0.004(1.009)
lnURB	0.072 (4.929***)	0.006 (0.163)	0.077(2.705***)
Short Run			
ECT (-1)	-0.963 (-4.335***)		
D(lnCO2)(-1)	0.221 (2.902**)		
D(lnUEP)	0.679 (0.800)		
D(lnGDP)	0.171 (2.157**)		
D(lnGDP2)	0.424 (2.173**)		
D(lnRE)	1.570 (2.427*)		
D(lnNRE)	0.011 (2.910**)		
D(lnURB)	0.009(0.103)		

5. Conclusion

The study analyzed annual panel data of South Asian countries from 1991 to 2021 to determine the impact of urban energy poverty on environmental pollution. The findings showed that a 1% increase in urban energy poverty leads to a 0.323% increase in environmental pollution, making it challenging to achieve carbon reduction targets due to the widespread use of nonrenewable energy sources in South Asia. Furthermore, Economic growth is a significant driver of carbon emissions in South Asian nations. The research suggests that encouraging renewable energy use in clean industry sectors can reduce pollution and increase the economic activities of South Asian nations. Urbanization in South Asia is often fast and uncontrolled, resulting in areas with insufficient infrastructure and services. This leads to more pollution and deforestation. For instance, urban centers are overwhelmed by the influx of population.

However, replacing conventional high-polluting energy sources with energy access is not a clean energy poverty reduction technique, as it depends on the energy source. The study suggests that the governments of South Asian nations and the market must work together to combat the greenhouse effect, eliminate urban energy poverty, increase production, and promote renewable energy. Local governments should establish laws and programs promoting clean energy industry growth, allocate financial resources for infrastructure development, and recruit talented professionals to improve clean energy technology.

Furthermore, given the heterogeneous relationship between urban energy poverty and environmental pollution across South Asian countries, governments should tailor their strategies to specific circumstances to effectively address energy poverty and reduce environmental pollution. Governments should provide financial assistance to firms building critical infrastructure. These initiatives can reduce urban energy poverty and greenhouse gases.

This study provides significant empirical evidence for the environmental implications of Urban energy poverty through modern energy usage. However, it has limitations, such as only focusing on five economies. Future research should focus on different developing regions to investigate the potential impact of urban energy poverty.

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