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Energy Poverty, Economic Growth, and Industrialization Nexus in South Asian Countries: Panel Data Analysis

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Abstract

Energy inflation is measured as a person's inability to obtain sufficient energy sources. It's a diverse and complicated issue. This study investigates how economic growth, industrialization, urbanization, and employment in South Asian countries are all linked to energy poverty. In the South Asian region, the relationship between these factors has not been thoroughly examined. This study uses the panel data collected from South Asia's most energy-intensive countries from 1995 to 2000. Advanced econometric methodologies and panel estimations are applied to explore the dynamic relationship. The long-run co-integration study reveals that economic growth reduces but industrialization increases energy poverty in these countries. Furthermore, energy poverty has a negative association with employment but a positive association with urbanization. The findings offer a framework for energy policymakers to establish policies that will assist them to meet the Sustainable Development Goals' objectives (SDGs).

Keywords: Energy poverty; Panel data; Econometrics; South Asia; Sustainable Development Goals.

1. Introduction

Energy poverty has a detrimental effect on both the global and local levels, and it is still a relatively new issue on the world arena. Energy poverty is becoming an emerging concern because of its significant linkages to absolute poverty, gender inequality, economic advancement, and climate change [1]. Energy poverty is defined as a "condition of inability to realize critical capacities due to a shortage of adequate access to reasonable, efficient, satisfactory, high-quality, and secure energy services" [2].

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Poverty, according to Sen and his colleagues [3], is described as the lack of opportunities to live a basic human life. Different sources, such as European Poverty Observatory [4], and González-Eguino [5], include crucial individual needs such as food, health, education, livelihoods, and warmth among others. To put it another way, energy poverty is defined as a lack of sufficient, economical, and safe energy services, which results in social inequality [6]. The global financial crisis that emerged in 2008 has significant negative economic consequences all around the world. The financial system crumbled, debt levels soared, and global economic growth was severely hampered. Furthermore, unemployment rates increased, and economic and social disparities widened [7]. Since problems with modern energy service access have arisen, and the economic crisis is now regarded one of energy poverty's driving drivers, the subject of energy poverty has also been raised. The negative impact on developing countries was greater, but energy poverty was also a problem in some industrialized countries during and after the crisis [8]. In recent years, many countries have experienced rapid industrialization, population growth, and significant shifts in trade and financial sector development patterns [9]. The need for energy is increasing day by day, owing to the expansion of contemporary economic growth driven by increased industrialization and considerable changes in trade patterns [10]. Measurement and consistency of measurement are also challenging in different developed countries [11]. As a result, the energy-income ratio ignores restricted behaviors generated by high fuel costs, particularly with regard to heating needs. The pre-bound effect [12] is an example of this notion. Because of limitation behavior and possible energy savings, the pre-bound effect shows that the policymakers who want to implement energy efficient efforts may be overestimating the advantages, and the rate of pay-back may be inflated. The trend of urbanization has increased energy and resource use, resulting in climate change and environmental deterioration, as well as having a substantial impact on human production's natural environment and lifestyle [13]. Using panel analysis, Rahman and his colleagues [14] studied the impact of remittance on energy consumption in South Asian nations and found that remittance had a significant positive impact on energy consumption. Nicholas and his colleagues [15] examined at energy poverty and education in a panel data analysis of emerging countries. Nicholas and his colleagues [15] examined at energy poverty and education in a panel data analysis of emerging countries. They discovered that education has a negative impact on energy poverty. On a national, regional, and municipal level, Austria [16], France [17], New Zealand [18], Germany [19], Denmark [20], Ireland [21], Greece [22–24], Spain [25], and Italy [26] have all explored into energy poverty. The incorporation of employment of the people of South Asian countries has an impact on energy poverty. A panel examination of the relationship between energy poverty, economic growth, industrialization, urbanization, and employment is also lacking. To fill this research gap, this study focuses on the link between energy poverty, economic growth, and industrialization in South Asia. The variables urbanization and employment are considered as control variables. This nexus of energy poverty, economic growth, and industrialization is investigated using a panel cointegration based on augmented mean group (AMG) approaches, which significantly increase statistical power. The findings of the AMG reveal that economic growth has a negative impact on energy poverty, implying that as GDP rises, energy poverty decreases over time, and the link is statistically significant at 5% level of significance.

2. Empirical Model and Data

2.1. Econometric Model

To examine the nexus between energy poverty, economic growth, industrialization, urbanization, and employment, we consider the following model. The control variables in this study are urbanization and employment. Equation 1 describes the model's function:

$$EP_{it} = f\left(GDP_{it}, IND_{it}, UP_{it}, EMP_{it}\right) \quad (1)$$

Where EP_{it} stands for energy poverty index, which is calculated based on PCA using access to clean fuel and cooking technologies and electricity, GDP is the economic growth, IND measures industrialization, UP signifies urbanization, and EMP is the employment of the people. A basic multivariate framework is used to find the link between the variables of interest. We smooth the data by transforming all series to their natural logarithm, with the exception of the major component scores of energy poverty. This conversion, when compared to a basic linear approach, helps to eliminate autocorrelation and heteroscedasticity problems while also providing more accurate and reliable results. Equation 2 shows the model in log-linear form:

$$EP_{it} = \alpha_0 + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(IND_{it}) + \beta_3 \ln(UP_{it}) + \beta_4 \ln(EMP_{it}) + \varepsilon_{it} \quad (2)$$

Here, $i(1,2,\ldots,N)$, and $t(1,2,\ldots,T)$ represent countries and year of recorded data respectively. The parameter α_0 measures the intercept of the linear model, the coefficients $\beta_1, \beta_2, \beta_3$ and β_4 denote the instantaneous rate of change of energy poverty due to change in the logarithm of economic growth, urbanization, urbanization, and employment, respectively. The random error term ε_{it} refers to the unobserved factors.

2.2. Data Sources

Table 1: Summary of the variables and data sources.

Variable	Notation	Measure	Data source
Energy poverty (PCA score)	EP	Electricity access (% of total population)	WDI
		Clean fuels and cooking technologies access (% of total population)	WDI
GDP	EG	Per capita GDP (current US$)	WDI
Industrialization	IND	Industry (including value added) (% of GDP)	WDI
Employment	EMP	Employment of population ratio, 15+, total (%)	WDI
Urbanization	UP	Urban population (% of total population)	WDI

Annual panel data were collected from six South Asian developing countries from 1995 through 2020. Bangladesh, India, Sri Lanka, Nepal, Bhutan, and Pakistan are among the countries that use the most energy, hence included in this study. Per capita GDP was utilized as an indication of economic growth, and energy poverty (EP) was measured using a PCA score based on access to electricity, clean fuels, and cooking technology. Table 1 contains all variable descriptions, including notation, measurement methods, and data sources. The six South Asian developing countries included in this study were chosen based on the availability of data for all variables. In this study, N * T = 156 observations were employed, with N = 6 and T = 26. The World Bank published the World Development Indicators (WDI), which provided all variable data [27]. Because data on access to clean fuels and cooking technologies for all countries was available in the WDI until 2015, data for these variables for the years 2016-2020 was sourced from country level energy poverty surveys.

3. Methodology

Advanced econometric methodologies are employed to determine the long-run and dynamic causality between energy poverty, economic growth, industrialization, urbanization, and employment. The methodology comprises the following steps. 1) Cross-section dependency test 2) Panel unit root test of the second generation 3) Panel cointegration tests, such as the Westerlund and Pedroni tests 4) Parameter estimation using the second-generation augmented mean group (AMG) approach.

3.1. Cross-sectional Dependence Tests

The cross-sectional dependency problem in panel data could be caused by the relationship and dependence across the countries as a result of globalization and economic collaboration. The study conclusions from such techniques may be skewed if cross-section dependency is not taken into account in the panel [28–30]. In order to address this issue we ran cross-sectional dependence (CD) tests. The cross-section dependence is determined using Breusch and Pagan's [31] LM test and Pesaran's [32] CD test. Cross-sectional units are assumed to be independent in the null hypothesis, but cross-sectional units are assumed to be dependent in the alternative hypothesis. Breusch and Pagan LM statistic is given by Equation 3.

$$LM_{BP} = T\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\hat{r}_{ij}^2 \tag{3}$$

If the value of T is relatively large, the LM test is ineffective. Pesaran suggests the following CD test as an alternative to fixing this problem:

$$CD_P = \sqrt{\frac{2T}{n(n-1)}}\left(\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\hat{r}_{ij}^2\right) \tag{4}$$

where i and j expressed as the countries, T denotes the studied years, n is the number of nations, and $\hat{r}_{ij}^2$ indicates the correlation of the error in Equation 3 and Equation 4.

3.2. Panel unit root and Cointegration Tests

As non-stationary variables might lead to erroneous regression results, it is essential to double-check the variables' stationary features. Pesaran’s [33] cross-sectional augmented IPS (CIPS) test was used to look for cross-sectional dependency across nations. If the series has unit root, a test of cointegration can be used to find the long term relationship among the variables before estimating the long-run coefficient. At this point, we employed the Pedroni [34,35] and Westerlund [36] methods, which deal with cross-sectional dependency.

3.3. Estimation of Long-run Coefficients

Long-run parameters must be estimated after confirming that the variables are co-integrated. In the presence of cross-sectional dependency and slope heterogeneity, the long-run parameters can be assessed using the augmented mean group (AMG) [37] estimation technique. The AMG estimator is divided into two parts. First, it combines the unobserved common factor with the time factors in the following equation using first difference OLS:

$$\Delta y_{it} = \alpha_i + \beta_i \Delta x_{it} + \phi_i f_t + \sum_{t=2}^{T} \theta_t Dummy_t + u_{it} \quad (5)$$

where Δ is difference operator, α_i measures intercept, x_{it} and y_{it} are the independent and dependent variables, respectively, β_i presents the slope of every cross-section, and u_{it} indicates random error. Second, the panel’s cross-section model parameters are averaged.

$$AMG = \frac{1}{n} \sum_{i=1}^{n} \tilde{\beta}_i \quad (6)$$

where $\tilde{\beta}_i$ is the estimates of β_i .

4. Results and Discussion

All findings based on indicated methodological techniques are reported in this section. The findings of the cross-section dependence test are also shown in Table 2.

Table 2: Cross-section dependency results

Variables	**LM test**		**CD test**	
	Test Stat.	p-value	Test Stat.	p-value
EP	5362.251	0.000	52.361	2.3E-12
Ln(EG)	5624.351	0.000	66.254	3.1E-11
Ln(IND)	2365.158	0.000	45.234	2.4E-13
Ln(UP)	6568.894	0.000	39.254	3.4E-14
Ln(EMP)	2541.326	0.000	55.234	1.2E-10

Given the corresponding p-values of LM and CD test in table 2, the null hypothesis of cross-sectional independence for energy poverty, economic growth, industrialization, urbanization, and employment can be rejected. As a result, cross-section dependence exists for all variables in our study. Before analyzing cointegration, it is crucial to identify whether or not the data are non-stationary. The CADF tests were employed in this study to detect unit roots in the variables under investigation. The results of this test are summarized in Table 3.

Table 3: Results of panel unit root test

Variables	CADF	
	Level	1st diff.
EP	-4.361	-4.321**
Ln(EG)	-5.321**	-7.624***
Ln(IND)	-1.524	-4.351**
Ln(UP)	-4.321	-5.157**
Ln(EMP)	-3.215	-5.879*

It can be observed that the null hypothesis of non-stationary series at the level is not rejected for the variables. However, the first differences demonstrate evidence of stationary series. Thus, according to the CADF tests, the variables have a unit root at the level but none of the variables have a unit root at the first difference, which is of degree I(1). Because all of the variables in Equation 2 were in the I(1) process, the panel cointegration approach was utilized to determine the long-run linkages between them. The results of Pedroni [34,35] and Westerlund [36] are shown in Table 4.

Table 4: Results of panel cointegration tests

Approaches	**t-value**
Westerlund (2005)	
Variance ratio	3.2654**
Pedroni (1999, 2004)	
Phill-Perron t	-5.2351**
Aug. D-Fuller t	-2.2541***

In these tests, the null hypothesis is that there is no cointegration in the panel. Table 4 reveals that the variables studied have a long-term relationship, rejecting the null hypothesis at 5% significance level. This finding explains why all of the variables in the study are co-integrated. The coefficients in Equation 2 were determined using the augmented mean group (AMG) technique after establishing a long-run relationship between variables. Table 5 displays the estimated coefficients, standard errors, and p-values for the associated predictor variables regressed on energy poverty (EP).

Table 5: AMG estimation results

variables	coefficients	Std. error of coefficient	p-value
Ln(EG)	-0.021	0.227	0.031
Ln(IND)	1.004	0.624	0.044
Ln(UP)	5.326	2.365	0.032
Ln(EMP)	-1.326	0.568	0.426

The AMG outcomes show that economic growth has a negative impact on energy poverty, indicating that as a country's economic development improves, energy poverty falls, and the link is statistically significant at the 5% level of significance. The discovery of the desired industrialization and urbanization have a considerable positive impact on energy poverty, implying that as a country's industrialization and urbanization develops, energy poverty rises. On the other hand, employment has a negative but statistically insignificant impact on energy poverty, indicating that employment and energy poverty have an inversely proportional relationship. Figure 1 depicts the long-run causalities of the analyzed variables. The AMG estimation outcomes show that economic growth reduces energy poverty significantly for the studied nations; indicating that if the economic development of a country improves, then energy poverty of this country reduces, and the link is statistically significant at the 5% level of significance. The finding supports the previous studies [38–40] . Industrialization and urbanization increase energy poverty. Industrialization and urbanization demand for more energy needs which are not sometimes fulfilled by the energy supply [41]. This situation prevents the households to get adequate energy for their daily energy needs [10]. For this reason, industrialization and urbanization may be increasing energy poverty for the studied nations. On the other hand, employment helps to improve energy poverty; indicating that employment and energy poverty are inversely proportionally linked. Figure 1 depicts the long-run causalities of the analyzed variables.

The findings of the long-run relationship using AMG analysis have implications for researchers and policymakers to best realize the opportunities to reduce energy poverty in the South Asian energy sector by leveraging the nexus between energy poverty, economic growth, and industrialization to boost economic performance in the digitalization era.

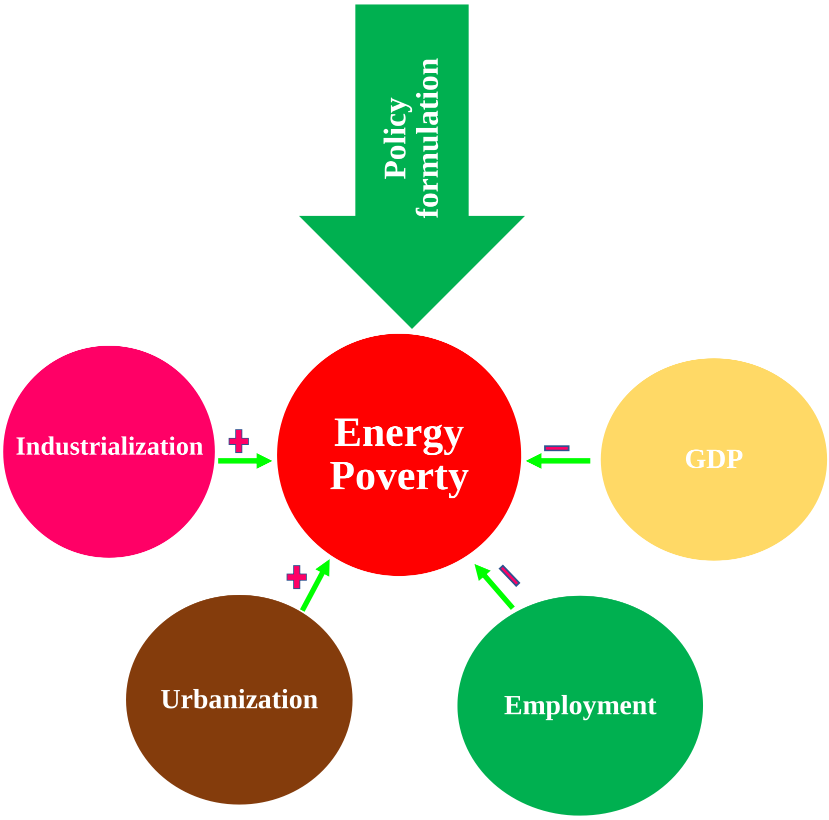

Figure 1: The graphical presentation of long-run causality among studied variables

5. Conclusions and Policy Implications

This study focuses on the relationship between energy poverty, economic growth, industrialization, urbanization, and employment from 1995 to 2020. We employed second generation unit root tests, the Pedroni, Westerlund cointegration technique, and AMG estimation to diagnose the causal link between the underlying variables. Economic growth and employment tend to have a negative impact on energy poverty. In Southeast Asian countries, however, urbanization exacerbates energy poverty. According to policy guidelines for Southeast Asian countries, access to sustainable energy is a "key component" of economic growth, and access to renewable and modern forms of energy is a "important precondition" for combating energy poverty, promoting economic growth, encouraging industrialization, expanding employment opportunities, and supporting foundational social services. Economic growth and job inflows have been found to alleviate energy poverty, meaning that raising GDP and implementing policies to enhance employment can help to reduce energy poverty. Despite the fact that this study clarifies the overall impact of energy poverty on economic growth, industrialization, and urbanization, the most affected groups are household members. However, panel data on energy poverty, demography, and economic characteristics at the household level is not available for the analyzed countries, which is one of the study's primary shortcomings. Future study could build on our findings to uncover more about the economic impacts of energy poverty for households.

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