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Empirical Insights into the Health Impacts of Energy Poverty: The Case of Vietnam

エネルギー貧困の健康への影響に関する実証的な洞察: ベトナムの事例

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エネルギー貧困の健康への影響に関する実証的な洞察:

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要旨：本研究は、エネルギー貧困が入院率に及ぼす影響を、2016 年ベトナム生活水準調査（VHLSS）のデータを用いて分析する。 潜在的な内生性の問題を軽減するために、情報通信技術（ICT）インフラの発展を操作変数とした 2 段階最小二乗（2SLS）回帰を適用する。 分析の結果、エネルギー貧困は入院率を有意に増加させることが示された。 また、一連の頑健性検証を行い、結果の安定性を確認した。 さらに、エネルギー貧困とベトナムにおける健康への影響の関係は、生活習慣上のリスク行動や世帯の生活環境によって媒介されることが明らかになった。

キーワード：エネルギー貧困；多次元エネルギー貧困指数；入院率；操作変数；VHLSS

Empirical Insights into the Health Impacts of Energy Poverty: The Case of Vietnam

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Abstract: This research investigates the impact of energy poverty on hospitalization rates using data from the 2016 Vietnam Household Living Standard Survey. To mitigate potential endogeneity concerns, a two-stage least squares regression is applied, leveraging the expansion of information and communications technology infrastructure as an instrumental variable. The findings indicate that energy poverty significantly increases hospitalization admissions. Additionally, a series of robustness tests confirm the stability of these results. Further analysis reveals that the relationship between energy poverty and health outcomes in Vietnam is influenced by lifestyle risk behaviors and household living conditions.

Keywords: energy poverty; multidimensional energy poverty index; hospitalization admissions; instrumental variable; VHLSS.

1. Introduction

Access to modern and clean energy is essential for poverty reduction, economic growth, and public health. However, energy poverty—defined as limited access to electricity and clean cooking solutions—remains a critical challenge, particularly in developing nations (Adusah-Poku & Takeuchi, 2019). According to the International Energy Agency (IEA, 2022), 2.4 billion people worldwide lack access to clean cooking facilities, primarily in developing Asia (55%) and sub-Saharan Africa (40%). In 2021, indoor air pollution was linked to 3.6 million premature deaths, while outdoor pollution contributed to 4.2 million fatalities. These health consequences have drawn increasing attention from researchers and policymakers.

In many developing nations, households still rely on traditional biomass for cooking, exposing them to harmful pollutants. The IEA (2022) notes that the number of people using biomass, coal, and kerosene for cooking has been rising since 2020. The combustion of these fuels releases toxic particulate matter (PM), which has been associated with respiratory diseases, cardiovascular issues, and increased child mortality (Baldacci et al., 2015; Mukherjee & Agrawal, 2018). Those experiencing energy poverty often face prolonged exposure to these pollutants, exacerbating health risks.

Given these adverse effects, examining the link between energy poverty and health is crucial, especially in developing countries. Vietnam has made significant progress in electrification, increasing access from 14% in 1990 to 97% by 2010, driven by government efforts and international support (Gencer et al., 2011). However, affordability remains a challenge, with 25% of households reporting insufficient electricity supply in 2010 (Ha-Duong & Nguyen, 2018). Energy poverty is not just about access but also the type of energy used. The WHO (2020) reports that many Vietnamese households still rely on traditional fuels and outdated technologies.

Using data from the 2016 Vietnam Household Living Standard Survey (VHLSS), this study examines the relationship between energy poverty and hospitalization rates. Employing a multidimensional measure (Nussbaumer et al., 2012) and a two-stage least square (2SLS) regression model, we use ICT infrastructure development as an instrumental variable (IV) to address endogeneity concerns. Our results show a significant positive relationship between energy poverty and hospitalization, consistent across different energy poverty measures. We conduct several robustness checks, including alternative IVs and an adjusted Multidimensional Energy Poverty (MEP) index, to confirm these findings. Additionally, our analysis suggests that lifestyle risk behaviors and household living conditions mediate this relationship.

This study makes two key contributions. First, it provides empirical evidence on the causal relationship between energy poverty and hospitalization in Vietnam, addressing endogeneity with two IVs. Second, it explores potential pathways, including living conditions and lifestyle behavior, through which energy poverty affects health. Given the significant impact of energy access on well-being, addressing energy poverty is crucial for improving public health.

The remainder of this paper is organized as follows: Section 2 provides a review of relevant literature, Section 3 details the data sources, variable definitions, and the methodology, Section 4 presents the empirical findings, and Section 5 offers the conclusion.

2. Literature review

The existing research on the link between energy poverty and healthcare utilization remains limited, though several studies have offered valuable insights into this relationship. Atsalis et al. (2016) investigated the impact of inadequate household heating on cardiovascular and respiratory conditions in Greece, finding that between 2.7% and 7.4% of cardiovascular cases and 3.1% to 8.5% of respiratory cases treated in two major hospitals were linked to heating insufficiency.

Similarly, Oliveras et al. (2020) found that individuals in Barcelona who identified as experiencing energy poverty were 1.7 times more likely to have been hospitalized in the previous year compared to those not facing such conditions. Additionally, Cook et al. (2008) reported that energy insecurity in low-income American families was associated with a higher risk of hospitalization among children under three, with those from moderately energy-insecure households facing a 22% higher likelihood of hospitalization compared to those in energy-secure homes. Based on these findings, we propose the following hypothesis:

Hypothesis 1: *Energy poverty increases hospitalization rates in Vietnam.*

A significant gap in the existing literature is the lack of a thorough exploration of the mechanisms by which energy poverty contributes to higher hospitalization rates. However, two key pathways can be considered.

The first pathway involves household living conditions. Energy access is crucial for maintaining a safe and comfortable home environment, which directly influences physical and mental well-being (Njiru & Letema, 2018). Adequate energy supply supports essential services that enhance living conditions, ultimately reducing the risk of health complications and hospital admissions (Karmaker et al., 2022). A well-equipped home with stable energy access promotes both physical and emotional health, thereby lowering the likelihood of hospitalization.

The second pathway relates to risky lifestyle behaviors. Households experiencing energy poverty are more likely to encounter stress-related challenges, which can lead to unhealthy coping mechanisms (Charlier & Legendre, 2023). Research has consistently demonstrated a strong connection between mental health issues and substance use, particularly alcohol and beer consumption (Lien et al., 2021). Individuals facing energy poverty may turn to alcohol as a way to manage stress (Hailemariam et al., 2021), and studies by Jemberie et al. (2022) indicate that regular alcohol consumption is associated with an increased likelihood of hospitalization. These findings suggest that energy poverty can indirectly contribute to adverse health outcomes through risky lifestyle behaviors.

Given this framework, we propose the following hypothesis:

Hypothesis 2: *The impact of energy poverty on health outcomes in Vietnam is mediated by household living standards and lifestyle risk behaviors.*

3. Materials and methods

3.1. Data source

This study utilizes data from the 2016 Vietnam Household Living Standard Survey (VHLSS), conducted by the General Statistics Office of Vietnam in collaboration with the World Bank. The VHLSS provides comprehensive information on households and individuals, including demographic characteristics and health-related indicators. To ensure data reliability and address missing values, our final sample consists of 25,428 individuals aged 18 and above.

3.2. Variable definitions

3.2.1. Measures of energy poverty

Energy poverty in this study is assessed using a multidimensional approach developed by Nussbaumer et al. (2012). The Multidimensional Energy Poverty (MEP) index serves as a robust framework to identify households facing multiple barriers in accessing clean, secure, and sustainable energy. According to Nussbaumer et al. (2012), the MEP index is instrumental in shaping policy decisions by capturing both the extent and severity of energy poverty.

Our study defines seven key indicators of energy poverty, grouped into five core dimensions: cooking, lighting, essential services, entertainment, and communication. These indicators are derived from previous research and context-specific data on Vietnam (Feeny et al., 2021; Que et al., 2022). Each dimension is assigned an equal weight of 0.2 to ensure a balanced evaluation. Appendix Table A1 presents a detailed summary of these indicators and their classification. Each indicator is coded as a binary variable, with a value of 1 indicating deprivation and 0 signifying no deprivation. For instance, a household is considered deprived in the "lighting" category if its annual per capita electricity consumption is below 100 kWh.

To compute the MEP index, we aggregate the weighted dimensions to derive a deprivation score for each household. A household is classified as energy-poor if its deprivation score exceeds a predefined threshold. In this study, we adopt a threshold of 0.33, a commonly used benchmark for developing countries (Alkire & Santos, 2014), as it effectively captures severe energy poverty. To ensure robustness, we also consider alternative thresholds of 0.25 and 0.5 to accommodate varying definitions of energy poverty.

3.2.1. Other variables

Hospitalization in this study is defined as the total number of inpatient admissions within the past 12 months for individuals aged 18 and above. To account for potential confounding factors, we categorize covariates into two broad groups. The first includes demographic characteristics such as age, gender, education level, and marital status. The second consists of household-level factors, including household size, rural or urban residence, regional location, and the logarithm of total household income.

Table 1 provides summary statistics for the dataset, which consists of 25,428 valid observations. Based on our energy poverty thresholds of 0.33, 0.25, and 0.5, we find that approximately 15%, 22%, and 8% of individuals, respectively, are classified as energy-poor. Additionally, nearly 70% of respondents reside in rural areas.

Table 1. Descriptive statistics.

Variables	N	Mean	SD	Min	Max
Hospitalization admissions	25,428	0.144	0.622	1	15
EP1	25,428	0.150	0.357	0	1
EP2	25,428	0.222	0.416	0	1
EP3	25,428	0.076	0.264	0	1
Age	25,428	44.075	17.020	18	104
Female	25,428	0.521	0.500	0	1
Level of education	25,428	1.752	1.260	0	4
Marital status	25,428	0.730	0.444	0	1
Household size	25,428	4.290	1.648	1	12
Log of household income	25,428	4.025	5.191	0	13.199
Rural resident status	25,428	0.691	0.462	0	1
Region	25,428	1.752	1.260	1	6

Notes: SD: standard deviation, N: number of observations. EP1, EP2, and EP3 refer to energy poverty measured at thresholds of 0.33, 0.25, and 0.5, respectively.

3.3. Identification strategy

3.3.1. Ordinary least squares (OLS) regression

To examine the effects of energy poverty on health outcomes, we present the following econometric model:

$$Y_i = \alpha_0 + \alpha_1 EP_i + \alpha_2 \boldsymbol{X} + \varepsilon_i \qquad (1)$$

where Y_i denotes the number of hospitalization admissions for individual i. The variable EP_i is binary and indicates whether an individual experiences energy poverty. A value of 1 signifies that the individual is experiencing energy poverty, while a value of 0 indicates the absence of energy poverty. $\boldsymbol{X}$ denotes a set of control variables. Specifically, we control for: (1) several characteristics of the individual, including age, gender, educational levels, and marital status; (2) various characteristics of the household, including household size, location of residence, geographical region, and the logarithm of the total household income. α_0, α_1, and α_2 are unknown parameters and ε_i is an error term.

3.3.2. Two-stage least square regression

The ordinary least squares regression discussed earlier may be subject to endogeneity concerns due to omitted variable bias or reverse causality. To address these potential issues, we implement a 2SLS regression. As an IV, we use the development of provincial-level ICT infrastructure[1], as it serves as a proxy for local infrastructure that is unlikely to be directly affected by an individual's hospitalization admissions. We employ the 2SLS framework to estimate the impacts of energy poverty on an individual's hospitalization admission. In the first stage, we extract the exogenous part of energy poverty that is not related to the error term by performing a regression of energy poverty (EP_i) on provincial-level ICT infrastructure with other control variables ($\boldsymbol{X}$):

$$EP_i = \delta_0 + \delta_1 ICT_p + \delta_2 \boldsymbol{X} + u_i \qquad \text{(2a)}$$

where ICT_p denotes the development of ICT infrastructure in province p. δ_0, δ_1, and δ_2 are parameters and u_i is an error term. The predicted value of energy poverty $\widehat{EP}_i$ obtained from this regression is then employed as the main covariate in the following second stage:

$$Y_i = \beta_0 + \beta_1 \widehat{EP}_i + \beta_2 \boldsymbol{X} + \vartheta_i \qquad \text{(2b)}$$

We assume that $\widehat{ICT}_p$ is uncorrelated with an individual's hospitalization admission. Consequently, β_1 can be interpreted as the causal effect of energy poverty on an individual's hospitalization admissions.

[1] The ICT Infrastructure assesses the development and readiness of ICT infrastructure across various sectors, including government agencies, provinces, commercial banks, and economic corporations. It focuses on key aspects such as the availability of computers per employee, Internet bandwidth capacity, and cybersecurity measures. These cybersecurity measures include the implementation of firewalls, antivirus software, unauthorized access alerts, and data storage systems. The index provides a comprehensive view of how well different entities are equipped to adopt and integrate ICT for operational efficiency, security, and digital transformation.

The validity of the IV is based on two key assumptions. The first is the exclusion restriction, which requires that the instrument influences the outcome only through its effect on infrastructure development. This study posits that ICT infrastructure expansion impacts hospitalization rates solely via its influence on energy poverty. This assumption is considered reasonable since provincial ICT infrastructure development primarily represents local infrastructure, which is unlikely to be directly affected by an individual's hospital admissions. Although this assumption cannot be tested directly, we evaluate its validity through a series of robustness checks, which are discussed later in this paper. The second assumption is instrument relevance, which requires a strong correlation between the IV and energy poverty. Table 2 presents an assessment of this relationship, with results exceeding the standard thresholds for detecting weak instruments (Staiger & Stock, 1994).

4. Results and discussions

4.1. Main findings

Table 2 presents the key findings of our analysis. Panel A reports the baseline OLS results, which indicate no statistically significant relationship between energy poverty and hospitalization admissions.

Panel B of Table 2 provides the primary 2SLS estimates. The analysis considers three thresholds—0.33 (EP1), 0.25 (EP2), and 0.5 (EP3)—to measure the severity of energy poverty. Across all three measures, the results consistently show a positive and statistically significant effect. Specifically, being energy-poor leads to a significant increase in hospitalization admissions, with effect sizes of approximately 0.333 for EP1, 0.251 for EP2, and 0.614 for EP3.

Table 2. Energy poverty and hospitalization admission.

	Different threshold to measure energy poverty		
	EP1	EP2	EP3
Panel A: OLS estimates			
Hospitalization admission	0.007	0.012	0.009
	(0.011)	(0.010)	(0.017)
R^2	0.020	0.020	0.020
Number of observations	25,428	25,428	25,428
Panel B: 2SLS estimates			
Hospitalization admission	0.333**	0.251**	0.614*
	(0.162)	(0.119)	(0.318)
Centered R^2	-0.014	-0.005	-0.045
Number of observations	25,428	25,428	25,428
Weak id.	17.279	20.827	10.265
First-stage results			
ICT Infrastructure	-0.338***	-0.448***	-0.183***
	(0.081)	(0.098)	(0.057)

Notes: EP1, EP2, and EP3 refer to energy poverty measured at thresholds of 0.33, 0.25, and 0.5, respectively. Standard errors cluster at provincial level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Weak id. refers to Kleibergen-Paap rk Wald F statistic.

To ensure the robustness of our main findings in Table 2, we conduct a series of robustness checks. First, we replace ICT infrastructure development with an alternative instrumental variable—specifically, the number of Internet users per 100 people at the provincial level. The results of this alternative specification are presented in Table 3. Consistent with our primary analysis, we observe a positive and statistically significant relationship across all three measures of energy poverty. Notably, the estimated effects in this alternative model are slightly larger compared to the main results.

Table 3. Different measures of instrumental variable.

	Different threshold to measure energy poverty		
	EP1	EP2	EP3
Hospitalization admission	0.458***	0.340***	0.750***
	(0.123)	(0.086)	(0.231)
Centered R^2	-0.046	-0.028	-0.078
Number of observations	25,428	25,428	25,428
Weak id.	22.182	28.667	14.865
First-stage results			
Number of internet users per 100 population	-0.0009***	-0.0013***	-0.0006***
	(0.0002)	(0.0002)	(0.0001)

Notes: EP1, EP2, and EP3 refer to energy poverty measured at thresholds of 0.33, 0.25, and 0.5, respectively. Standard errors cluster at provincial level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Weak id. refers to Kleibergen-Paap rk Wald F statistic.

To further validate the robustness of our findings, we explore an alternative method for constructing the MEP index. While our primary analysis assigns equal weights to each dimension following the approach of Bukari et al. (2021), we introduce an alternative weighting scheme: 0.4 for cooking, 0.3 for lighting, and 0.1 each for services, entertainment/education, and communications. This adjustment reflects the critical role of cooking in daily life, as emphasized in prior research (Feeny et al., 2021). The revised estimates, presented in Table 4, continue to show a positive and statistically significant association between energy poverty and hospitalization admissions across all three newly constructed measures.

Table 4. Different weight scale of energy poverty.

	Different weight scale of energy poverty		
	New EP1	New EP2	New EP3
Hospitalization admission	0.233**	0.225**	0.389**
	(0.111)	(0.109)	(0.195)
Centered R^2	-0.003	-0.004	-0.018
Number of observations	25,428	25,428	25,428
Weak id.	22.194	24.685	13.837
First-stage results			
ICT Infrastructure	-0.482***	-0.499***	-0.289***
	(0.102)	(0.100)	(0 .078)

Notes: EP1, EP2, and EP3 refer to energy poverty measured at thresholds of 0.33, 0.25, and 0.5, respectively. Standard errors cluster at provincial level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Weak id. refers to Kleibergen-Paap rk Wald F statistic.

4.2. Mechanisms

Table 5 examines the underlying pathways linking energy poverty to hospitalization admissions. The first pathway involves lifestyle risk behaviors, specifically alcohol and beer consumption within households over the past 30 days. Columns 1 and 2 reveal a significant association between energy poverty and increased alcohol intake. Households experiencing energy poverty consume an additional 7 liters of alcohol and 18 liters of beer over a 30-day period.

The second pathway focuses on household living standards, measured through several key indicators: access to improved drinking water, water treatment methods, toilet facilities, kitchen and toilet types, and housing materials. Each indicator is coded as 1 if improved and 0 otherwise, with detailed descriptions provided in Appendix Table A2. A composite score ranging from 0 to 5 is constructed, where households meeting at least four of these criteria (scoring 80% or above) are classified as “improved,” while others are categorized as “unimproved,” following the methodology of Karmaker et al. (2022). Column 3 of Table 5 demonstrates that individuals in energy-poor households are approximately 44% less likely to live in improved conditions.

Table 5. Possible pathways.

	Alcohol consumption (1)	Beer consumption (2)	Household's living standard (3)
EP1	6.877***	18.063***	-0.438***
	(0.648)	(3.152)	(0.045)
Centered R^2	-0.432	-1.098	-0.078
Number of observations	12,182	5,713	25,428
Weak id.	290.902	68.747	546.520
First-stage results			
ICT Infrastructure	-0.390***	-0.227***	-0.338***
	(0.023)	(0.027)	(0.014)

Notes: EP1 refers to energy poverty measured at the threshold of 0.33. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Weak id. refers to Kleibergen-Paap rk Wald F statistic.

5. Conclusions

This study examines the effects of energy poverty on hospitalization admissions in Vietnam, highlighting its relevance to Sustainable Development Goal 7 (SDG7), which advocates for universal access to affordable, reliable, sustainable, and modern energy. We adopt a multidimensional approach to measure energy poverty, utilizing data from the 2016 Vietnam Household Living Standard Survey (VHLSS) and following the methodology of Nussbaumer et al. (2012). To address potential endogeneity and identify causal effects, we employ a 2SLS regression, using provincial-level ICT infrastructure development as the primary instrumental variable. The findings indicate a statistically significant increase in hospitalization admissions linked to energy poverty. To ensure the robustness of our results, we conduct additional tests, including the use of an alternative instrumental variable (the number of Internet users per 100 population at the provincial level) and a modified construction of the Multidimensional Energy Poverty (MEP) index. Furthermore, our analysis suggests that the relationship between energy poverty and hospital admissions in Vietnam is mediated by lifestyle risk behaviors and household living conditions.

These findings carry important policy implications. In alignment with SDG7, promoting the adoption of modern and sustainable energy sources should be a priority. Investments in renewable energy infrastructure and technology can help reduce energy poverty and its associated negative health outcomes, ultimately improving public health and lowering hospitalization rates. Additionally, since lifestyle behaviors and living conditions play a role in this relationship, targeted educational campaigns can raise awareness about the significance of energy access and healthy living practices. These campaigns should also include education on the negative effects of excessive alcohol consumption and its link to stress, particularly in energy-poor communities. Furthermore, implementing community-based support programs, expanding access to affordable mental health services, and enforcing stricter alcohol regulations—such as higher taxation, advertising restrictions, and controlled sales hours—can help mitigate alcohol-related health risks. Addressing the root cause by improving household energy access and affordability will further reduce stress levels, ultimately lowering reliance on alcohol as a coping mechanism and decreasing hospitalization rates.

Appendix

Table A1. MEP Index.

Dimension	Indicator	Weight	Household is deprived if
Cooking	Modern cooking fuel	0.1	Use coal/coal briquette/firewood/farm products
	Indoor pollution	0.1	Do not have gas/magnetic/electric cooker
Lighting	Electricity consumption	0.2	Per capita electricity consumption less than 100 kW
Services	Household appliance ownership	0.1	Has no fridge
	Heating or cooling	0.1	Has no water heater and electric fan and air conditioner
Entertainment	Household appliance ownership	0.2	Has no TV (either black or color TV)
Communication	Telecommunication means	0.2	Has no phone (either landline or mobile phone)

Note: Dimensions have equal weight of 0.2. Source: adopted from VHLSS (2016) and Feeny et al. (2021).

Table A2. Definition and measurements of a household's living standard.

Indicators	Definition
Improved source of drinking water	This category encompasses various sources of drinking water that are considered improved, including tap water supplied directly to the house, public tap water, protected dug wells, protected stream water, and purchased water (in bottles, jars, or small containers).
Treated drinking water	Treated drinking water refers to water that has undergone processes to ensure its safety for consumption. This treatment can include methods such as boiling, filtration, or the use of chemical disinfectants.
Improved housing materials	Housing materials are categorized as improved when they include reinforced concrete, bricks or stones, and iron, steel, or high-quality wood components.
Improved toilet facilities	Improved toilet facilities are those that provide enhanced sanitation and hygiene. These facilities include septic or semi-septic tanks, toilets equipped with proper ventilation, and double septic tanks.
Not shared kitchen or toilet facilities	Housing accommodations are considered improved if they do not involve shared kitchen or bathroom/toilet facilities with other households.

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