Feminization of Energy Poverty in China: Contrasting Urban and Rural Experiences

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Abstract
Despite growing global interest in energy poverty and gender issues, limited research explores their intersection from a female perspective. This study examines the feminization of energy poverty in China, contrasting urban and rural experiences. Drawing on data from the China Family Panel Studies and applying mixed methods, the research finds that rural women face significantly higher levels of energy poverty than their urban counterparts. This disparity is linked to traditional Confucian gender norms, limited financial autonomy, and restricted access to education. Offering a feminist lens, the study enhances understanding of gendered energy disparities in China and proposes targeted strategies to support a more equitable and sustainable energy transition.

Keywords: Energy poverty; Gender bias; Urban-rural disparity; Confucian culture; China

1. Introduction

Promoting gender equality and access to affordable, reliable, sustainable and modern energy are two pivotal components of the Sustainable Development Goals (SDGs) outlined by the United Nations. Specifically, SDG7 calls for reducing dependence on biomass materials (carbon-based fuel like wood, leaves, straw, cow dung, coal, etc.) as the main source of cooking fuel. The progress toward achieving SDG7 has, however, been slow. As of 2023, around 2.3 billion households worldwide continue to suffer from energy poverty, lacking access to clean and efficient cooking solutions (International Energy Agency et al., 2023). Energy poverty is considered to have a woman's face (Sánchez et al., 2020). Earlier studies have revealed that the use of biomass in cooking imposes time, health, and environmental costs on households (World Economic Forum, 2022), with such costs often falling on women due to their traditional roles. For instance, Acheampong et al (2023) noted that using biomass fuels has disproportionately impacted women as they generally take on the more significant burden of household chores, including cooking and fuel collection. Moreover, energy poverty issues also affect women's well-being, as acquiring biomass fuels is time-consuming and often leads to indoor air pollution, posing significant health risks (Opoku, Kufuor, & Manu, 2021). In fact, the World Economic Forum (2021) has estimated that women are likely to spend close to 20 hours per week searching and collecting biomass fuels, whereas cooking with these fuels can take up to 4 hours per day. Furthermore, geographical inequalities in energy poverty further intensify these gendered burdens, particularly the urban-rural disparity. Research by Moniruzzaman and Day (2020) has underscored that rural woman, particularly in developing countries, face significant barriers to accessing clean and affordable energy, often due to limited infrastructure and low-income levels. These gendered responsibilities are compounded by the fact that rural communities, in comparison to urban areas, suffer from more frequent energy access disruptions, inefficient energy systems, and higher reliance on polluting energy sources (Revolve, n.d.). This phenomenon is rooted in the urban bias theory where social amenities provision and resource allocation (including energy access) disproportionately favors urban cities relative to rural communities. Moreover, rural women often have fewer opportunities for advocacy or policy engagement, leaving them more vulnerable to the negative impacts of energy poverty (Moniruzzaman & Day, 2020). As such, the urban-rural disparity in energy access not only deepens existing gender inequalities but also hinders progress toward energy justice, sustainable development, and human well-being (Scheier & Kittner, 2022).

China, as both the biggest developing economy and the world's largest carbon emitter, has committed to reducing energy poverty (Luan, Zou, & Huang, 2023). To address this issue, the Chinese government has launched a series of policy measures, such as the 'Household Biogas Project,' 'Photovoltaic Projects for Poverty Alleviation,' and 'Coal-to-electricity Project' (Shen et al., 2020). By 2013, China has achieved 100% access to electricity (World Bank, 2020), and the electricity consumption per capita has already surpassed the average level of the country's upper middle income (National Energy Administration, 2024). However, China is still facing serious challenges concerning energy accessibility, affordability, and service availability. According to Zhang et al. (2019), approximately 48.98% of Chinese households are still experiencing energy poverty, with over 400 million Chinese individuals relying

on traditional biomass and coal for cooking. The challenge is even more serious in terms of energy disparity. More than 75% of rural households primarily used coal and firewood as fuel sources (i.e., 17.1% and 58.6% with coal and biomass respectively), while 8.2% and 36.1% of households in urban and township areas used solid fuels for cooking (XX). Additionally, households using clean fuels accounted for 62.7% of the total townships, while the proportion was only 23.2% for rural areas. These facts indicate that the urban-rural disparity in energy poverty is still a pressing issue in China, which is one of the focal issues of this study.

Undoubtedly, gender inequality in the context of energy poverty is also a critical issue in China. This issue is particularly associated with the Chinese Confucian culture (Li, Leng, Hu, Cao, & Guo, 2023), which has long emphasized traditional gender roles and hierarchical social structures. As the core of traditional Chinese culture, Confucianism historically positions men as the primary decision-makers within the household, while women are largely restricted to domestic responsibilities (e.g., household chores and childcare). This cultural framework continues to influence contemporary societal norms, limiting women's access to energy resources and involvement in energy-related decisions, particularly in rural areas (Johnson et al., 2020). As such, households influenced by Confucian culture tend to exhibit gender bias and are more likely to experience energy poverty. Therefore, promoting gender equality in energy poverty requires not only an economic solution but also a deep understanding of the cultural norms that shaped gendered access to energy.

Despite the importance of gender inequality and geographical disparity in energy poverty, few studies have accounted for the geographical gender disparity and cultural norms' influence on women experience of energy poverty. We contend that such consideration is critical in ascertaining the fuller impact of energy poverty and to devise robust economic and social measures in countering the plights of women. Thus, the two main research gaps we seek to address include the following. Firstly, Gender Perspective: the general situation of women's vulnerability to energy poverty in China is still unclear, particularly the disparity in urban and rural area. Secondly, culture perspective, although the existing literature has explored the impact of culture on energy poverty, it has covered a wide range of cultures and has rarely focused on a country or region-specific culture.

Therefore, the aim of this study is to explore how energy poverty affects women in the Chinese context, with a specific focus on the disparities between urban and rural areas. It seeks to understand the risks women face in these settings and to examine how cultural norms (i.e. Confucian culture) shape women's experiences of energy poverty. By addressing these questions, this study may provide a nuanced understanding of the intersection between gender, culture, and energy poverty, contributing to more equitable energy policies and practices in China. This study contributes to the following aspects. First, this paper integrates feminization and energy poverty into a unified research framework. Accordingly, this paper can better analyze the factors of household energy poverty from the perspective of female. To the best of current knowledge, few studies have explored the situation regarding the feminization of energy poverty. Second, the possible factors (e.g., age, education level, financial status) concerning the feminization of energy poverty are captured. Third, the feminist approach can enhance our co. Therefore, this study adopts a feminist perspective while considering energy systems will establish the structure for creating a fair and equitable transformation in the energy sector. Understanding gender in energy concerns may help create alternatives to a more equitable and sustainable energy framework. The remainder of this study proceeds as follows. **Section 2** presents the background of this research, which includes a review of the relevant literature and the theoretical foundation guiding the study. **Section 3** introduces the data sources and empirical methodology. **Section 4** shows and discusses the empirical results of this study. **Section 5** offers further discussion based on qualitative data. **Section 6** concludes and provides policy implications.

2. Literature Review

2.1. Feminization of Energy Poverty

Research on energy poverty and gender dynamics, particularly in the Global South (Listo, 2018; Petrova & Simcock, 2019), highlights the specific vulnerabilities faced by women. While existing studies have recognized the feminization of energy poverty (Bartiaux et al., 2018), comprehensive evaluations remain limited, especially in Asian contexts. Wilson (2018) reframes feminization not as a purely feminist concept, but as a promising analytical lens to understand how gender shapes energy poverty, a perspective especially relevant in countries like China. The concept of feminization of energy poverty aligns with Chant's (1998, 2006, 2013) broader theory of feminization of poverty, which underscores women's lower income levels, their disproportionate burden as household heads, and their greater exposure to long-term poverty. These patterns are echoed in studies across both developing

(Sovacool et al., 2013; Winther et al., 2018) and developed countries (Fraune, 2015), reinforcing the need for gender-sensitive energy policies that prioritize care, health, and equity (Wilson, 2018; Bell et al., 2020).

Evidence shows that rural women are particularly affected. Cecelski (1995) and Bhattasali (2005) document the physical toll of traditional energy use, with women often walking long distances to collect firewood and facing severe indoor air pollution—comparable to inhaling the smoke of 20 cigarettes daily. These conditions underscore the urgency of integrating feminist perspectives in energy transition strategies, especially in rapidly developing nations like China.

2.2. Energy Poverty and Regional Disparities in China

Energy poverty in China exhibits pronounced disparities across urban-rural divides and regional geographies, with rural households and those in central and western regions disproportionately affected (Zhang et al., 2019; Cai et al., 2021; Zhao et al., 2022). For example, while 15% of urban families rely on solid fuels for cooking, the figure rises to 52% in rural areas. Moreover, recent studies underscore the growing regional divide in energy poverty levels, necessitating a more nuanced understanding of spatial variations (Lu et al., 2022; Wan et al., 2024).

Although much of the existing literature focuses on rural energy poverty, less attention has been given to identifying vulnerable groups across both urban and rural contexts (Zhang et al., 2023). This gap is particularly salient in light of China's unique geographical, climatic, and resource endowment differences, which shape its energy poverty landscape in ways distinct from other countries (Wang et al., 2017; Lin & Wang, 2020).

Cultural factors—especially those rooted in Confucian traditions—intersect with socioeconomic dimensions to exacerbate gendered energy poverty. Confucian norms, which historically restrict women's autonomy through principles such as the "three submissives" and "four virtues," limit female participation in decision-making, financial independence, and educational access (Tsai, 2006; Li et al., 2023). These constraints are particularly pronounced in rural areas, where Confucian influence is stronger, and women often bear greater childcare burdens, further limiting their income-generating opportunities (Mijnheer, 2023).

While urban women are not immune to gender biases, their relatively better access to education and employment enhances their economic agency and household decision-making power. Nonetheless, the broader link between Confucianism and energy poverty in China remains underexplored, representing a critical gap in the literature on culturally embedded energy inequalities (Chaudhry & Shafiullah, 2021).

2.3. Social Role Theory and Confucian Cultural Norms

This study employs social role theory, integrated with Confucian cultural norms, to examine how entrenched gender roles contribute to the feminization of energy poverty in China. Social role theory explains how gendered behaviors are shaped and sustained, particularly in rural households where Confucian values prevail (Tang et al., 2020). These values promote hierarchical family structures and the "three submissions" principle, which constrain women's agency and reinforce their economic dependency.

Confucianism assigns women primary responsibility for domestic tasks such as cooking and heating—activities that often rely on traditional, inefficient energy sources (Tsai, 2006). In rural areas, where modern energy access is limited and women have lower levels of education and financial autonomy, their exclusion from household energy decisions further increases their vulnerability to energy poverty.

Framing this within the feminization of energy poverty, the study highlights how the gendered division of labor and restricted decision-making power intensify women's energy-related burdens. By embedding Confucian values into the analysis, the framework reveals how cultural norms shape not only gender roles but also societal expectations around women's involvement in energy management. While urban women benefit from greater autonomy due to improved access to education and employment, rural women remain more constrained by tradition.

This combined framework—linking social role theory, Confucian culture, and feminization of energy poverty—offers a culturally grounded explanation for why rural women in China face disproportionate energy hardships. It supports the study's broader aim to identify socio-cultural drivers of energy poverty and inform policy interventions that promote gender equity and inclusive energy access.

3. Data and Methodology

3.1. Data sources

We collected data from two sources: a nationwide survey and in-depth interviews. The nationwide survey utilized in this study is the China Family Panel Studies (CFPS). CFPS is a nationally representative annual longitudinal survey that examines Chinese communities, families, and individuals, with a focus on the economic conditions and well-being of the population. The data covers economic activities, education outcomes, family dynamics and relationships, migration, and health for 25 provinces in mainland China (exclude Xinjiang, Tibet, Inner Mongolia, Ningxia, and Qinghai), which represent 95% of China's population. CFPS has been widely used to explore energy poverty in China, since it collects information on household fuel usage and energy expenditures related to heating, cooking, and other purposes (Li et al., 2023; Zhang, D., Li, J., & Han, P., 2019). For this study, we follow in the spirit of Li et al., (2023) and rely on the 2018 wave which is the most recent to construct our cross-sectional energy usage and gender disparities variables. The choice of 2018 wave is due to data availability and to align with our research focus (i.e. gender disparities in energy poverty), only data pertaining to women were retained for the analysis. Following the data filtering process, we ultimately employed a sample of 18,452 female-headed households.

In addition to the survey, we conducted a total of 43 in-depth, semi-structured, face-to-face interviews in Jiangsu, Zhejiang, and Shanghai between January and April 2024. The interview respondents include 20 women; 20 husbands of these women, and 3 related experts. Each interview lasted 60-100 minutes. We recorded and transcribed all the interviews. Data from the interviews were qualitatively coded using Atlas.ti, where we developed a coding framework and coded each interview.

The purpose of these interviews is to extend our quantitative findings by providing a more holistic understanding of energy poverty, considering the influence of socio-cultural factors that may not have surfaced in the statistical analysis but are crucial to addressing the issue comprehensively. This is indeed, lacking in the extant literature. We acknowledge that while these interviews may not be representative of the entire population of Chinese women, achieving representation was not our main goal. Instead, we hope to draw insight from this sample, which will be critical for comprehensive policy action towards tackling the gendered impact of energy poverty issues among rural women in China.

3.2. Variable selection

Table 1 outlines the definitions of the key variables used in this study. The dependent variable is energy poverty. Existing studies typically characterize household energy poverty based on energy accessibility and affordability (Li et al., 2023; Zhang et al., 2019; Llorca, Rodríguez-Álvarez, & Jamasb, 2020; Jayasinghe, Selvanathan, & Selvanathan, 2021). To effectively assess household energy poverty, we develop the following three proxy variables by integrating the dimensions of accessibility and affordability in the spirit of Zhang et al., (2019); Lloca et al., (2020); and Jayasinghe et al., (2021).

Energy accessibility is denoted as *EP1*, which reflects the type of fuel used for cooking by the respondents. Following Zhang et al. (2019), if a household primarily relies on solid fuels, such as firewood, coal, or charcoal, for cooking, it indicates limited access to modern energy sources. **Energy affordability** is measured as *EP2*, which captures the proportion of household income spent on energy. A commonly used threshold, known as the "Ten Percent Rule", categorizes households as energy-poor if their energy expenditure exceeds 10% of their total income (Zhang et al. (2019; Boardman, 1991). However, Hills (2011, 2012) argued that this rule could misclassify affluent households with high energy consumption as energy poor. To address this, Okushima (2016) proposed the adjusted Ten Percent Rule (aTPR), applying the 10% threshold to households within the bottom 30% of the income distribution. Another approach, known as After Energy Cost Poverty (AECP), defines energy poverty based on the household's remaining income after subtracting energy expenses. If the remaining income is less than 60% of the sample median, the household is considered to lack energy affordability (Hills, 2011). In this study, we adopt the AECP method to define energy affordability (*EP2*). Given that energy poverty in China reflects characteristics of

both developing countries (dependence on solid fuels) and developed countries (energy burden) (Wang and Lin, 2022), this study, following Zhang et al. (2019) and Luan et al. (2023), constructs a composite index (*EP*). We employ an equal-weight method to construct a multidimensional index by combining accessibility and affordability. Specifically, if a household has no issue with energy accessibility or affordability, *EP* is assigned a value of 1. If there is energy poverty in either aspect, *EP* is assigned a value of 2. *EP* is assigned a value of 3 for households experiencing severe energy poverty, defined as deficiencies in both energy accessibility and affordability.

Our independent variable captures the female population residing in both rural and urban locations, with the variable being represented as a dummy variable. The variable *urban_ruralfemale* is assigned a value of 1 if the female is in urban regions, and a value of 0 if she is not. Specifically, based on the person's identification and the identification of their respective families, the person was matched with the family, retaining only the data pertaining to females. For the control variables, we select age, schooling years, or education, which directly affect economic opportunities and knowledge of energy poverty following Wang and Lin, 2022; Luan et al., 2023). We also control for other socio-economic and demographic factors including personal income, total household assets, marital status and family harmony based on the literature (Dubois and Meier, 2016; Deller and Waddams, 2018; Llorca et al., 2020).

Table 1 Variable and their definitions

Variables		Label	Definition
Energy Poverty	Accessibility	EP1	Solid fuels (such as firewood and coal) for cooking, EP1 =1, others (such as gas/liquid, natural gas, solar energy, electricity) for cooking, EP1= 0
	Affordability	EP2	If remaining income after energy costs is < 60% of median income, EP2 = 1, others EP2 = 0
	Multidimensional	EP	EP = 1 if EP1 = 0 and EP2 = 0; EP = 2 if EP1 =1 or EP2 =1; EP = 3 if EP1 =1 and EP2 = 1
Locations of Female Householders		Urban_ruralfemale	1 = urban females, 0 = rural females
Age		Age	The age of the female householders. (years)
Education		Edu	The schooling years of the female householders. (years)
Personal Income		lnFincome	The individual's annual income generated from all personal sources, including wages, business profits, and other financial earnings. (in logs)
Total Asset of the Households		lnTotal_asset	The cumulative value of all assets owned by the households (real estate, vehicles, savings, investments, and other property). (in logs)
The Marital Status of the females		Marital_Status	The marital status of females, such as single, married, divorced, or widowed, rating from 1 to 5.
The Happiness of the females		Family_Harmony	The subjective happiness or harmony experienced by females within their family or household environment, rating from 1 to 5.

3.3. Descriptive statistics

The descriptive statistics for all variables are presented in Table 2 with a total of 17,004 households in our cross-sectional full sample. The average of EP (multidimensional Energy poverty proxy) is 0.278 with a standard deviation of 0.357, suggesting clear variability in the degree of energy poverty in the sample. EP1 (proxy for energy accessibility) and EP2 (proxy for energy affordability) show an average of 0.282 and 0.274 respectively with standard deviation of 0.450 for EP1 and 0.446 for EP2. These indicates that approximately 28.2% of households still rely on firewood or charcoal as cooking fuel mainly reflecting household energy accessibility concerns while at the same time, 27.4% of households face severe energy burdens, with their energy expenditures exceeding 10% of household income, reflecting energy affordability issues. Furthermore, approximately 49.1% of women live in

urban areas, while the rest reside in rural areas. This ratio is close to 1:1, indicating that the distribution of female samples in urban and rural areas is relatively balanced for the analysis. Given the dominant role of women in household energy use, this urban-rural disparity may have a significant impact on the two dimension of energy poverty. The average age of female householders is approximately 47.7 years, with a mean education level of 8.6 years. In terms of economic and social characteristics, the average personal income (fincome) is 10.955 with a substantial standard deviation, reflecting wide income disparities across the sample. Total household assets (total_asset) average 12.679 but exhibit high variability indicating large differences in household wealth levels. Marital status (Marital_Status) has an average value of 2.171, suggesting that a majority are married or in stable partnerships. Family harmony (Family_Harmony) has an average score of 4.657, showing relatively high levels of perceived family well-being among female respondents.

Table 2 Summary statistics

Variables	Samples	Mean	Min	Max	SD
EP	17004	0.278	0.000	1.000	0.357
EP1	17004	0.282	0.000	1.000	0.450
EP2	17004	0.274	0.000	1.000	0.446
Urban_ruralfemale	17004	0.491	0.000	1.000	0.500
Age	17004	47.673	10.000	100.000	18.039
Edu	7837	8.565	0.000	22.000	5.045
Age2	17004	2598.123	100.000	10000.000	1801.025
Edu2	7837	98.813	0.000	484.000	79.154
Ln(fincome)	17004	10.955	0.000	16.030	1.105
Ln(total_asset)	15712	12.679	0.000	17.737	1.392
Marital_Status	14989	2.171	1.000	5.000	0.934
Family_Harmony	14989	4.657	1.000	5.000	0.690

3.4. Identification strategies

This study aims to examine the association between feminization and household energy poverty and to further explore the internal mechanisms. Our empirical model can be expressed as follow:

$$\log\left(\frac{P(EP \le j)}{1 - P(EP \le j)}\right) = \theta_j - (\beta_1 urban\_ruralfemale + \gamma control\_variables) + \varepsilon$$

where EP is the explained variable, energy poverty; the explanatory variable *urban_ruralfemale* represents the location of residence of women, with urban-rural division being the part of the focus of this study. According to the social role theory of gender division of labor, women usually bear the main responsibility for household energy use, especially in the selection of cooking fuels. Therefore, the differences in the identity of urban and rural women may significantly affect the level of energy poverty in their families.

4. Empirical results

4.1. Correlation Analysis

The correlation analysis is shown in **Table 3**. The correlation coefficient between energy poverty (EP) and the urban-rural women variable (*urban_ruralfemale*) is -0.394, indicating a moderate negative relationship. This suggests that females living in rural areas are more likely to experience higher incidences of energy poverty compared to their urban counterparts. This preliminary finding aligns with Listo (2018) and Dutta and Sahu (2024) which have documented that rural populations, particularly women, tend to face higher energy poverty burdens than their urban counterparts due to limited access to modern cooking energy sources. We found the correlation coefficient between energy poverty and age and its squared term (age^2) to be close to zero (0.072), which indicates a weak linear relationship between age and energy poverty. This suggests that age alone may not be a significant predictor of energy poverty, and the role of age might be more complex, requiring the exploration of nonlinear or interaction effects to fully understand its impact. A significant negative correlation is found between energy

poverty and years of schooling (Edu), with a coefficient of -0.346. This finding indicates that individuals with lower levels of education are more likely to experience energy poverty, implying that education can play an important role in alleviating energy deprivation. Furthermore, the correlation between the squared term of education (Edu^2) and energy poverty is identical, which implies that the relationship between education and energy poverty may be non-linear, where increases in education levels may progressively reduce the risk of energy poverty. The positive correlation between the urban-rural women variable and education level (0.322) suggests that individuals in urban areas generally attain higher levels of education. This result is consistent with patterns in socio-economic development, where urban residents typically have greater access to educational resources and opportunities (Li et al., 2023). Additionally, the negative correlation between age and education level (-0.519) indicates that older individuals tend to have lower levels of education. This generational difference likely reflects varying access to education, with older cohorts having had fewer opportunities compared to younger generations, who benefit from improved educational systems. Income-related variables also show strong negative correlations with energy poverty: personal income (fincome) has a coefficient of -0.636, while total household assets (total_asset) show a coefficient of -0.494. These results indicate that households with higher incomes and assets are less likely to experience energy poverty, underscoring the critical role of financial resources in securing energy access (Bersisa, 2019). Lastly, the variables Marital_Status and Family_Harmony exhibit minimal correlation with energy poverty, with coefficients close to zero (-0.000 and -0.010, respectively). This suggests that these social factors may not have a direct impact on energy poverty as previously supposed, although they may still contribute indirectly through interactions with other socio-economic factors.

Overall, the correlation analysis reveals that urban-rural location, education, and economic resources are important variables related to energy poverty. Education, in particular, appears to be a key factor, as it is negatively correlated with energy poverty and positively associated with urban residency, which generally facilitates better energy access. While age shows a weak direct relationship, its interaction with education may provide insights into generational differences in energy poverty. These findings lay the groundwork for subsequent empirical analysis, where we employed an ordered logistic regression model to further investigate the specific impacts of these variables and their predictive power in explaining energy poverty.

Table 3 Correlation Analysis -- Spearman's rank correlation coefficients

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) EP	1.000									
(2) urban_ruralfemale	-0.394	1.000								
(3) age	0.072	-0.021	1.000							
(4) age2	0.072	-0.021	1.000	1.000						
(5) Edu	-0.346	0.322	-0.519	-0.519	1.000					
(6) Edu2	-0.346	0.322	-0.519	-0.519	1.000	1.000				
(7) fincome1	-0.636	0.311	-0.067	-0.067	0.370	0.370	1.000			
(8) total_asset	-0.494	0.391	-0.018	-0.018	0.347	0.347	0.592	1.000		
(9) Marital_Status	-0.000	-0.001	0.649	0.649	-0.334	-0.334	0.020	0.006	1.000	
(10) Family_Harmony	-0.010	-0.009	0.004	0.004	-0.016	-0.016	0.017	0.015	0.012	1.000

Spearman rho = 0.012

4.2. Baseline results

Table 4 presents the benchmark results based on the ordered logistic regression models, which progressively incorporate additional control variables to analyze their influence on energy poverty (EP). Column (1) includes only the main independent variable, urban_ruralfemale, while Columns (2) and (3) introduce demographic and socioeconomic variables to progressively adjust the model. In all models, the coefficients for the urban-rural female variable remain negative, and statistically significant at the 1% level ($p < 0.001$), with values of -1.6526,

-1.3534, and -1.2098 in columns (1), (2), and (3) respectively. This finding indicates that women residing in rural areas experience significantly higher levels of energy poverty compared to the urban groups. These results reinforce the previous correlation analysis, highlighting the profound impact of urban-rural disparities on energy poverty. To better visualize the impact of the urban-rural female variable on energy poverty, Figure 1 presents the predictive margins with 95% confidence intervals for the probabilities of experiencing different levels of energy poverty. As shown in the figure, the probability of avoiding energy poverty (red line) increases significantly while the probabilities of experiencing moderate (blue line) or severe energy poverty (green line) are substantially higher for rural females. This further supports our regression results, showing that women living in urban areas are less likely to face energy poverty.

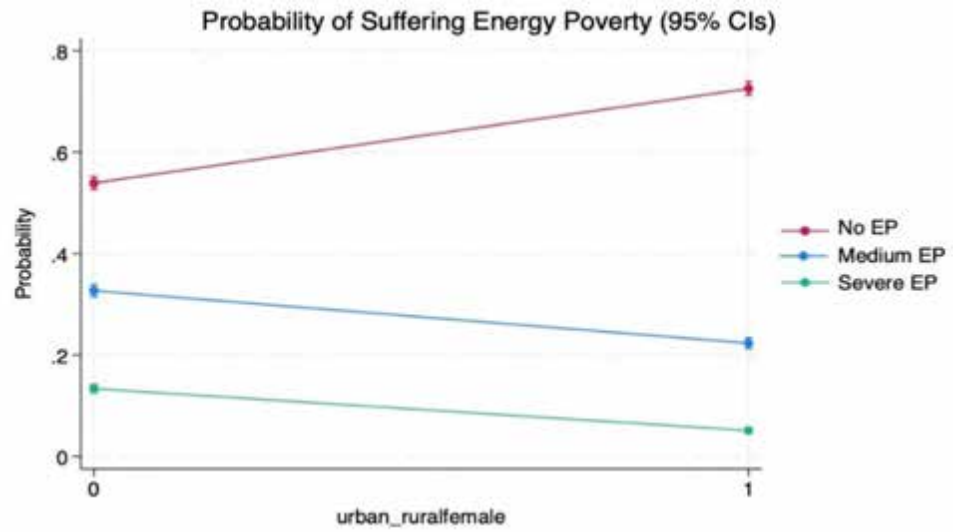

Fig.1 Marginalized plot for energy poverty and female in urban and rural areas

In column (2) we introduce age and education variables, along with their squared terms, to account for potential nonlinear effects. The coefficient for age is -0.0703 and statistically significant ($p < 0.001$), while its squared term (age^2) shows positive and statistically significant coefficient of 0.0006 ($p < 0.001$), indicating existence of a nonlinear relationship. This suggests that while energy poverty initially decreases with age, it begins to increase again as individuals grow older, potentially reflecting greater energy needs or financial constraints among older populations. Unlike most of the extant studies which found a more linear or straightforward impact of age on energy poverty, our results have shown that an inverse U-shape relationship might exist when one accounts for older age groups in energy poverty studies. Thus, our findings suggest a complex relationship between age and energy poverty, warranting further exploration of interaction effects or segmentation by age groups. Next, the Education level (Edu) also demonstrates a strong, and statistically significant negative association with energy poverty, with coefficients of -0.1546 and -0.1348 in columns (2) and (3) respectively ($p < 0.001$). This relationship suggests that higher education levels contribute significantly to reducing energy poverty, likely due to better economic opportunities or return on education and access to energy-efficient resources among educated individuals. Interestingly, the squared term for education (Edu^2) shifts from insignificant in column (2) to positive and significant (0.0027, $p < 0.05$) in column (3), indicating a more complex, possibly diminishing effect of education at very high levels. In column (3), we account for additional economic and social variables such as personal income (fincome) and total household assets (total_asset). Both variables show highly significant negative coefficients (-0.0000, $p < 0.001$), further affirming that economic stability and financial resources play a crucial role in mitigating energy poverty. More speficially, the results imply that households with higher incomes and assets are less likely to experience energy poverty, highlighting the importance of economic capacity in ensuring energy access and affordability. The variables Marital_Status and Family_Harmony do not show significant associations with energy poverty. This possibly suggests that, unlike economic factors, social dynamics may have a less direct impact on energy poverty.

The cut-off values (cut1 and cut2) provide thresholds for categorizing the levels of energy poverty. Each model iteration shows improvements in Pseudo R-squared, values, indicating a better fit as more control variables are

included. These improvements in model fit demonstrate that the inclusion of demographic and socioeconomic variables such as age, education, income, and assets significantly enhance the model's ability to capture variations in energy poverty. This progressive enhancement of fit metrics underscores the importance of a comprehensive set of control variables in accurately modeling the determinants of energy poverty among households. Overall, our baseline results emphasize the significant influence of urban-rural disparities, age, education, and financial resources on energy poverty. In particular, the complex relationships involving age and education suggest that addressing energy poverty may require targeted interventions based on age-demographic and economic characteristics.

Table 4 Benchmark results

	(1)	(2)	(3)
	EP	EP	EP
EP			
urban_ruralfemale	-1.6526***	-1.3534***	-1.2098***
	(0.0332)	(0.0536)	(0.0609)
age		-0.0703***	-0.0446***
		(0.0083)	(0.0094)
age^2		0.0006***	0.0004***
		(0.0001)	(0.0001)
Edu		-0.1546***	-0.1348***
		(0.0167)	(0.0184)
Edu^2		-0.0002	0.0027**
		(0.0011)	(0.0012)
lnfincome			-0.0000***
			(0.0000)
lntotal_asset			-0.0000***
			(0.0000)
Marital_Status			-0.0005
			(0.0439)
Family_Harmony			-0.0609
			(0.0383)
cut1	-0.4639***	-2.9893***	-4.3632***
	(0.0217)	(0.1990)	(0.2902)
cut2	1.3136***	-1.0927***	-1.9936***
	(0.0250)	(0.1967)	(0.2846)
Pseudo R-squared	0.0847	0.1382	0.2813
Chi2	2721.3265	1901.0797	3678.7069
log-likelihood	-14701.4660	-5925.4920	-4700.1492

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: This table shows the results of the baseline regression using an ordered logistic model to examine the determinants of energy poverty (EP) among households. Column (1) of this table shows the results of the first regression model, which only contains the independent variable urban_ruralfemale. Column (2) expands the model by incorporating demographic variables, specifically age and education, along with their squared terms to capture potential nonlinear effects. Column (3) further extends the model with additional economic and social control variables, including personal income, total assets, marital status, and family harmony. The coefficients for each variable represent their estimated impact on energy poverty, with negative coefficients indicating a reduction in the likelihood of experiencing energy poverty. The **Cut1** and **Cut2** are the threshold parameters for the ordered logit model. They separate the different categories of energy poverty (e.g., no energy poverty, moderate energy poverty, and severe energy poverty).

4.3. Robustness checks

To enhance the reliability of the empirical results, the robustness of the estimation results given below. It employs the ordered probit (***oprobit***) model as an alternative to the baseline ordered logistic (***ologit***) model. While both models are appropriate for analyzing energy poverty problem, they differ in their underlying statistical assumptions. Specifically, the ordered logistic model assumes a logistic distribution for the error term, whereas the ordered probit model assumes a standard normal distribution. These differences in distributional assumptions allow for a thorough test of the stability of the results. The findings of this robustness analysis are presented in **Table 5**.

The results indicate that the primary conclusions remain consistent across the two model specifications. The independent variable urban_ruralfemale retains its negative and statistically significant effect on EP, although the magnitude of the coefficient is smaller under the ordered probit model. The demographic control variables, including age and education level, exhibit similar results across the two models. It also suggests that elder and less educated female householders are more likely to experience energy poverty, though this effect could diminish at older ages as indicated by the positive coefficient of the quadratic term (age2, education2). Plus, the control variables related to economic state remain highly significant and negative in both models, highlighting the importance of household financial capacity in mitigating energy poverty problem. On the other hand, those related to social well-being continue to lack statistical significance, potentially suggesting limited influence on energy poverty, which is left to be further discussed in the next qualitative analysis section.

Regarding the fitness of the model, the R^2 values and log-likelihood statistics demonstrate comparable levels of explanatory power across the two different models. Slight improvements in the R2 values in the ordered probit model suggest a marginally better fit when using a normal distribution assumption. Additionally, the threshold parameters (Cut1 and Cut2) in the ordered probit model differ from those in the baseline model, which is consistent with the theoretical differences in the error term distributions. However, these differences do not alter the substantive interpretation of the results.

Table 5 Robustness Analysis

	(1)	(2)	(3)
	EP	EP	EP
EP			
urban_ruralfemale	-0.9901***	-0.7971***	-0.6643***
	(0.0192)	(0.0308)	(0.0351)
age		-0.0424***	-0.0170***
		(0.0048)	(0.0059)
age^2		0.0004***	0.0001*
		(0.0001)	(0.0001)
Edu		-0.0897***	-0.0788***
		(0.0096)	(0.0109)
Edu^2		-0.0002	0.0016**
		(0.0006)	(0.0007)
lnfincome			-0.6581***
			(0.0176)
lntotal_asset			-0.2129***
			(0.0147)
Marital_Status			-0.0160
			(0.0263)
Family_Harmony			0.0014
			(0.0245)
/			
cut1	-0.2724***	-1.7692***	-10.8590
	(0.0132)	(0.1153)	(.)
cut2	0.7719***	-0.6728***	-9.4019***
	(0.0142)	(0.1142)	(0.0283)
Pseudo R-squared	0.0855	0.1406	0.3142
Chi2	2745.2202	1933.2275	3960.3626
log-likelihood	-14689.5192	-5909.4182	-4322.6643

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note: This table shows the results of the robustness analysis using an ordered probit model to examine the determinants of energy poverty (EP) among households. Column (1) of this table shows the results of the simplest model, which only includes the independent variable *urban_ruralfemale*. Column (2) expands the analysis by incorporating demographic variables, specifically age and education, along with their squared terms to capture potential nonlinear effects. Column (3) further extends the model with additional economic and social control variables, including personal income, total assets, marital status, and family harmony. The coefficients for each variable represent their estimated impact on energy poverty, with negative coefficients indicating a reduction in the likelihood of experiencing energy poverty.

The **Cut1** and **Cut2** are the threshold parameters for the ordered probit model, separating the different categories of energy poverty (e.g., no energy poverty, moderate energy poverty, and severe energy poverty). The pseudo R-squared values and log-likelihood statistics indicate improved model fit as additional variables are included across the results, which helps to confirm the robustness of the results.

In conclusion, the robustness analysis confirms that the key findings of the baseline ordered logistic model are not sensitive to the choice of model specification. The consistent direction, significance, and interpretation of the coefficients across both models provide strong evidence for the stability and reliability of the conclusions regarding the determinants of energy poverty. These results enhance the credibility of the baseline analysis and further support the role of demographic and economic factors in shaping household energy poverty outcomes.

5. Results and discussions

The quantitative analysis reveals that factors such as urban-rural residency, age, education, and financial resources significantly influence energy poverty among female-headed households, while socio-cultural variables like marital status and family harmony show no direct statistical impact. However, these factors may still shape energy-related behaviors and coping strategies in indirect ways. To capture these nuanced dynamics, the following qualitative analysis explores how cultural norms, household roles, and societal expectations affect women's experiences of energy poverty, offering a more holistic understanding that complements the quantitative findings.

5.1. Limited financial independency

Interviews reveal a consistent perception among participants: women experience and cope with energy poverty differently from men. This disparity is largely attributed to the gendered division of labor, where women disproportionately bear responsibility for childcare and domestic work. As a result, they spend more time at home and have reduced access to income-generating opportunities, increasing their exposure to energy poverty (Mijnheer, 2023). One respondent observed: "*Women persist in shouldering the primary obligation of caring for their kids... while their husbands chase careers.*" (Female respondent 03). These dynamics are further exacerbated in rural areas, where traditional Confucian cultural norms remain deeply entrenched. Principles such as the "three submissives" and "four virtues" restrict women's autonomy in household decision-making, especially concerning energy use (Li et al., 2023). Household energy decisions, particularly those related to fuel choices and appliance purchases, are often made solely by men. "*When I try to talk to my husband about our enhanced energy requirements... he reprimands me.*" (Female respondent 07) This reflects the broader gender hierarchy embedded in Confucian family structures (Van, 2019).

By contrast, urban households—where Confucian influence has diminished due to socioeconomic development and shifting gender norms—offer women greater participation in household energy management. Women in these contexts often have access to financial resources and information, facilitating more equitable decision-making. As one urban participant noted: "*When I talk to my husband... he listens and tries to understand... we could discuss together how to make our home more energy efficient.*" (Female respondent 11)

Rural women also reported significant health concerns related to traditional fuels, such as smoke inhalation and heat exposure. Many advocated for adopting safer alternatives, like electric rice cookers, which improve efficiency and reduce hazards. However, resistance from male family members—grounded in perceptions of tradition, cost-effectiveness, and skepticism toward change—remains a barrier. "*Smoke poses no issue... our mums used firewood... Why is she unable to do it?*" (Male respondent 08). Furthermore, intra-household dynamics, particularly the influence of in-laws, pose additional challenges. Women often lack support from their husbands, who prioritize familial harmony and parental authority over spousal concerns. "*Whenever I mention replacing the gas range... he ends up resenting me... he always prioritises making [his mother] happy.*" (Female respondent 02) Nevertheless, the study also finds evidence of transformation in urban areas. Women who contribute financially to the household tend to wield greater influence over energy decisions, and younger husbands are more open to shared decision-making, regardless of their wives' income status. These findings suggest that shifting gender norms, financial autonomy, and intergenerational change are gradually enhancing women's agency in energy management, offering a pathway toward more equitable outcomes in energy access and use.

5.2. Limited education opportunities

Confucian cultural norms have historically constrained women's access to education, particularly in rural China,

due to deeply rooted beliefs about women's intellectual inferiority (Tsai, 2006). These norms reinforced traditional gender roles by relegating women to the domestic sphere and discouraging formal education, resulting in long-lasting effects that continue to shape gendered vulnerabilities to energy poverty. Less-educated rural women often lack awareness of energy-efficient technologies and available support systems, leaving them particularly exposed to energy-related hardships. The insularity of rural communities further exacerbates these challenges. Many women remain unaware of external assistance mechanisms due to limited exposure and economic barriers such as consultation fees or transportation costs. These constraints discourage help-seeking behavior, reinforcing passivity in the face of energy deprivation. As one expert noted, "*I am aware of a collective of individuals who, due to feelings of shame or apprehension about incurring supplementary expenses, are reluctant to be linked with the issue of energy poverty... leaving us unable to assist them.*" (Expert 03)

Education plays a pivotal role in enabling women to adopt modern energy solutions. Studies show that women with limited educational backgrounds are less inclined to utilize technologies such as solar water heaters, improved cooking stoves, LED bulbs, or water purification systems—despite their proven effectiveness in reducing energy poverty (Paudel et al., 2018; Belmin et al., 2022). "*When I first heard about solar water heaters, I thought they were too complicated to maintain... why change now?*" (Female respondent 06)

The continued influence of Confucian gender roles further delays the adoption of modern views, particularly in rural areas. Li et al. (2023) found that less-educated female householders are more likely to retain traditional energy practices, reinforcing their energy vulnerability. National survey data supports this trend: between 2010 and 2016, use of modern cooking energy increased modestly in rural households (from 1.30% to 3.90%) and more substantially in urban households (from 23.43% to 30.02%) (Adusah-Poku & Takeuchi, 2019). These figures underscore the persistent resistance to change in rural communities, where Confucian values remain deeply embedded. "*My husband's mother still insists on using firewood, saying it's what she knows and trusts.*" (Female respondent 08)

This cultural inertia presents significant barriers to the uptake of modern energy practices. Women are expected to maintain traditional domestic routines, and without adequate education or decision-making power, many lack the confidence or means to initiate change. As one respondent shared, "*When I realized how much energy our old heater was wasting... I found a much more efficient model. I knew it would save us money in the long run, so we made the switc.*" (Female respondent 11). Such proactive behavior, however, remains uncommon in rural contexts.

In contrast, urban women generally benefit from higher educational attainment, broader access to information, and greater financial autonomy. These conditions foster a more proactive approach to energy management. Empowered by education, urban women are more likely to seek out and adopt energy-efficient technologies, thereby reducing their exposure to energy poverty. Nonetheless, the urban-rural divide in energy awareness persists. As an expert noted, "*We had a meeting in the village about switching to cleaner energy, but only a few of the women attended... They feel they're doing just fine with what they've always used.*" (Expert 05)

In sum, Confucianism's enduring emphasis on women's subordinate roles and limited education continues to influence patterns of energy poverty in rural China. Addressing this issue requires not only technical interventions but also culturally informed strategies. Promoting energy literacy and empowering women through targeted educational programs are essential steps toward disrupting the intergenerational cycle of energy poverty, particularly in areas where traditional values remain dominant.

5.3. Mental health impacts of both factors

The mental health of rural women in China is deeply affected by the intersection of energy poverty and limited educational opportunities, both of which are shaped by enduring Confucian cultural norms. Confucianism reinforces traditional gender roles and the subordination of women, confining them to domestic responsibilities and restricting access to education. Consequently, rural women are disproportionately affected by energy poverty, a condition that not only undermines physical health but also imposes significant psychological burdens. In rural areas, the reliance on inefficient and hazardous energy sources—such as firewood and biomass—exacerbates this vulnerability. Prolonged exposure to smoke and odors from these fuels harms physical well-being and contributes to chronic psychological stress. The responsibility for managing household energy within

tight constraints often leads to anxiety, especially as women are expected to uphold familial well-being without the necessary resources. Confucian values amplify these pressures, reinforcing women's perceived duty to the home while limiting their autonomy. One woman remarked, "*I never imagined that I would be stuck using these old methods to keep our home warm... It's as if I'm trapped in the past, with no way out.*" (Female respondent 16) The absence of educational opportunities further compounds women's sense of powerlessness. Many lack the knowledge and confidence to seek alternatives or access support, leaving them emotionally isolated. The mental toll intensifies when women feel they cannot meet familial expectations, particularly under constant criticism or blame. As one participant shared, "*If the electricity bill is too high, he blames me, even though I'm just trying to keep the house comfortable for the children. It's exhausting.*" (Female respondent 09)

This psychological strain often leads to reduced self-confidence and deep emotional distress, especially in cultural settings where failure to fulfill domestic duties is associated with shame. The risk of depression and other mental health disorders increases under these conditions. Cultural norms discourage women from discussing their struggles or seeking help, for fear of being perceived as weak. "*They don't want to be seen as unable to handle their household duties. It's this feeling of shame that often prevents them from seeking help.*" (Expert 01)

Confucian traditions also inhibit women's capacity to advocate for change or adopt new energy practices. In many cases, women internalize their culturally defined roles, adhering to outdated energy use practices despite the harm they cause. "*My mother-in-law insists that we keep using the old stove, saying it's what we know and trust. It's hard to convince anyone otherwise.*" (Female respondent 08)

These cultural and psychological pressures are further exacerbated by familial discord. Many women report feeling incapable of satisfying their husbands' expectations, leading to emotional fatigue and withdrawal. A lack of emotional and social support compounds this experience, impairing women's ability to respond proactively to their circumstances. "*This society has a way of making us women feel completely powerless... I occasionally use the air conditioning to keep my home at a comfortable temperature. My husband was pleased with it initially, but when he saw the electricity bill, he scolded me again. There isn't much to discuss.*" (Female respondent 09)

Ultimately, the psychological effects of energy poverty are not merely the result of material deprivation but are deeply entangled with cultural and educational barriers. Addressing these challenges requires more than just expanding access to clean energy technologies. It also necessitates efforts to confront and transform the Confucian cultural norms that restrict women's roles, discourage education, and suppress their voices. A culturally informed, gender-sensitive approach to both mental health and energy policy is essential to breaking this cycle of vulnerability and enabling rural women to regain agency over their lives.

6. Conclusions and implications

Based on China Family Panel Studies (CFPS) data, this study finds that rural women are significantly more affected by energy poverty than their urban counterparts. Energy poverty is measured through access and affordability, and benchmark regressions confirm that rural women, especially those with lower education and older age, face higher risks. The correlation analysis reveals that variables such as educational attainment, age, and geographic location influence women's exposure to energy poverty, with little evidence of multicollinearity in the models.

The findings suggest a strong link between limited education and increased energy poverty risk, highlighting education and financial resources as key factors for mitigation. Age shows a nonlinear relationship, indicating evolving energy needs over the life course. Urban women are generally more resilient due to greater autonomy and access to social and economic resources, while rural women remain disadvantaged by household responsibilities, lack of voice in energy decisions, and entrenched social norms.

The study also explores energy injustice, pointing to rural women's restricted access to renewable energy, their heavy domestic burden, and mental health challenges stemming from energy deprivation. These issues are compounded by Confucian cultural norms that limit women's decision-making power, especially in rural areas where gender roles are more rigidly enforced.

To address these challenges, a multidimensional policy response is required. First, expanding access to education and skills training for rural women can strengthen their capacity to engage in energy-related decisions and

improve their socio-economic status. Second, building localized support systems—such as community networks, NGOs, and government-led initiatives—can provide emotional support and practical guidance to women in energy-poor households. Third, implementing sustained and regionally tailored subsidy programs for low-income rural households can ease their transition to modern, clean energy sources while reducing long-term dependency on traditional fuels. Finally, broader societal change is essential: challenging deeply rooted gender norms through public awareness campaigns and institutional reforms can promote greater gender equity in both domestic and public spheres. These interventions, collectively, will be crucial for reducing gendered energy inequalities and advancing an inclusive, culturally informed energy transition in China.

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