

## Article

# Alleviating Parental Energy Poverty: The Role of Adult Children's Education

Zhou Jiang <sup>1</sup>, Hong Su <sup>1,\*</sup> and Qi Wang <sup>2</sup>

<sup>1</sup> Institute of Western China Economic Research, Southwestern University of Finance and Economics, Chengdu 611130, China; jiangzhou@swufe.edu.cn

<sup>2</sup> Business School, Sichuan University, Chengdu 610065, China; qiawangphd@scu.edu.cn

\* Correspondence: 1230202z8001@smail.swufe.edu.cn

## Abstract

Alleviating energy poverty is fundamental to enhancing societal well-being and advancing sustainable development. This paper examines the relationship between adult children's education and parental energy poverty alleviation. We draw on microdata from the China Health and Retirement Longitudinal Study (CHARLS) and exploit the Compulsory Education Law reforms implemented across China around 1986 as a source of exogenous variation in schooling years. Our findings reveal that each additional year of offspring schooling significantly reduces the likelihood of parental energy poverty. We identify two potential mechanisms: promoting internet adoption and improving access to modern energy equipment. Heterogeneity analysis further reveals that the effect is more pronounced in rural households and among families with male children than among those with female children. These findings offer actionable insights for addressing energy poverty and advancing intergenerational sustainability.

**Keywords:** household energy poverty; adult children's education; intergenerational spillover; sustainable development; energy sustainability

## 1. Introduction

Energy poverty, characterized by inadequate access to affordable, reliable, and modern energy services [1], remains a critical barrier to human development and well-being, particularly in developing countries [2]. According to the World Energy Outlook 2023, more than 750 million individuals globally lack electricity access, while nearly 2.2 billion depend on biomass and other polluting fuels for cooking purposes [3]. The impacts of energy poverty extend substantially beyond immediate material deprivation and environmental degradation, impairing educational attainment, health, and productivity [4,5], thereby perpetuating economic poverty. Regarding households, energy access fundamentally shapes household welfare, income, and poverty [6,7]. In some rural regions, women and children allocate considerable portions of daily activity to gathering cooking fuel and fetching water, which undermines opportunities for education and personal development, thereby exacerbating poverty. At the macro level and over the long run, a lack of energy access cripples human capital accumulation and economic advancement, given energy's critical role in powering productivity and sustaining essential services like healthcare, employment, and education [8]. It follows that energy constraints serve as a major impediment to life satisfaction and household well-being; expanding energy access constitutes a critical pathway for improving household welfare and life quality.



Academic Editor: Camelia Delcea

Received: 6 June 2026

Revised: 8 July 2026

Accepted: 13 July 2026

Published: 17 July 2026

**Copyright:** © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

In China, advancing the energy transition is one of the major tasks at present [9]. A series of targeted policies and measures have been implemented to address energy poverty, such as the “Household Biogas Project” and “Coal-to-Electricity Project”. A cornerstone of these efforts is the nationwide “Rural Electrification Program”, which achieved 100% electricity coverage by 2020 through grid expansion and off-grid renewable solutions like solar microgrids in remote areas. Additionally, energy infrastructure investments under the “Targeted Poverty Alleviation” strategy integrate renewable energy projects with job creation in underdeveloped regions. Despite progress, challenges persist. Numerous rural households still depend on solid fuels for their energy consumption, and rural-urban disparities in energy affordability persist. Consequently, identifying effective strategies for energy development remains a policy priority [10]. As one of the world’s most populous countries, China’s progress in addressing domestic energy issues has global implications [11].

Existing literature has extensively examined determinants of household energy poverty, such as income inequality, gender educational inequality, household wealth, financial market engagement, digital divide and infrastructural deficits [4,12,13]. Individuals with restricted engagement in financial markets may face barriers in accessing affordable energy services due to insufficient financial resources [14]. In the digital economy, households that cannot effectively access and process critical information may face a higher likelihood of falling into energy poverty [12]. Education also plays a role. Liang et al. (2025) found that each additional year of schooling reduces an individual’s likelihood of experiencing energy poverty by 2.3 percentage points [15]. This effect may vary by gender. In rural areas, a 1% increase in male schooling reduces energy poverty by 3.252%, while that for female schooling stands at 1.702% [15]. These studies primarily concentrate on the ways in which personal characteristics influence individuals’ exposure to energy poverty. Despite its importance, the intergenerational dimension of this issue has received little empirical attention. While the transfer of human capital across generations is acknowledged as a critical socioeconomic force, the particular pathway by which the educational achievements of adult children mitigate the energy poverty of their parents remains largely unexplored. This study addresses this gap by investigating how the adult children’s education levels mitigate the energy poverty of their parents, with a focus on underlying mechanisms and heterogeneous effects across socioeconomic and geographic contexts.

Many studies suggest that the educational attainment of adult children significantly shapes parents’ behaviors through health, technology adoption, and social network channels [16–18]. Yu et al. (2025) found that children’s education significantly increases parental deposits by 18.8% and non-risk assets by 25.6% [19]. Co-residence with adult children is positively associated with elderly internet literacy [20]. Higher-educated offspring are better positioned to facilitate their parents’ adoption of Internet technologies. Lei et al. (2023) found that a one-year increase in children’s educational attainment leads to a 3.4 percentage-point rise in the probability that their parents use the Internet [16]. Furthermore, highly educated adult children can also enhance their parents’ health by promoting parental health awareness and shaping healthier behaviors [21].

Based on the existing literature, we posit possible pathways through which adult children’s education may shape parental energy poverty. First, we argue the importance of internet adoption. Many studies suggest that the adoption of digital technologies can proficiently reduce household energy poverty [12,22,23]. Adult children with higher educational attainment have a propensity to demonstrate higher digital proficiency [24,25], which raises parents’ access to and familiarity with new technologies, potentially reducing parents’ energy poverty. Second, we emphasize the mediating effect of access to modern energy equipment. Adult children with higher educational attainment can alleviate parental

energy poverty by enhancing their parents' willingness to adopt modern energy equipment such as water heaters.

This study examines the impact of adult children's educational attainment on parental energy poverty using panel data from five waves of the China Health and Retirement Longitudinal Study (CHARLS), spanning 2011–2020. A critical challenge in the study arises from the potential endogeneity associated with children's educational levels. A critical identification challenge arises from unobserved heterogeneity, such as parental cognitive abilities or underlying socioeconomic status, which may simultaneously predispose children toward higher educational achievements and account for the household's vulnerability to energy poverty. For instance, more capable parents tend to invest more effectively in their offspring's education while they also exhibit lower risks of energy poverty. As a strategy to mitigate the bias stemming from unobserved confounders, we turn to an instrumental variable approach, utilizing the geographic and temporal variation in the implementation of China's Compulsory Education Law to instrument for the educational duration of adult children. This approach leverages exogenous variation in schooling years created by policy implementation across birth cohorts and regions, thereby enabling the isolation of the causal influence of adult children's educational achievements on their parental energy consumption. The identification strategy effectively addresses the endogeneity problem by exploiting institutional constraints on educational choices rather than family-specific decisions.

Although our study is closely related to Gan et al. (2025) [17], it differs in several important aspects. First, Gan et al. (2025) use data from the China Family Panel Studies (CFPS) for the years 2016 and 2018 [17], whereas our study employs data from the China Health and Retirement Longitudinal Study (CHARLS) spanning from 2011 to 2020. This extended panel window allows us to capture long-term dynamics in the relationship between adult children's education and their parents' energy poverty. Second, our study identifies additional mechanisms beyond those examined in Gan et al. (2025) [17]. While Gan et al. (2025) focus on intergenerational financial transfers, the digital divide, and social capital [17], we further establish two complementary pathways: promoting Internet adoption and increasing parents' access to modern energy equipment. These channels reflect the practical, technology-oriented support that educated children provide to their parents. Third, our heterogeneity analyses also reveal some different patterns. We examine heterogeneous effects by children's visit frequency, though the cross-group difference remains statistically insignificant.

Thus, the contributions of this paper are threefold. First, different from existing studies, we adopt an intergenerational perspective to examine the impact of children's education on parental energy poverty and analyze the underlying mechanisms. Following Offer and Fischer (2018) [18], we recognize that adult children shape their parents' living conditions and behaviors, and thus conceptualize children's education as a pathway through which parental energy poverty is determined. By highlighting the role of adult children's education in mitigating energy poverty in older generations, this research extends and enriches the existing body of work on household energy deprivation. It also contributes to a more nuanced understanding of intergenerational spillovers in human capital.

Second, this study also contributes by exploring heterogeneity. We explore whether the effect of adult children's education varies across key dimensions, including urban versus rural household settings, the child's gender, and the frequency of parent–child visits. Such analysis is critical for designing targeted policies, as the returns to children's education may differ markedly depending on family characteristics.

Third, this study not only adopts a unique perspective for addressing the issue of household energy poverty but also extends the frontier of spillover literature by document-

ing how the educational attainment of adult progeny exerts a tangible influence on parental well-being, thus enriching our understanding of the multifaceted channels through which non-material resources flow across generations.

The remainder of this study is structured as follows. Section 2 reviews the relevant literature. Section 3 presents the research hypotheses. Section 4 details the dataset, variable definitions, and econometric methodology. Section 5 reports the empirical results, examines the transmission channels, and explores heterogeneous effects. Section 6 concludes with policy implications.

## 2. Literature Review

### 2.1. Related Research on Household Energy Poverty

The definition of energy poverty has expanded considerably over time, moving beyond a narrow emphasis on physical electricity to a more comprehensive multidimensional framework incorporating considerations of affordability, reliability, and environmental sustainability [5,26,27]. Some studies emphasized income-based thresholds, which are used to examine the share of energy expenditures to total household income [7,28,29]. In this context, a household is categorized as experiencing energy poverty if its energy costs exceed a specific threshold relative to its income. And one of the most widely used methods is the 10% indicator, which was introduced by Boardman (1991) [30]. Hills (2011) advanced this line of inquiry by proposing the Low-Income/High-Cost (LIHC) indicator [26]. Multidimensional composite indicators have also gained considerable traction in energy poverty scholarship. The Multidimensional Energy Poverty Index (MEPI) exemplifies this framework, providing a holistic evaluation of energy poverty through criteria such as technological accessibility thresholds and availability of modern energy services [31]. The methodological robustness of MEPI has led to extensive adoption in many studies [5,12,32,33].

Building on assessments of energy poverty, scholars have increasingly investigated its multifaceted drivers and the effective approaches for energy poverty alleviation. On the one hand, existing literature commonly holds that the primary forces behind energy deprivation stem from financial hardship and disadvantaged social and economic positions [34,35], and by inadequate infrastructure on the other [36]. Households with constrained income means face a heightened risk of inadequate access to energy as they struggle to afford sufficient energy services [13,37]. As for energy poverty alleviation, new energy technology innovation and clean energy transition are essential [38].

While energy poverty emerges from a multitude of complex scenarios, the relevant literature has highlighted the role of household characteristics. Numerous empirical studies have found that household structure type, the education level and cognitive capability of household members, the age and sex of the household head, household wealth status and locational characteristics are all significantly correlated with multidimensional energy poverty [39–43]. Abbas et al. (2020) found that larger house size, greater household wealth, higher education level, more prestigious occupation, and male gender of the household head tend to reduce the likelihood of experiencing multidimensional energy poverty [4]. The impact of energy policies is also heterogeneous across households [44,45]. Based on an analysis of the impacts brought by the household clean heating initiative in northern rural China, Xie et al. (2022) revealed that low-income households and those without housing insulation tend to experience more adverse consequences [44]. These findings imply that policies aimed at eliminating energy poverty should thoroughly account for the heterogeneous effects of policy interventions on households with diverse socioeconomic, demographic, and geographic characteristics. Additionally, it is important to identify vulnerable households.

## 2.2. Related Research on Education and Household Energy Poverty

A substantial body of academic research has investigated the interplay between educational levels and energy poverty. Certain scholars have centered their analyses on the educational consequences of energy poverty. Using data from 50 developing countries, Banerjee et al. (2021) found that reducing energy poverty contributes to a notable improvement in educational attainment [46]. Oum (2019) also reported that energy poverty exerts harmful influences on households, including reducing the average number of school years of households and impairing overall health conditions [47]. The influence of energy poverty on educational outcomes is more pronounced in developing nations, as evidenced by empirical studies across diverse socioeconomic contexts: Omar and Hasanujjaman (2021) in Bangladesh [48], Oum (2019) in Laos [47], and Rafi et al. (2021) in India [5].

On the other hand, a growing number of academic investigations have highlighted the pivotal role of education in alleviating energy poverty [13,15,49,50]. Fang et al. (2022) found that in the emerging economies, the distribution of educational attainment fails to restrain the consumption of fossil fuels, yet it encourages the adoption of renewable energy sources [50]. Liang et al. (2025) documented a robust inverse relationship between educational attainment and household energy poverty [15]. They further decompose this effect, revealing that it is mediated primarily by the augmented earnings capacity derived from human capital investment and the concomitant relaxation of credit constraints. Nepal et al. (2025) further found that the role of female education in alleviating urban energy poverty is considerably more prominent [13].

However, these studies focus primarily on how individual characteristics shape one's own energy poverty experiences, while overlooking the upward intergenerational spillover of education. Given that adult children's educational attainment can substantially affect their parents' outcomes through health behaviors, technology adoption, and social network expansion [16], it may serve as a meaningful lever for alleviating parental energy poverty. Households with middle-aged and older members warrant particular attention, as population aging and intergenerational co-residence are fundamentally reshaping energy demand structures, yet this group remains understudied. Barry (2025) showed that energy hardship exacerbates physical, mental, and cognitive decline among older adults [51]. Yue et al. (2025) also found that aging-stage households are more susceptible to energy poverty than those in earlier stages, with health status as a key mediating mechanism [23]. The potential upward spillover of children's education on parents' energy poverty thus calls for systematic investigation.

To address these research gaps, this study leverages data from the China Health and Retirement Longitudinal Study to investigate how the educational attainment of adult children shapes the energy poverty status of their parents, with particular emphasis on elucidating the underlying mechanisms and examining heterogeneous effects across household characteristics. By repositioning the analytical lens to foreground the upward intergenerational influence of offspring education, our findings contribute evidence to the broader discourse on the nexus between human capital accumulation and energy justice.

## 3. Research Hypotheses

The intergenerational spillover literature documents that children's human capital generates significant upward benefits for their parents, improving parental health outcomes, cognitive function, and overall living standards [52,53]. Higher education can equip children with greater economic capacity, cognitive skills, and information-processing abilities, which can be transmitted to parents through intergenerational interactions and practical support in daily life. Since energy poverty is fundamentally shaped by household income constraints and limited information access [35], better-educated children are

uniquely positioned to help their parents overcome energy deprivation across multiple dimensions such as fuel choice and energy expenditure burden.

**H1.** *Higher educational attainment among adult children is associated with a reduction in parental energy poverty.*

The digital exclusion has been identified as a significant structural barrier to energy poverty reduction, as households with limited digital access face constrained information regarding available energy subsidies, efficient appliance options, clean energy alternatives, and online service platforms [12]. Adult children with higher educational attainment typically demonstrate substantially greater digital proficiency and technological adaptability, enabling them to serve as effective intermediaries in facilitating parents' adoption of Internet services and mobile payment systems [54]. This digital diffusion process broadens parents' access to energy-related information and services. It enables online applications for government subsidies, price comparisons of clean energy options, digital scheduling of maintenance services, and efficient household energy management through smart monitoring tools.

**H2.** *Adult children's educational attainment affects parents' energy poverty by facilitating parental Internet adoption.*

The acquisition and effective utilization of modern energy equipment such as clean cookstoves, electric water heaters and energy-efficient lighting represent critical material prerequisites for alleviating energy poverty. However, older parents often encounter substantial barriers in accessing these technologies, including limited purchasing power, inadequate technical knowledge for installation and maintenance, and restricted access to reliable distribution channels in remote areas [33]. Better-educated children can help their parents overcome these obstacles. First, they can offer hands-on technical assistance with installation, troubleshooting, and routine maintenance. Second, they leverage their broader social networks and digital literacy to identify reliable suppliers and favorable pricing. Third, children can transmit norms and knowledge regarding the benefits of modern energy equipment such as improved health outcomes, time savings, and environmental advantages, thereby enhancing parents' willingness to adopt and consistently use these technologies. Through these tangible forms of practical support and normative influence, children substantially enhance their parents' access to and utilization of modern energy equipment.

**H3.** *Adult children's educational attainment influences parents' energy poverty by enhancing their access to modern energy equipment.*

## 4. Data and Methods

### 4.1. Data

Our data is drawn from the China Health and Retirement Longitudinal Study (CHARLS), jointly performed by Wuhan University and Peking University in China. The questionnaire contains basic personal information, family structure, financial support, income, and consumption, etc. CHARLS is a high-quality micro-dataset designed to analyze population aging and its related issues. It covers Chinese middle-aged and elderly individuals aged 45 and above. The baseline survey was launched in 2011, and a national tracking survey has been conducted every two years since 2013.

In our empirical analysis, we employ five waves of CHARLS data (2011–2020), which include detailed information on household energy consumption. The survey also captures

comprehensive demographic data on respondents' children, such as birth year, gender, and highest educational attainment. To construct the analytical sample, we applied the following sequential procedures. First, we restricted the sample to parents aged 45 and above and following Ma (2019) and Liu et al. (2022) [52,55], we restricted the children's birth cohort to 1956–1991. This restriction ensures that the CEL exposure instrument captures meaningful variation in educational attainment. Children born before 1956 would have exceeded the compulsory education age ceiling (15 years) by the time the CEL was implemented in any province (1985–1994), rendering them fully unexposed and thus invalid for IV identification. The upper bound (1991) ensures that children had completed their formal education by the survey waves (2011–2020).

Second, we applied several cleaning procedures to address outliers and ensure data comparability across survey waves. We excluded observations with negative values for household total income and energy expenditure, and further dropped households with an annual total income below 2000 RMB following the basic pension for urban and rural residents and the minimum wage standard in China. All monetary values were deflated to the 2011 price level using provincial Consumer Price Indices (CPIs) to ensure comparability across waves. To mitigate the influence of extreme values, we winsorized both household total income and energy expenditure at the 1st and 99th percentiles separately for each survey wave, and also winsorized the resulting energy expenditure-to-income ratio (EP2) at the 1st and 99th percentiles.

Third, to ensure a household-level unit of analysis, we retained only one observation per household per wave. After excluding missing values on key variables, the final sample is an unbalanced panel of 15,049 household-wave observations from 8632 unique households across 28 provinces over five waves.

## 4.2. Variable Specification

### 4.2.1. Energy Poverty

Energy poverty serves as the core research variable of this paper. Following Luan et al. (2023), it is a composite indicator constructed on the basis of the Multidimensional Energy Poverty Indicator (MEPI) [12]. First, energy poverty stems from unmet basic energy needs. Referring to Zhang et al. (2019), first-order energy poverty (EP1) is operationalized based on the type of fuel utilized for primary cooking [32]. Specifically, we characterize households that rely on the combustion of solid fuels, such as coal, crop residues, or wood, as energy poor. Second, the affordability of energy serves as one of the important indicators reflecting energy poverty, and this indicator is quantified as the proportion of energy consumption costs to the overall household income (EP2). In CHARLS, household energy consumption is proxied by total expenditures on utilities (water and electricity), fuel, and central heating. As water and electricity are not separately identifiable in the data, our energy expenditure measure necessarily includes water costs. Third, a higher share of energy expenditure in household income indicates greater energy poverty severity. A predetermined level of 10% is commonly adopted to classify a household as energy poor [32,56]. Therefore, households are classified as third-level energy deprivation if their energy consumption expenditure accounts for greater than 10 percent and their income level is below the median income level for the region (EP3). Thus, energy poverty is a multidimensional indicator that needs to be measured based on the above three indicators. Table 1 reports the details of its construction.

**Table 1.** Definition of energy poverty.

| Variables      | Label | Definition                                                                                                                                                                                                                                                                                                                                            |
|----------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Energy poverty | EP    | EP1: A value of 1 is assigned to households that rely on solid fuels for cooking purposes, while a value of 0 is given to those that do not use such fuels.                                                                                                                                                                                           |
|                |       | EP2: The proportion of energy spending relative to the overall amount of household income.                                                                                                                                                                                                                                                            |
|                |       | EP3: A household is classified as experiencing dual-dimension energy poverty (coded as 1) if its energy expenditure-to-income ratio (EP2) surpasses the 10 percent benchmark while its total income simultaneously lies beneath the regional median threshold; households failing to meet either or both of these criteria are assigned a value of 0. |
|                |       | $EP = 1$ if $EP1 = 0$ and $EP3 = 0$ ;<br>$EP = 2$ if $EP1 = 1$ or $EP3 = 1$ ;<br>$EP = 3$ if $EP1 = 1$ and $EP3 = 1$ .                                                                                                                                                                                                                                |

#### 4.2.2. Education of Adult Children

The educational attainment of adult offspring is measured as years of formal schooling, derived from their highest degree obtained. For the baseline analysis, we adopt the educational attainment of the eldest adult child, following Lei et al. (2023), Gan et al. (2025), and Torssander (2013) [16,17,57]. As a robustness check, we alternatively employ the average years of schooling across all children. According to China's current education system, the corresponding years of schooling for each level are as follows: 0 years for illiteracy, 6 years for elementary school, 9 years for junior high school, 12 years for senior high school or vocational secondary school, 15 years for three-year college, 16 years for four-year university, 19 years for a master's degree, and 22 years for a doctoral degree.

#### 4.2.3. Control Variables

Following Koomson and Danquah (2021), Luan et al. (2023), and Gan et al. (2025), we include three sets of control variables in our empirical analysis [12,17,58]. The selection of these variables is grounded in two fundamental dimensions shaping household energy poverty. These are accessibility and affordability. Parental characteristics are controlled for, including gender, age, employment status, marital status, and education. These factors directly influence affordability through income-generating capacity. They also affect accessibility by shaping information acquisition and energy-saving awareness [59]. Household characteristics, such as family size, are included. Household registration is also controlled for, as it reflects spatial inequalities in energy infrastructure access [60]. In addition, adult children's characteristics such as gender are accounted for since sons may bear a disproportionate share of caregiving duties under traditional Chinese cultural norms [17]. Following Liu et al. (2022), we further control for province-specific linear cohort trends [55].

#### 4.3. Descriptive Statistics

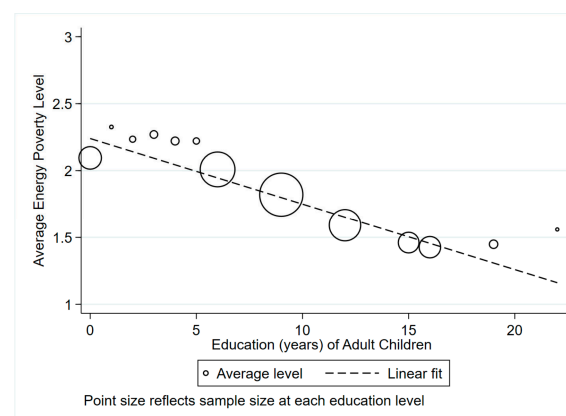
Descriptive statistics pertaining to the core variables utilized in this research are exhibited in Table 2, with a total of 15,049 observations included in the analysis. Compared with the full CHARLS sample across five waves, this sample size reflects the exclusion of observations with missing values on key variables (energy expenditure, household income, children's education information and other control variables). Around 39.7% of the sampled observations depend on solid fuels for their cooking needs, and the mean ratio of household energy costs to total household income is 15.5%, indicating that a subset of households bears a disproportionately high energy burden. Additionally, approximately 31.6% of the sampled observations are characterized by a dual condition of energy poverty. With respect to the central tendency

of the multidimensional measure, the index registers a mean of 1.712, reflecting the typical level of overlapping energy and income poverty experienced by households in the study population. Regarding the characteristics of the eldest children, the average years of education is 9.204, aligning with China's nine-year compulsory education requirement. The average age of parents is 62.655 years. Among them, 46% of household heads are male, 35.3% of parents remain employed, and 78.8% are married. The average educational attainment of parents is 1.987 years. Regarding household characteristics, the average household size is about 3 members, with 59.6% of the sample residing in rural areas.

**Table 2.** Descriptive statistics.

| Variables                   | N      | Mean   | S.D.  | Median |
|-----------------------------|--------|--------|-------|--------|
| EP1                         | 15,049 | 0.397  | 0.489 | 0      |
| EP2                         | 15,049 | 0.155  | 0.235 | 0.071  |
| EP3                         | 15,049 | 0.316  | 0.465 | 0      |
| EP                          | 15,049 | 1.712  | 0.694 | 2      |
| Education of adult children | 15,049 | 9.204  | 4.420 | 9      |
| Eldest children's gender    | 15,049 | 0.527  | 0.499 | 0      |
| Gender                      | 15,049 | 0.460  | 0.498 | 0      |
| Employ                      | 15,049 | 0.353  | 0.478 | 0      |
| Marital status              | 15,049 | 0.788  | 0.409 | 1      |
| Age                         | 15,049 | 62.655 | 8.766 | 62     |
| Education                   | 15,049 | 1.987  | 1.060 | 2      |
| Rural                       | 15,049 | 0.596  | 0.491 | 1      |
| Family size                 | 15,049 | 3.312  | 1.751 | 3      |

As a precursor to the main econometric analysis, Figure 1 presents an exploratory visualization of the correlation between offspring education and parental energy poverty, offering an initial glimpse into the intergenerational patterns that merit further investigation. The scatter plot depicts the correlation between adult children's educational attainment and their parents' average energy poverty level, with a dashed red line representing the linear regression trend. A negative linear association is observed. Higher educational attainment among adult children is correlated with a reduced degree of energy poverty among their parents. The downward-sloping regression line reinforces this inverse trend, suggesting that higher educational attainment may contribute to reducing energy poverty in the parental generation.



**Figure 1.** Correlation between adult children's education and parental energy poverty. Notes: The figure plots parental energy poverty against adult children's years of education. The negative slope of the dashed line indicates that high levels of offspring education are associated with reduced energy poverty in parents. Point size reflects the sample size at each education level.

#### 4.4. Empirical Model

To examine the effect of the eldest adult child's education on parental energy poverty, we employ the following empirical model:

$$EP_{ijkt} = \beta_0 + \beta_1 Adultchild_{ijkt} + \beta_2 X_{ijkt} + \lambda_j + \psi_t + \eta_k + \phi_{kj} + \varepsilon_{ijkt} \quad (1)$$

$EP_{ijkt}$  denotes the energy poverty status of parent  $i$  residing in province  $j$  who has a child born in year  $k$  and was interviewed during year  $t$ .  $Adultchild_{ijkt}$  represents the number of years of formal education completed by the oldest adult child. The corresponding coefficient,  $\beta_1$ , reflects the impact of one extra year of the eldest adult children's education on their parents' energy poverty.  $X_{ijkt}$  is a vector of controls as listed in Table 2. To address regional and time-related differences in parents' energy poverty, we incorporate fixed effects for the provinces  $\lambda_j$  where parents reside, fixed effects for the survey years  $\psi_t$ , and fixed effects for the seven-year birth cohort of the oldest adult child  $\eta_k$ . We further allow for province-specific linear cohort trends  $\phi_{kj}$ , where the province is defined as the parents' province of residence. Robust standard errors are clustered at the provincial level of parents' residence to account for potential correlations in energy poverty among individuals within the same province.

The consistency ( $\beta_1$ ) of ordinary least squares (OLS) estimates is threatened by the potential correlation between the educational achievements of the eldest adult children and unobserved factors subsumed in the error term ( $\varepsilon_{ijkt}$ ) that simultaneously influence parental energy poverty. To surmount this identification challenge and establish causal inference, we turn to an instrumental variable strategy that leverages the plausibly exogenous variation in schooling generated by the rollout of China's Compulsory Education Law (CEL). Specifically, we estimate the following first-stage equation to quantify the impact of CEL exposure on the eldest child's years of education:

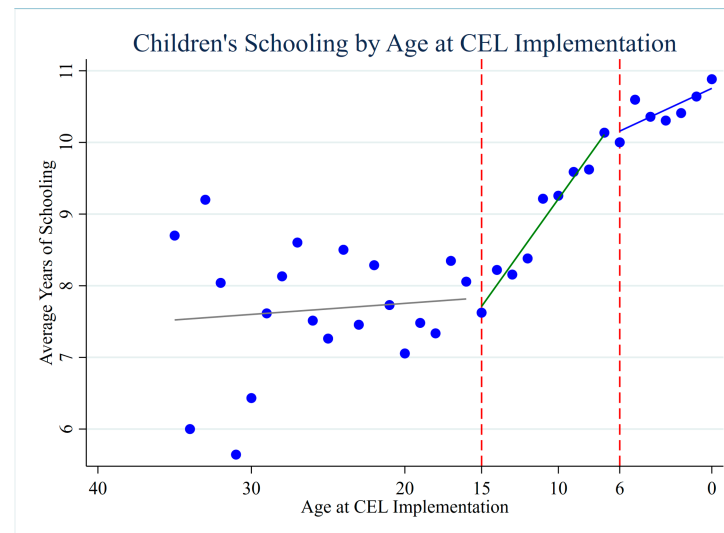
$$Adultchild_{ijkt} = \beta_0 + \beta_1 CEL\ exposure_{ijkt} + \beta_2 X_{ijkt} + \lambda_j + \psi_t + \eta_k + \phi_{kj} + \varepsilon_{ijkt} \quad (2)$$

The dependent variable is the eldest adult child's education in the household. The instrumental variable for the eldest adult child's education is a measure of the child's intensity of exposure to the Compulsory Education Law.

The Compulsory Education Law (CEL) is designed to guarantee that all individuals complete nine years of compulsory education. It stipulates that children must enroll in school upon reaching six years of age, though enrollment may be delayed until age seven in regions with inadequate educational resources. The province-specific implementation years of the Compulsory Education Law are listed in Table A1 of Appendix A. Accordingly, we regard this variable as a continuous variable with a range of 0 to 1. At the time of the CEL's enforcement, children who were six years old or below were categorized as having full policy exposure (with  $CEL\ exposure = 1$ ), while those aged sixteen or above were deemed unexposed (with  $CEL\ exposure = 0$ ). As for children in the 7 and 15 age bracket, who had partial exposure to the CEL, we postulate that the extent of their policy exposure varies in a linear manner with age:  $CEL\ exposure = (16 - \text{age in the year of CEL implementation})/10$ . This linear functional form implies an inverse relationship: the CEL effect weakens as the birth cohort age increases. Younger cohorts, whose schooling years overlapped more with the policy window, were more strongly affected.

Figure 2 visualizes the first-stage relationship between the instrument and the endogenous variable. The horizontal axis represents adult children's age at the time of the Compulsory Education Law (CEL) implementation, and the vertical axis represents their average years of schooling. The left red vertical line marks the cohort aged 15 at implementation (the unaffected threshold group), while the right red vertical line marks the cohort

aged 6 at implementation (the fully affected school-entry group). Two clear patterns emerge from the figure. First, the unaffected group exhibits a flat baseline with average schooling years stabilizing around 7.5 across the entire age spectrum, suggesting that educational attainment remained relatively constant for cohorts not exposed to the policy. Second, the affected group displays a pronounced age gradient. As the age at implementation decreases from 15 to 6, average years of schooling rise monotonically from approximately 7.5 to 10 years. This monotonic relationship implies that individuals exposed to compulsory schooling for a longer duration accumulated substantially more educational capital. The figure provides compelling visual evidence that the CEL policy effectively raised children's educational attainment.



**Figure 2.** Adult children's years of schooling by age at CEL implementation. The left red rule indicates age 15 at CEL implementation, and the right red rule indicates age 6 at CEL implementation. Each line represents the fitted trend line for the scatter plot of average years of schooling by age group within the sample.

A key identification concern is that CEL rollout may coincide with provincial economic and developmental trajectories. To mitigate this, we include province fixed effects to capture time-invariant provincial heterogeneity, and province-specific linear cohort trends to absorb observed and unobserved province-cohort-specific confounders. Another concern involves the possibility of endogenous mobility, whereby families relocate across provincial boundaries specifically to exploit compulsory schooling opportunities. Several institutional constraints render this scenario empirically negligible. Prior to the late 1980s, the stringent hukou regime functioned as a formidable barrier to internal population movements, rendering inter-provincial relocation an anomaly rather than the norm throughout the 1980s and 1990s [61]. Furthermore, the absence of local registration status imposed prohibitive costs on school-age migrants, most saliently the exclusion from publicly funded education [62].

## 5. Results

### 5.1. Baseline Results

Table 3 presents the estimated effects of adult children's educational attainment on parental energy poverty. Column (1) reports estimates from a baseline specification that includes only children's years of schooling, without controlling for fixed effects or additional covariates. Column (2) incorporates survey-year fixed effects, and Column (3) further adds a fixed effect for parents' resident province. Column (4) introduces narrow children's birth-year cohort fixed effects to absorb secular educational trends and cohort-level differences.

Column (5) adds province-specific cohort trends to control for province-level differential development trajectories that may confound the relationship. Column (6) introduces controls for adult children's characteristics, while Column (7) includes a comprehensive set of parental and household characteristics.

**Table 3.** OLS estimates of the effect of adult children's educational attainment on parents' energy poverty.

| Variables                              | (1)                   | (2)                   | (3)                   | (4)                   | (5)                   | (6)                   | (7)                   |
|----------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                                        | EP                    | EP                    | EP                    | EP                    | EP                    | EP                    | EP                    |
| Education of adult children            | −0.043 ***<br>(0.002) | −0.043 ***<br>(0.002) | −0.041 ***<br>(0.002) | −0.039 ***<br>(0.002) | −0.039 ***<br>(0.002) | −0.039 ***<br>(0.002) | −0.024 ***<br>(0.002) |
| Adult children's gender                |                       |                       |                       |                       |                       | 0.036 ***<br>(0.010)  | 0.034 ***<br>(0.008)  |
| Gender                                 |                       |                       |                       |                       |                       |                       | 0.023 *<br>(0.012)    |
| Employ                                 |                       |                       |                       |                       |                       |                       | 0.194 ***<br>(0.020)  |
| Marital status                         |                       |                       |                       |                       |                       |                       | 0.095 ***<br>(0.020)  |
| Age                                    |                       |                       |                       |                       |                       |                       | 0.003<br>(0.002)      |
| Edu                                    |                       |                       |                       |                       |                       |                       | −0.062 ***<br>(0.009) |
| Rural                                  |                       |                       |                       |                       |                       |                       | 0.266 ***<br>(0.032)  |
| Family size                            |                       |                       |                       |                       |                       |                       | −0.044 ***<br>(0.006) |
| Cluster at parents' resident province  | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     |
| Survey year FE                         |                       | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     |
| Parents' resident province FE          |                       |                       | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     |
| Narrow children's birth year cohort FE |                       |                       |                       | ✓                     | ✓                     | ✓                     | ✓                     |
| Province-specific cohort trends        |                       |                       |                       |                       | ✓                     | ✓                     | ✓                     |
| Observations                           | 15,049                | 15,049                | 15,049                | 15,049                | 15,049                | 15,049                | 15,049                |
| R <sup>2</sup>                         | 0.076                 | 0.094                 | 0.133                 | 0.138                 | 0.138                 | 0.138                 | 0.215                 |

Note: This table reports ordinary least squares (OLS) estimates of the effect of adult children's educational attainment on parents' energy poverty. The dependent variable is EP, which ranges from 1 to 3. Except for Column (1), all regression specifications incorporate survey year fixed effects. Column (3) to Column (7) control for parents' resident province fixed effects. Column (4) to Column (7) introduce narrow children's birth-year cohort fixed effects. Column (5) to Column (7) extra add province-specific cohort trends. Robust standard errors in parentheses are clustered at parents' resident province level. Robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*  $p < 0.1$ .

Across all specifications, the estimated effects of adult children's education on their parents' energy poverty remain consistently negative and statistically significant, indicating a robust inverse relationship between children's education and parental energy poverty. We adopt Column (7) as our preferred specification. According to the results, a standard deviation increase in adult children's years of schooling is linked to a 0.024 standard deviation reduction in parental energy poverty.

As for controls, parents' own education exhibits a strong negative effect, consistent with human capital theory. Rural residence is associated with a substantial increase in energy poverty, reflecting structural disadvantages in infrastructure and energy access in rural areas. Employment status and marital status show positive associations, possibly reflecting higher energy needs or different household structures.

## 5.2. IV Results

Table 4 reports the first-stage results, examining the relationship between Compulsory Education Law (CEL) exposure and the educational attainment of adult children. Columns (1)–(7) mirror the specification sequence in Table 3. The estimated coefficients on CEL exposure are consistently positive and statistically significant at the 1% level across all seven specifications, confirming that the instrument is a strong predictor of children’s educational attainment. The coefficient ranges from 2.862 in the baseline specification (Column 1) to 1.975 in the fully specified model (Column 7), indicating that exposure to the Compulsory Education Law increases the eldest child’s years of schooling by approximately 2.0 to 2.9 years. A critical diagnostic for the validity of our instrumental variable strategy involves assessing the strength of the first-stage relationship. The Kleibergen–Paap *rk* F-statistics, which we report for all specifications, uniformly surpass the widely accepted benchmark of 10, comfortably rejecting the null of weak identification and confirming the relevance of the Compulsory Education Law exposure as a predictor of adult children’s educational attainment.

**Table 4.** Impact of CEL mandate on educational attainment of adult children.

| Variables                              | (1)                  | (2)                  | (3)                  | (4)                  | (5)                  | (6)                  | (7)                  |
|----------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                                        | Schooling            | Schooling            | Schooling            | Schooling            | Schooling            | Schooling            | Schooling            |
| CEL exposure                           | 2.862 ***<br>(0.165) | 2.970 ***<br>(0.167) | 2.970 ***<br>(0.157) | 2.367 ***<br>(0.141) | 2.231 ***<br>(0.441) | 2.266 ***<br>(0.447) | 1.975 ***<br>(0.404) |
| First-stage F-statistics               | 301.78               | 316.35               | 357.34               | 35.17                | 25.62                | 25.67                | 23.93                |
| Observations                           | 15,049               | 15,049               | 15,049               | 15,049               | 15,049               | 15,049               | 15,049               |
| Cluster at parents’ resident province  | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    |
| Survey year FE                         |                      | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    |
| Parents’ resident province FE          |                      |                      | ✓                    | ✓                    | ✓                    | ✓                    | ✓                    |
| Narrow children’s birth year cohort FE |                      |                      |                      | ✓                    | ✓                    | ✓                    | ✓                    |
| Province-specific cohort trends        |                      |                      |                      |                      | ✓                    | ✓                    | ✓                    |
| Children’s characteristics             |                      |                      |                      |                      |                      | ✓                    | ✓                    |
| Parents’ and household characteristics |                      |                      |                      |                      |                      |                      | ✓                    |

Note: For the sake of the table, “schooling” is short for the eldest children’s years of schooling. Children’s characteristics include the gender of the eldest child. Parents’ characteristics include gender, employment situation, marital status, age, and education level. And household characteristics include household registration and family size. The F-statistic declines from 301.78 in Column (1) to 23.93 in Column (7), which is expected after the inclusion of all the fixed effects that absorb part of the identifying variation. The F-statistic of 23.93 remains well above the conventional threshold of 10, confirming instrument relevance. \*\*\*  $p < 0.01$ .

Table 5 presents the second-stage estimates of the effect of adult children’s educational attainment on parental energy poverty using an instrumental variables approach. As shown in Column (5), the educational achievements of adult children exhibit a statistically significant negative association with parental energy poverty. After instrumenting, the coefficient remains significant, indicating that higher education levels among adult children reduce their parents’ likelihood of experiencing energy poverty. The empirical findings lend support to Hypothesis 1. Moreover, the magnitude of the estimated coefficient increases from  $-0.024$  in the baseline model to  $-0.048$ . This underscores the importance of addressing endogeneity when evaluating intergenerational educational spillovers. By isolating the exogenous variation in schooling through the instrument, the IV specification uncovers a more substantive protective effect. The doubled magnitude implies that the average treatment effect (ATE) conceals significant heterogeneity. The IV estimate specifically captures the effect for “compliers”, children who upgraded their education in response to the policy shock. For these households, the returns to education in terms of improving

energy literacy and household budget allocation are substantially higher, making the policy intervention particularly impactful for vulnerable families.

**Table 5.** Effect of eldest children’s educational attainment on parents’ energy poverty.

| Variables                              | (1)                   | (2)                   | (3)                   | (4)                   | (5)                   | (6)                   | (7)                  |
|----------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------|
|                                        | EP                    | EP                    | EP                    | EP                    | EP                    | EP                    | EP                   |
| Education of adult children            | −0.073 ***<br>(0.008) | −0.059 ***<br>(0.008) | −0.059 ***<br>(0.007) | −0.064 ***<br>(0.017) | −0.066 ***<br>(0.022) | −0.065 ***<br>(0.022) | −0.048 **<br>(0.023) |
| First-stage F-statistics               | 301.78                | 316.35                | 357.34                | 35.17                 | 25.62                 | 25.67                 | 23.93                |
| Observations                           | 15,049                | 15,049                | 15,049                | 15,049                | 15,049                | 15,049                | 15,049               |
| Centered R <sup>2</sup>                | 0.040                 | 0.066                 | 0.053                 | 0.032                 | 0.028                 | 0.032                 | 0.124                |
| Cluster at parents’ resident province  | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                    |
| Survey year FE                         |                       | ✓                     | ✓                     | ✓                     | ✓                     | ✓                     | ✓                    |
| Parents’ resident province FE          |                       |                       | ✓                     | ✓                     | ✓                     | ✓                     | ✓                    |
| Narrow children’s birth year cohort FE |                       |                       |                       | ✓                     | ✓                     | ✓                     | ✓                    |
| Province-specific cohort trends        |                       |                       |                       |                       | ✓                     | ✓                     | ✓                    |
| Children’s characteristics             |                       |                       |                       |                       |                       | ✓                     | ✓                    |
| Parents’ characteristics               |                       |                       |                       |                       |                       |                       | ✓                    |

Note: This table reports the second-stage estimates of the two-stage least squares (2SLS) regressions, using CEL exposure as the instrumental variable for children’s educational attainment (years of schooling). Children’s characteristics include the gender of the eldest child. Parents’ characteristics include gender, employment situation, marital status, age, and education level. And household characteristics include household registration and family size. The R<sup>2</sup> values reported are centered R<sup>2</sup> from 2SLS estimation. First-stage F-statistics for the excluded instrument are reported for each specification to assess instrument relevance. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ .

### 5.3. Validity Checks

One concern with our causal inference is that the staggered adoption of the Compulsory Education Law (CEL) across provinces could be conflated with underlying cohort-specific trends that predate the policy. To mitigate this threat, we conduct a placebo test by counterfactually moving the effective date of the CEL backwards by 4, 6, 8, and 10 years relative to its actual implementation in each province. We construct placebo exposure variables using the identical definition as our main instrument, and we confine the sample to parents whose eldest child was between 16 and 30 years old when the law was actually introduced in parents’ resident provinces [16].

Column (2) of Table 6 reports the reduced-form estimates of placebo CEL exposure on parental energy poverty under counterfactual scenarios in which the CEL was implemented 4, 6, 8, and 10 years prior to its actual rollout, respectively. Column (1) presents the first-stage estimates for the four placebo exposures, each regressed on children’s years of schooling. In sharp contrast to the baseline IV results, where the genuine CEL exposure shows a significant and negative effect on parental energy poverty, the placebo estimates fail to reach statistical significance at conventional levels. The magnitudes are also substantially smaller than those obtained with the actual rollout. This stark discrepancy suggests that the observed reduction in parental energy poverty is primarily attributable to the genuine policy exposure, rather than to pre-existing cohort trends or other time-varying confounders, thus providing support for the validity of our instrument.

**Table 6.** Validity checks, effects of exposure to placebo compulsory education laws.

|                                                            | (1)               | (2)               |
|------------------------------------------------------------|-------------------|-------------------|
|                                                            | Schooling         | EP                |
| <b>Panel A. Counterfactual CEL Implementation (t – 4)</b>  |                   |                   |
| Placebo CEL exposure                                       | 0.327<br>(1.017)  | 0.022<br>(0.144)  |
| <b>Panel B. Counterfactual CEL Implementation (t – 6)</b>  |                   |                   |
| Placebo CEL exposure                                       | –0.347<br>(0.697) | –0.019<br>(0.091) |
| <b>Panel C. Counterfactual CEL Implementation (t – 8)</b>  |                   |                   |
| Placebo CEL exposure                                       | –0.448<br>(0.603) | 0.001<br>(0.078)  |
| <b>Panel D. Counterfactual CEL Implementation (t – 10)</b> |                   |                   |
| Placebo CEL exposure                                       | –0.163<br>(0.546) | 0.013<br>(0.074)  |
| Observations                                               | 4421              | 4421              |

Note: Each cell gives a separate regression. The dependent variable in Column (1) is adult children’s years of schooling, whereas the other columns use parents’ energy poverty as the dependent variable. The analysis sample is restricted to parents whose eldest child was aged 16 to 30 when the CEL was implemented in their province of residence. All regressions include the same set of controls and fixed effects as those in Column (7) of Table 3.

#### 5.4. Robustness Tests

To enhance the robustness and credibility of the empirical results, we perform a series of robustness checks on the baseline estimates through the following approaches:

(1) Alternative measures of energy poverty are employed. Since there is no consensus in the literature on how to measure energy poverty, we use EP1 as an alternative proxy to re-examine the effect of adult children’s educational attainment on parents’ energy poverty. (2) We respecify the measurement of the explanatory variable. Instead of using the years of education of the oldest adult child, we use the average years of education across all children to capture the overall educational influence of offspring. (3) To account for provincial-level macroeconomic influences, we incorporate the following provincial-level control variables: per capita gross regional product, per capita government expenditure, the number of primary and secondary schools per student, and the number of full-time teachers per student in these schools. (4) Given that EP is a categorical variable taking values of 1, 2, and 3 rather than a continuous variable, we use an extended ordered probit model as a robustness check.

The results in Table 7 show that the central finding remains highly robust. Across all alternative specifications, the negative relationship between children’s education and parental energy poverty persists and remains statistically significant at the 5% level. This confirms that the estimated effect is not driven by any particular modeling choice and measurement approach.

**Table 7.** Robustness checks.

|                             | (1)                                       | (2)                                             | (3)                      | (4)                  |
|-----------------------------|-------------------------------------------|-------------------------------------------------|--------------------------|----------------------|
| Variables                   | Alternative Measure of Dependent Variable | Alternative Measure of the Independent Variable | Province Characteristics | Alternative Model    |
| Education of adult children | –0.045 **<br>(0.020)                      |                                                 | –0.048 **<br>(0.022)     | –0.068 **<br>(0.027) |

Table 7. Cont.

| Variables                                      | (1)<br>Alternative Measure of<br>Dependent<br>Variable | (2)<br>Alternative Measure of the<br>Independent Variable | (3)<br>Province<br>Characteristics | (4)<br>Alternative<br>Model |
|------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------|------------------------------------|-----------------------------|
| Average years of schooling for<br>all children |                                                        | −0.060 **<br>(0.029)                                      |                                    |                             |
| First-stage F-statistics                       | 23.93                                                  | 25.86                                                     | 23.91                              |                             |
| Observations                                   | 15,049                                                 | 15,049                                                    | 15,049                             | 15,049                      |
| Centered R <sup>2</sup>                        | 0.104                                                  | 0.130                                                     | 0.124                              |                             |
| Cluster at parents' resident<br>province       | ✓                                                      | ✓                                                         | ✓                                  | ✓                           |
| Survey year FE                                 | ✓                                                      | ✓                                                         | ✓                                  | ✓                           |
| Parents' resident province FE                  | ✓                                                      | ✓                                                         | ✓                                  | ✓                           |
| Narrow children's birth year<br>cohort FE      | ✓                                                      | ✓                                                         | ✓                                  | ✓                           |
| Province-specific cohort trends                | ✓                                                      | ✓                                                         | ✓                                  | ✓                           |

Note: Each column presents a separate regression. Column (1) uses an alternative measure of the dependent variable. Column (2) uses an alternative measure of the independent variable. Column (3) further incorporates province-level characteristics. The province's characteristics include gross regional product per capita (deflated to constant prices using provincial CPI), government expenditure per capita, number of primary and middle schools per student, and number of full-time teachers in primary and middle schools per student. Column (4) reports the results from an extended ordered probit (eoprobit) model. In the auxiliary equation for the endogenous covariate, the excluded instrument (CEL exposure) is strongly correlated with children's education, confirming instrument relevance. Note that conventional first-stage F-statistics and R<sup>2</sup> are not reported for the eoprobit model, as it is estimated by maximum likelihood rather than 2SLS. \*\*  $p < 0.05$ .

### 5.5. Potential Mechanisms

This section examines potential pathways by which the duration of children's schooling may influence parental energy poverty. Specifically, we examine two plausible channels: internet adoption and access to modern energy equipment.

Many studies suggest that adult children's education significantly shapes parental behaviors through technology adoption [16,17] and the adoption of digital technologies can effectively reduce household energy poverty [12,22]. Better-educated children exhibit a greater propensity to demonstrate stronger digital literacy and cognitive skills [24,25], helping their parents learn to use the internet and smart devices, potentially reducing parents' energy poverty. We measure Internet adoption using the CHARLS question "Does your residence have broadband Internet connection?" with responses coded as 1 for "yes" and 0 for "no", serving as the single proxy for Internet use. As shown in Columns (1) and (2) of Table 8, adult children's educational attainment exhibits a significant positive effect on parents' internet adoption. Specifically, each extra year of children's education is correlated with a 4.3% increase in the likelihood of parents using the internet. In Column (2), internet use is negatively and significantly associated with parental energy poverty, with a coefficient of −0.180, while children's education retains a negative and significant direct effect on energy poverty. The indirect effect of children's education on parental energy poverty through internet adoption is estimated at 0.008, accounting for approximately 16.67% of the total effect. Given that the direct effect of children's education remains negative and statistically significant after controlling for internet use, these results suggest that internet adoption serves as a partial mediator in the relationship between children's education and parental energy poverty. The findings provide support for Hypothesis 2.

**Table 8.** Potential mechanisms, internet adoption and access to modern energy equipment.

| Variables                                                       | (1)                 | (2)                   | (3)                               | (4)                   |
|-----------------------------------------------------------------|---------------------|-----------------------|-----------------------------------|-----------------------|
|                                                                 | Internet Adoption   | EP                    | Access to Modern Energy Equipment | EP                    |
| <b>Panel A. Internet use as a mediator</b>                      |                     |                       |                                   |                       |
| Education of adult children                                     | 0.043 **<br>(0.020) | −0.041 *<br>(0.023)   |                                   |                       |
| Internet adoption                                               |                     | −0.180 ***<br>(0.027) |                                   |                       |
| <b>Panel B. Access to modern energy equipment as a mediator</b> |                     |                       |                                   |                       |
| Education of adult children                                     |                     |                       | 0.041 **<br>(0.018)               | −0.040 *<br>(0.023)   |
| Access to modern energy equipment                               |                     |                       |                                   | −0.207 ***<br>(0.032) |
| First-stage F-statistics                                        | 24.16               | 20.94                 | 23.93                             | 22.81                 |
| Indirect effect                                                 |                     | −0.008 ***            |                                   | −0.009 ***            |
| Proportion                                                      |                     | 16.67%                |                                   | 18.75%                |
| Control variables                                               | ✓                   | ✓                     | ✓                                 | ✓                     |
| Survey year FE                                                  | ✓                   | ✓                     | ✓                                 | ✓                     |
| Parents' resident province FE                                   | ✓                   | ✓                     | ✓                                 | ✓                     |
| Cluster at parents' resident province                           | ✓                   | ✓                     | ✓                                 | ✓                     |
| Narrow children's birth year cohort FE                          | ✓                   | ✓                     | ✓                                 | ✓                     |
| Province-specific cohort trends                                 | ✓                   | ✓                     | ✓                                 | ✓                     |
| Observations                                                    | 15,024              | 15,024                | 15,049                            | 15,049                |
| Centered R <sup>2</sup>                                         | 0.043               | 0.145                 | 0.082                             | 0.152                 |

Note: Control variables include the gender of the eldest child, parents' gender, employment situation, marital status, age, education level, household registration, and family size. The indirect effects and their statistical significance are estimated using bootstrap standard errors with 1000 replications. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

Then, we examine the effect of access to modern energy equipment. The acquisition and effective utilization of modern energy equipment such as clean cookstoves, electric water heaters, and energy-efficient appliances are essential for alleviating energy poverty. However, middle-aged and older parents often encounter substantial barriers in accessing these technologies, including inadequate technical knowledge for installation and maintenance and restricted access to reliable distribution channels in rural areas. Better-educated children can help overcome these obstacles in several ways. They can offer hands-on technical assistance with installation and maintenance and leverage their social networks to identify reliable suppliers and favorable pricing. They may also transmit norms about the benefits of modern energy equipment, enhancing parental willingness to adopt and use these technologies consistently.

Columns (3) and (4) of Table 8 present the effects of adult children's education on parental access to modern energy equipment, using the installation of a water heater as the indicator. Column (3) shows a significant positive association between children's educational attainment and the probability of water heater installation. Specifically, each additional year of children's schooling increases the likelihood of parental water heater adoption by 4.1 percentage points, suggesting that better-educated children enhance their parents' physical access to modern energy equipment. Column (4) reports the effect of the mediator on parental energy poverty, conditional on children's education. Access to modern energy equipment is negatively and significantly associated with parental energy poverty, with a coefficient of  $-0.207$ , while children's education retains a negative and significant direct effect on energy poverty. The indirect effect transmitted through access to modern energy equipment is estimated at  $0.009$ , representing  $18.75\%$  of the total effect. Taken together, the results identify modern energy equipment access as a quantitatively meaningful mediator, suggesting that adult children's educational attainment can influ-

ence parents' energy poverty by enhancing their access to modern energy equipment. Hypothesis 3 is corroborated by the results.

### 5.6. Heterogeneous Effects Analysis

To uncover potential heterogeneity in the intergenerational transmission of educational benefits, this section systematically examines how the estimated effect of adult children's schooling on parental energy poverty varies across a range of contextual dimensions, including the frequency of intergenerational contact, urban–rural residence, and the child's gender.

We construct visit frequency from the CHARLS question: “How often do you see (child's name)?” Responses range from (1) almost every day to (10) almost never. We code answers 1–5 as “frequent” and 6–10 as “occasional.” Results in Columns (1) and (2) of Table 9 indicate that the effect of children's educational attainment on alleviating parental energy poverty is significant in the “frequent visit” subsample. However, Fisher's permutation test statistic of 0.018 does not reach conventional significance thresholds, indicating that the observed difference between contact-frequency groups is not statistically robust. We therefore refrain from claiming that visit frequency constitutes a reliable moderator of the main effect. This lack of significant difference may partly reflect the evolving nature of intergenerational support in the digital era, wherein technological advancements enable children to provide remote assistance such as online bill payments and virtual guidance.

**Table 9.** Heterogeneity analysis.

| Variables                              | (1)                  | (2)               | (3)                   | (4)              | (5)                 | (6)               |
|----------------------------------------|----------------------|-------------------|-----------------------|------------------|---------------------|-------------------|
|                                        | Frequently           | Occasionally      | Rural                 | Urban            | Son                 | Daughter          |
| Education of adult children            | −0.080 **<br>(0.034) | −0.006<br>(0.041) | −0.080 ***<br>(0.027) | 0.065<br>(0.064) | −0.060 *<br>(0.032) | −0.039<br>(0.033) |
| First-stage F-statistics               | 18.92                | 14.90             | 22.26                 | 7.17             | 16.05               | 16.01             |
| Observations                           | 9334                 | 5715              | 8973                  | 6076             | 7927                | 7122              |
| Centered R <sup>2</sup>                | 0.080                | 0.090             | −0.084                | −0.183           | 0.109               | 0.133             |
| Fisher's permutation test              | 0.018                |                   | 0.083 ***             |                  | 0.063 ***           |                   |
| Control variables                      | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |
| Survey year FE                         | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |
| Parents' resident province FE          | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |
| Cluster at parents' resident province  | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |
| Narrow children's birth year cohort FE | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |
| Province-specific cohort trends        | ✓                    | ✓                 | ✓                     | ✓                | ✓                   | ✓                 |

Note: Fisher's permutation test was obtained by the difference test between the analysis groups. Control variables include the gender of the eldest child, parents' gender, employment situation, marital status, age, education level, household registration and family size. The centered R<sup>2</sup> can be negative and is not meaningful for IV estimation. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ .

Rural households generally have lower income levels and often rely on traditional, low-cost energy sources such as coal, firewood, and liquefied petroleum gas to reduce energy expenditures, which in turn exacerbates their energy poverty. To examine whether the mitigating effect of adult children's education on parental energy poverty differs between urban and rural areas, we divide the sample into two subgroups. Heterogeneity analysis reveals an urban–rural divide. As shown in Table 9, Columns (3) and (4), adult children's education significantly reduces parental energy poverty in rural areas but has no significant effect for urban households. According to the Seventh National Population Census, there were 120 million people aged 60 and above in rural China. This figure accounts for 23.81% of the total rural population, which is 7.99 percentage points higher than that in urban areas. Compounding this demographic pressure, rural elderly receive pensions markedly lower

than those of urban workers. With such constrained income and underdeveloped energy infrastructure, rural households have scarce exposure to modern energy sources. Thus, rural residents may rely heavily on educated children as information brokers and financial supporters. In contrast, urban households enjoy steadier incomes and better infrastructure, making children's education less critical for reducing energy poverty.

To examine whether the mitigating effect of adult children's education on parental energy poverty differs by the child's gender, we split the full sample into two subgroups based on the eldest child's gender. As shown in Table 9, Columns (5) and (6), the negative effect of children's education on parental energy poverty is significant for households with male children. And for families with female children, the coefficient is smaller in magnitude and statistically insignificant. This pattern suggests a noticeable gender-based disparity in the intergenerational educational spillover on energy poverty. In traditional Chinese families, sons are expected to shoulder greater responsibility for elderly parents' care and financial support [63]. Consequently, the economic returns to sons' education, in terms of higher income and stronger financial capacity, are more likely to be transferred to elderly parents, thereby alleviating their energy poverty. Moreover, sons typically maintain closer geographic proximity to their parents than daughters. Daughters often relocate after marriage due to patrilocal customs. This spatial pattern enables sons to provide more frequent in-kind support and direct assistance in household energy management. These gendered patterns of resource allocation and support behavior may explain why sons' education exerts a more pronounced effect on reducing parental energy poverty.

## 6. Discussion and Conclusions

This study investigates how adult children's educational attainment affects their parents' energy poverty in China. Using panel data from CHARLS (2011–2020), we find that adult children's education exerts a significant mitigating effect on parental energy poverty. Heterogeneity analysis further reveals that the impact is more pronounced in rural households and for male children, highlighting the role of rural infrastructure gaps and gendered patterns of intergenerational support. While the effect also appears stronger when adult children visit their parents more frequently, this difference does not pass formal cross-group significance tests. Furthermore, we explore the underlying mechanisms through which adult children's education levels exert an influence on parental energy poverty. The mechanism analysis suggests that children's education effectively affects parental energy poverty through promoting Internet adoption and increasing access to modern energy equipment.

Our results carry significant practical implications for the formulation and optimization of targeted policies aimed at alleviating energy poverty.

First, integrate energy-related knowledge into school curricula to enhance long-term energy literacy. Our findings suggest that adult children's education can mitigate parental energy poverty. To strengthen this intergenerational spillover, policymakers should consider incorporating energy literacy, covering topics such as energy efficiency, clean energy alternatives, and household energy conservation into formal education curricula at primary and secondary levels. Such an approach would cultivate energy-conscious habits from an early age and, over the long term, amplify the intergenerational transmission of energy-saving knowledge and practices from children to parents.

Second, expand targeted energy subsidies and clean fuel infrastructure in rural areas. Our heterogeneity results show that the mitigating effect of children's education on energy poverty is significantly stronger in rural households, where energy poverty may be more severe due to limited infrastructure and lower income. This suggests that rural energy poverty cannot be addressed by education alone. Complementary policies such as

subsidizing clean stove adoption, expanding rural electricity grids, and ensuring affordable access to liquefied petroleum gas would help translate the benefits of children's education into actual clean energy use.

Third, integrate digital literacy training into public services for middle-aged and older individuals. Our mechanism analysis indicates that children's education facilitates parents' Internet adoption, which may broaden their access to information on energy subsidies and modern appliances, thereby alleviating energy poverty. Community-based training programs and senior education initiatives can help bridge the information gap for older parents by teaching them how to use mobile payments, apply for energy subsidies online, and compare clean energy options, thereby enabling them to benefit from digitalized energy services.

Due to data constraints and other factors, this study has several limitations that warrant acknowledgment. First, we use the eldest child's educational attainment as a proxy for the overall human capital of adult children, which may not fully capture the influence of younger siblings. This approach follows established conventions in the intergenerational spillover literature [52,55], where the eldest child typically serves as the primary reference point for parental investment decisions and family resource allocation. Nevertheless, the educational composition of all siblings may matter, particularly in multi-child households. Future studies with detailed sibling-level data could examine how the distribution of education across all children, rather than the eldest alone, affects parental energy poverty.

Second, our findings are circumscribed by China's institutional context. The compulsory education reform and the structure of intergenerational support in China reflect specific historical, cultural, and policy conditions that may not directly generalize to other countries. However, this contextual specificity also provides a valuable benchmark for comparative analysis. Future cross-national research could examine whether similar intergenerational education effects operate in societies with different pension systems, energy subsidy structures, and family support norms, thereby enriching our understanding of how institutional contexts moderate these relationships.

Finally, self-reported energy expenditure may introduce measurement error. While CHARLS employs standardized survey protocols and quality controls to minimize reporting bias, recall errors remain inherent limitations of household expenditure data. To address this, future research could incorporate objective energy consumption measures such as smart-meter data or utility billing records to validate self-reported estimates and enhance measurement precision.

These limitations notwithstanding, we believe our study provides a meaningful examination of the intergenerational effects of children's education on parental energy poverty, and we hope the directions outlined above will stimulate further inquiry in this important area.

**Author Contributions:** Conceptualization, Z.J. and Q.W.; Methodology, Q.W.; Software, H.S. and Q.W.; Formal analysis, Z.J. and H.S.; Data curation, H.S.; Writing—original draft, Z.J., H.S. and Q.W.; Writing—review & editing, Z.J. and H.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This work was supported by the Sichuan Provincial Science and Technology Program (Entrusted Project of Sichuan Provincial Social Science Fund) (Grant No. SCJJ25RKX155).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available in the China Health and Retirement Longitudinal Study (CHARLS) database at <https://charls.pku.edu.cn/>. These data were derived from the following resources available in the public domain: Peking University, China

Health and Retirement Longitudinal Study (CHARLS), available online: <https://charls.pku.edu.cn/>. We accessed the data on 15 September 2025, in accordance with CHARLS' official data use agreement.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

**Table A1.** Temporal variation in the 1986 compulsory education law implementation across provinces.

| Province       | CEL Effective Year | First Affected Birth Cohort |
|----------------|--------------------|-----------------------------|
| Beijing        | 1986               | 1971                        |
| Tianjin        | 1987               | 1972                        |
| Hebei          | 1986               | 1971                        |
| Shanxi         | 1986               | 1971                        |
| Inner Mongolia | 1988               | 1973                        |
| Liaoning       | 1986               | 1971                        |
| Jilin          | 1987               | 1972                        |
| Heilongjiang   | 1986               | 1971                        |
| Shanghai       | 1985               | 1970                        |
| Jiangsu        | 1987               | 1972                        |
| Zhejiang       | 1985               | 1970                        |
| Anhui          | 1987               | 1972                        |
| Fujian         | 1988               | 1973                        |
| Jiangxi        | 1986               | 1971                        |
| Shandong       | 1987               | 1972                        |
| Henan          | 1987               | 1972                        |
| Hubei          | 1987               | 1972                        |
| Hunan          | 1991               | 1976                        |
| Guangdong      | 1987               | 1972                        |
| Guangxi        | 1991               | 1976                        |
| Chongqing      | 1986               | 1971                        |
| Sichuan        | 1986               | 1971                        |
| Guizhou        | 1988               | 1973                        |
| Yunnan         | 1987               | 1972                        |
| Shaanxi        | 1987               | 1972                        |
| Gansu          | 1991               | 1976                        |
| Qinghai        | 1988               | 1973                        |
| Xinjiang       | 1988               | 1973                        |

Data cite:

The specific questionnaire items used in this study

We construct visit frequency from the CHARLS question: “How often do you see (child’s name)?”

Q1: How often do you see (child’s name)?

1. Almost every day
2. 2–3 times a week
3. Once a week
4. Every two weeks
5. Once a month
6. Once every three months
7. Once every six months
8. Once a year
9. Almost never
10. Other

We measure Internet adoption using the CHARLS question “Does your residence have broadband Internet connection?” with responses coded as 1 for “yes” and 0 for “no”, serving as the single proxy for Internet use.

Q2: Does your residence have broad-band internet connection?

1. Yes
2. No

## References

1. Dogan, E.; Madaleno, M.; Inglesi-Lotz, R.; Taskin, D. Race and Energy Poverty: Evidence from African-American Households. *Energy Econ.* **2022**, *108*, 105908. [\[CrossRef\]](#)
2. Qi, H.; Xue, Q.; Shi, Y.; Qi, X.; Yang, J.; Zheng, J.; Ren, L. Leveraging Explainable AI to Decode Energy Poverty in China: Implications for SDGs and National Policy. *Sustainability* **2025**, *17*, 11080. [\[CrossRef\]](#)
3. International Energy Agency. *World Energy Outlook 2023*; World Energy Outlook; OECD: Paris, France, 2023; ISBN 978-92-64-64773-2.
4. Abbas, K.; Li, S.; Xu, D.; Baz, K.; Rakhmetova, A. Do Socioeconomic Factors Determine Household Multidimensional Energy Poverty? Empirical Evidence from South Asia. *Energy Policy* **2020**, *146*, 111754. [\[CrossRef\]](#)
5. Rafi, M.; Naseef, M.; Prasad, S. Multidimensional Energy Poverty and Human Capital Development: Empirical Evidence from India. *Energy Econ.* **2021**, *101*, 105427. [\[CrossRef\]](#)
6. Bridge, B.A.; Adhikari, D.; Fontenla, M. Household-Level Effects of Electricity on Income. *Energy Econ.* **2016**, *58*, 222–228. [\[CrossRef\]](#)
7. Awaworyi Churchill, S.; Smyth, R. Ethnic Diversity, Energy Poverty and the Mediating Role of Trust: Evidence from Household Panel Data for Australia1. *Energy Econ.* **2020**, *86*, 104663. [\[CrossRef\]](#)
8. Acharya, R.H.; Sadath, A.C. Energy Poverty and Economic Development: Household-Level Evidence from India. *Energy Build.* **2019**, *183*, 785–791. [\[CrossRef\]](#)
9. Li, Z.; Meng, F.; Wu, S.; Afthanorhan, A.; Hao, Y. Guiding Clean Energy Transitions in Rural Households: Insights from China’s Pilot Low-Carbon Policies. *J. Environ. Manag.* **2024**, *370*, 122782. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Huang, J.; Xiang, S.; Wu, P.; Chen, X. How to Control China’s Energy Consumption through Technological Progress: A Spatial Heterogeneous Investigation. *Energy* **2022**, *238*, 121965. [\[CrossRef\]](#)
11. Lin, B.; Wang, Y. Does Energy Poverty Really Exist in China? From the Perspective of Residential Electricity Consumption. *Energy Policy* **2020**, *143*, 111557. [\[CrossRef\]](#)
12. Luan, B.; Zou, H.; Huang, J. Digital Divide and Household Energy Poverty in China. *Energy Econ.* **2023**, *119*, 106543. [\[CrossRef\]](#)
13. Nepal, R.; Dong, J.; Zhao, J.; Jamasb, T. Addressing Energy Poverty through Education: How Does Gender Matter? *Energy Econ.* **2025**, *141*, 108029. [\[CrossRef\]](#)
14. Cheng, S.; Wei, T.; Wang, F.; Zhuang, L. Does Financial Market Participation Eradicate Household Energy Poverty? *Energy Econ.* **2023**, *122*, 106687. [\[CrossRef\]](#)
15. Liang, Y.; Liu, X.; Yu, S. Education and Energy Poverty: Evidence from China’s Compulsory Education Law. *Energy* **2025**, *314*, 134135. [\[CrossRef\]](#)
16. Lei, L.; Yu, D.; Zhou, Y. Better Educated Children, Better Internet-Connected Elderly Parents. *Res. Policy* **2023**, *52*, 104743. [\[CrossRef\]](#)
17. Gan, H.; Lin, C.; Zhou, Y.; Zhuo, Z. Adult Children’s Education and Elderly Parents’ Energy Poverty: Evidence from China. *Energy Policy* **2025**, *202*, 114604. [\[CrossRef\]](#)
18. Offer, S.; Fischer, C.S. Calling on Kin: The Place of Parents and Adult Children in Egocentric Networks. In *Social Networks and the Life Course*; Alwin, D.F., Felmlee, D.H., Kreager, D.A., Eds.; Frontiers in Sociology and Social Research; Springer International Publishing: Cham, Switzerland, 2018; Volume 2, pp. 117–138, ISBN 978-3-319-71543-8.
19. Yu, S.; Wang, M.; Liang, Y. Child Education and Parental Financial Outcomes: Evidence from a Schooling Reform. *Financ. Res. Lett.* **2025**, *83*, 107659. [\[CrossRef\]](#)
20. Wang, L.; Rau, P.-L.P.; Salvendy, G. Older Adults’ Acceptance of Information Technology. *Educ. Gerontol.* **2011**, *37*, 1081–1099. [\[CrossRef\]](#)
21. Wei, N.; Zhou, L.; Huang, W. Does an Upward Intergenerational Educational Spillover Effect Exist? The Effect of Children’s Education on Chinese Parents’ Health. *Int. J. Health Econ. Manag.* **2022**, *22*, 69–89. [\[CrossRef\]](#) [\[PubMed\]](#)
22. Yue, Q.; Zhang, M.; Song, Y. Impact of Digital Divide on Energy Poverty across the Globe: The Mediating Role of Income Inequality. *Energy Policy* **2024**, *195*, 114349. [\[CrossRef\]](#)
23. Yue, J.; Chen, S.; Weng, Z.; Xie, Y.; Xu, M. Heterogeneous Characteristics of Household Energy Poverty and Sustainable Development: Perspective from the Household Life Cycle. *Energy* **2025**, *337*, 138581. [\[CrossRef\]](#)

24. Riddell, W.C.; Song, X. The Role of Education in Technology Use and Adoption: Evidence from the Canadian Workplace and Employee Survey. *ILR Rev.* **2017**, *70*, 1219–1253. [[CrossRef](#)]
25. Ackermann, K.; Awaworyi Churchill, S.; Smyth, R. High-Speed Internet Access and Energy Poverty. *Energy Econ.* **2023**, *127*, 107111. [[CrossRef](#)]
26. Hills, J. *Fuel Poverty: The Problem and Its Measurement*; CASereports; Department for Energy and Climate Change: London, UK, 2011.
27. Bouzarovski, S.; Petrova, S. A Global Perspective on Domestic Energy Deprivation: Overcoming the Energy Poverty–Fuel Poverty Binary. *Energy Res. Soc. Sci.* **2015**, *10*, 31–40. [[CrossRef](#)]
28. Munyanyi, M.E.; Awaworyi Churchill, S. Foreign Aid and Energy Poverty: Sub-National Evidence from Senegal. *Energy Econ.* **2022**, *108*, 105899. [[CrossRef](#)]
29. Biermann, P. *How Fuel Poverty Affects Subjective Well-Being: Panel Evidence from Germany*; Oldenburg Discussion Papers in Economics, No. V-395-16; University of Oldenburg: Oldenburg, Germany, 2016.
30. Boardman, B. *Fuel Poverty: From Cold Homes to Affordable Warmth*; Belhaven Press: London, UK; New York, NY, USA, 1991; ISBN 978-1-85293-139-1.
31. Alem, Y.; Demeke, E. The Persistence of Energy Poverty: A Dynamic Probit Analysis. *Energy Econ.* **2020**, *90*, 104789. [[CrossRef](#)]
32. Zhang, D.; Li, J.; Han, P. A Multidimensional Measure of Energy Poverty in China and Its Impacts on Health: An Empirical Study Based on the China Family Panel Studies. *Energy Policy* **2019**, *131*, 72–81. [[CrossRef](#)]
33. Nussbaumer, P.; Bazilian, M.; Modi, V. Measuring Energy Poverty: Focusing on What Matters. *Renew. Sustain. Energy Rev.* **2012**, *16*, 231–243. [[CrossRef](#)]
34. Wang, H.; Qian, Z.; Liu, Q.; Liu, Y.; Wang, H.; Wei, S. Predicting and Explaining Household Energy Poverty in China Using Bayesian-Optimised XGBoost Models. *Sustainability* **2026**, *18*, 5416. [[CrossRef](#)]
35. Wang, Y.; Lin, B. Can Energy Poverty Be Alleviated by Targeting the Low Income? Constructing a Multidimensional Energy Poverty Index in China. *Appl. Energy* **2022**, *321*, 119374. [[CrossRef](#)]
36. Ahmed, A.; Gasparatos, A. Multi-Dimensional Energy Poverty Patterns around Industrial Crop Projects in Ghana: Enhancing the Energy Poverty Alleviation Potential of Rural Development Strategies. *Energy Policy* **2020**, *137*, 111123. [[CrossRef](#)]
37. Gelo, D.; Kollamparambil, U.; Jeuland, M. The Causal Effect of Income on Household Energy Transition: Evidence from Old Age Pension Eligibility in South Africa. *Energy Econ.* **2023**, *119*, 106538. [[CrossRef](#)]
38. Wei, T.; Pan, H.; Duan, Z.; Xie, P. New Energy Technology Innovation and Energy Poverty Alleviation in China. *Renew. Energy* **2024**, *235*, 121348. [[CrossRef](#)]
39. Wang, Y.; Hou, L.; Hu, L.; Cai, W.; Wang, L.; Dai, C.; Chen, J. How Family Structure Type Affects Household Energy Consumption: A Heterogeneous Study Based on Chinese Household Evidence. *Energy* **2023**, *284*, 129313. [[CrossRef](#)]
40. Crentsil, A.O.; Asuman, D.; Fenny, A.P. Assessing the Determinants and Drivers of Multidimensional Energy Poverty in Ghana. *Energy Policy* **2019**, *133*, 110884. [[CrossRef](#)]
41. Karpinska, L.; Śmiech, S. Breaking the Cycle of Energy Poverty. Will Poland Make It? *Energy Econ.* **2021**, *94*, 105063. [[CrossRef](#)]
42. Drescher, K.; Janzen, B. Determinants, Persistence, and Dynamics of Energy Poverty: An Empirical Assessment Using German Household Survey Data. *Energy Econ.* **2021**, *102*, 105433. [[CrossRef](#)]
43. Du, J.; Song, M.; Xie, B. Eliminating Energy Poverty in Chinese Households: A Cognitive Capability Framework. *Renew. Energy* **2022**, *192*, 373–384. [[CrossRef](#)]
44. Xie, L.; Hu, X.; Zhang, X.; Zhang, X.-B. Who Suffers from Energy Poverty in Household Energy Transition? Evidence from Clean Heating Program in Rural China. *Energy Econ.* **2022**, *106*, 105795. [[CrossRef](#)]
45. Yan, Y.; Jiao, W.; Wang, K.; Huang, Y.; Chen, J.; Han, Q. Coal-to-Gas Heating Compensation Standard and Willingness to Make Clean Energy Choices in Typical Rural Areas of Northern China. *Energy Policy* **2020**, *145*, 111698. [[CrossRef](#)]
46. Banerjee, R.; Mishra, V.; Maruta, A.A. Energy Poverty, Health and Education Outcomes: Evidence from the Developing World. *Energy Econ.* **2021**, *101*, 105447. [[CrossRef](#)]
47. Oum, S. Energy Poverty in the Lao PDR and Its Impacts on Education and Health. *Energy Policy* **2019**, *132*, 247–253. [[CrossRef](#)]
48. Omar, M.A.; Hasanujjaman, M. Multidimensional Energy Poverty in Bangladesh and Its Effect on Health and Education: A Multilevel Analysis Based on Household Survey Data. *Energy Policy* **2021**, *158*, 112579. [[CrossRef](#)]
49. Sun, C.; Khan, A.; Ren, Y. Empowering Progress: Education, Innovations and Financial Development in the Battle against Energy Poverty. *J. Clean. Prod.* **2023**, *425*, 138941. [[CrossRef](#)]
50. Fang, J.; Gozgor, G.; Mahalik, M.K.; Mallick, H.; Padhan, H. Does Urbanisation Induce Renewable Energy Consumption in Emerging Economies? The Role of Education in Energy Switching Policies. *Energy Econ.* **2022**, *111*, 106081. [[CrossRef](#)]
51. Barry, C.; Denieffe, S. Energy Poverty and Aging: A Scoping Review of Health Impacts and Policy Gaps. *Age Ageing* **2025**, *54*, afaf318.057. [[CrossRef](#)]
52. Ma, M. Does Children’s Education Matter for Parents’ Health and Cognition? Evidence from China. *J. Health Econ.* **2019**, *66*, 222–240. [[CrossRef](#)] [[PubMed](#)]

53. Lundborg, P.; Majlesi, K. Intergenerational Transmission of Human Capital: Is It a One-Way Street? *J. Health Econ.* **2018**, *57*, 206–220. [[CrossRef](#)] [[PubMed](#)]
54. Zhao, C.; Wu, Y.; Guo, J. Mobile Payment and Chinese Rural Household Consumption. *China Econ. Rev.* **2022**, *71*, 101719. [[CrossRef](#)]
55. Liu, Y.; Ma, Y.; Smith, J.P. Adult Children's Education and Older Parents' Chronic Illnesses in Aging China. *Demography* **2022**, *59*, 535–562. [[CrossRef](#)] [[PubMed](#)]
56. Fry, J.M.; Farrell, L.; Temple, J.B. Energy Poverty and Retirement Income Sources in Australia. *Energy Econ.* **2022**, *106*, 105793. [[CrossRef](#)]
57. Torssander, J. From Child to Parent? The Significance of Children's Education for Their Parents' Longevity. *Demography* **2013**, *50*, 637–659. [[CrossRef](#)] [[PubMed](#)]
58. Koomson, I.; Danquah, M. Financial Inclusion and Energy Poverty: Empirical Evidence from Ghana. *Energy Econ.* **2021**, *94*, 105085. [[CrossRef](#)]
59. Del Río, P.; Burguillo, M.; Kiefer, C.P. Which Are the Main Determinants of Energy Poverty? A Systematic Review of the Literature. *Energy Effic.* **2025**, *18*, 58. [[CrossRef](#)]
60. Ghosh, A. Decoding Energy Poverty: Rural-Urban Disparities and Structural Barriers in BRICS Countries. *Front. Environ. Econ.* **2025**, *4*, 1552502. [[CrossRef](#)]
61. Cui, Y.; Liu, H.; Zhao, L. Mother's Education and Child Development: Evidence from the Compulsory School Reform in China. *J. Comp. Econ.* **2019**, *47*, 669–692. [[CrossRef](#)]
62. Chen, Y.; Feng, S. Access to Public Schools and the Education of Migrant Children in China. *China Econ. Rev.* **2013**, *26*, 75–88. [[CrossRef](#)]
63. Zeng, Y.; Brasher, M.S.; Gu, D.; Vaupel, J.W. Older Parents Benefit More in Health Outcome from Daughters' Than Sons' Emotional Care in China. *J. Aging Health* **2016**, *28*, 1426–1447. [[CrossRef](#)] [[PubMed](#)]

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.