

## Article

# Green Growth's Unintended Burden: The Distributional and Well-Being Impacts of China's Energy Transition

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## Abstract

Achieving environmentally sustainable growth is a core challenge for developing economies, yet the welfare consequences of green development policies for vulnerable populations remain understudied. This article investigates the distributional impacts of one of the world's largest development interventions: China's energy transition. By integrating provincial-level energy metrics with a decade-long household panel survey (CFPS), we employ a fixed-effects model to provide a holistic assessment of the policy's effects on household well-being. The analysis reveals a stark trade-off: a 10% increase in clean energy adoption generates significant non-monetary well-being gains, equivalent to a 190,000 CNY annual income rise, primarily through improved environmental quality and cleaner cooking fuel access. However, these benefits are partially offset by rising energy costs. Our heterogeneity analysis reveals a clear regressive burden: the transition significantly increases energy expenditures for rural and low-income households, while having a negligible or even cost-reducing effect on their urban and high-income counterparts. Our findings demonstrate that while the energy transition promotes aggregate welfare, its benefits are unevenly distributed, potentially exacerbating energy poverty and inequality. This underscores a critical development challenge: green growth is not automatically inclusive. We argue that for the energy transition to be truly pro-poor, it must be accompanied by robust social protection mechanisms, such as targeted subsidies, to shield the most vulnerable from the adverse economic shocks of the policy.

**Keywords:** energy transition; well-being; poverty; inequality; development policy; China



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## 1. Introduction

The pursuit of environmentally sustainable development has become a central paradigm for middle-income countries, yet this structural shift presents a profound policy dilemma [1]. As nations like China move away from fossil fuels to mitigate climate change and achieve Sustainable Development Goals (SDGs), a critical question for development economics emerges: who bears the cost of this green growth? In this paper, we adopt the OECD's widely used definition of green growth as “fostering economic growth and development while ensuring that the natural assets continue to provide the resources and environmental services on which our well-being relies” [2]. This conception emphasizes the compatibility of economic expansion and environmental protection, but also underscores

the trade-offs and distributional challenges that may arise during the transition. While international agreements like the Paris Accord place increasing pressure on emerging economies to decarbonize, the domestic political and social feasibility of these transitions hinges on their distributional consequences [3]. While the long-term environmental benefits are widely acknowledged, the immediate, household-level welfare consequences—particularly for the poor and vulnerable—are far from certain. Large-scale development policies, from trade liberalization to infrastructure projects, are rarely distributionally neutral [4]. Understanding the winners and losers of the energy transition is therefore crucial for designing development strategies that are not only green but also equitable and pro-poor.

China's energy transition represents a concrete embodiment of the green growth paradigm. On the one hand, it aims to decouple economic expansion from carbon emissions through large-scale renewable energy adoption, industrial upgrading, and stricter environmental regulation [5]. On the other hand, because these measures directly affect household energy use and living costs, they also reshape welfare outcomes and equity across income groups [6]. This dual nature makes China a particularly relevant case for examining whether green growth can simultaneously deliver aggregate environmental benefits and equitable improvements in life satisfaction and well-being.

A key challenge in assessing such policies is measuring their impact on human welfare beyond simple income metrics. Development economics has long recognized the limitations of income as a proxy for well-being, advocating for multi-dimensional approaches that capture broader aspects of a good life, such as health and living standards [7]. In this vein, self-reported life satisfaction has gained traction as an empirical tool to measure experienced utility, providing a holistic assessment of how individuals perceive the net effects of policy changes on their lives [8,9]. This approach, part of the broader 'beyond GDP' movement, is particularly valuable for evaluating policies with significant non-market impacts, which are common in both environmental and social development contexts. This approach allows us to weigh non-market benefits, like cleaner air, against tangible costs, like higher energy bills, in a single, welfare-based framework, offering a powerful lens to analyze the distributional outcomes of development interventions.

Despite its importance, the literature on the distributional effects of energy transitions in developing countries remains fragmented. One stream of research focuses on the crucial issue of energy poverty and access to modern cooking fuels, documenting the significant health and time-use benefits for rural households [10,11]. Another stream examines the macroeconomic impacts of environmental policies or the technical aspects of renewable energy adoption [12]. However, these streams in the literature often run in parallel. Few studies provide an integrated assessment that simultaneously quantifies the significant non-market environmental benefits alongside the direct economic cost burdens imposed on households. This gap is significant, as a policy's overall effect on poverty and inequality depends on the net outcome of these competing pathways. Without such an integrated view, policymakers risk making decisions based on incomplete evidence, potentially overstating the benefits or underestimating the costs to the poor.

This study contributes to the development literature by providing a comprehensive, household-level analysis of the welfare and distributional consequences of China's energy transition. We conceptualize this transition as a major development policy and use a decade of nationally representative panel data to trace its multifaceted impacts. Our analysis offers three key contributions. First, we quantify the large, positive welfare effects stemming from improved environmental quality, a non-monetary benefit often overlooked in traditional poverty impact analyses. Second, we document the regressive nature of the associated energy cost increases, providing evidence of the policy's adverse impact on vulnerable groups. Third, by integrating these channels, we offer a net assessment of the policy's distri-

butional footprint. This speaks directly to the ongoing debate within development studies on how to manage policy-induced trade-offs and achieve ‘inclusive growth’. Our findings provide critical insights for policymakers in China and other developing nations on how to design inclusive social protection systems to mitigate the unintended consequences of the green transition, ensuring that the path to sustainability does not leave the poor behind.

## 2. Energy Transition and Individual Well-Being: An Analytical Framework

The intricate relationship between energy transition and individual well-being has garnered increasing attention lately. From a planning perspective, understanding this relationship is vital for designing policies that maximize social welfare. The vital role of the environment in this relationship has been confirmed. The health risks linked to environmental degradation can diminish individual well-being [13]. Additionally, environmental degradation can limit social and outdoor activities, resulting in elevated mental health risks and diminished individual well-being [14]. Energy transition has been confirmed to play a role in preventing environmental degradation. For example, Yuan et al. [15] discovered that PM<sub>2.5</sub> concentration can be mitigated by energy transition by predicting it under different energy transition scenarios. Similarly, Galimova et al. [16] asserted that a complete transition to renewable energy by 2050, as opposed to 2015, will lead to reductions of 99.8%, 96.7%, and 99.4% in SO<sub>x</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub>, respectively. Shen et al. [17] substantiated the contribution of energy transition to enhancing air quality in the overall setting of residential energy transition. Therefore, energy transition will improve the environment, potentially increasing individual well-being.

Existing studies have also explored other potential mechanisms through which the energy transition affects individual well-being, emphasizing the importance of cooking energy. The energy transition will globally encourage residents to opt for clean cooking energy. Illustrative instances encompass fuel subsidy policies in Latin America [18] and India [19]. The transition from traditional fossil fuels to renewable energy has rendered clean cooking energy more accessible to households [20]. Moreover, it takes a considerable amount of time to gather and use traditional cooking fuels like firewood and coal [21]. Clean cooking energy is accessible, efficient, and time-saving. It minimizes the effort required for fuel collection and cooking. For example, Akter and Pratap [22] found that households opting for clean cooking energy in India collect firewood less frequently, leading to an average daily reduction of 15 min in cooking time. The energy transition can incentivize residents to choose clean cooking energy, potentially enhancing individual well-being.

Additionally, studies have shown that the transition to clean energy may result in higher energy costs, resulting in a decline in individual well-being. Implementing energy transition necessitates innovation in renewable energy technologies and equipment investment [23], upgrading current power grids [24], and gradually phasing out fossil fuel-based infrastructure [25], all of which incur high costs. For instance, even in Canada, where 67% of electricity is generated from renewable sources, an annual investment of USD 34.6 billion would still be required to achieve a comprehensive energy transition for all sectors [26]. Residents will experience a rise in energy expenditures due to the substantial costs of energy transition [27]. For instance, in comparison to 2013, the median annual energy expenses for urban and rural families in China rose by 12.5% and 25% in 2017, respectively [6]. Residents will encounter more pronounced energy poverty challenges as economic pressure on households escalates due to rising energy expenditures [28]. Ultimately, the heightened household energy expenditures resulting from the energy transition might result in a sustained reduction in residents’ well-being.

### 3. Hypothesis Development

Hypothesis development will be guided by several key aspects to address the issues in this study. In existing research, life satisfaction or happiness has been recognized as an approximation of experienced utility [29]. Life Satisfaction Approach (LSA) has been considered an alternative method for environmental assessment in recent studies [30]. This method does not rely on specific decisions but instead assesses overall life satisfaction, linking self-reported life satisfaction with environmental factors, income, and other variables into a function that ultimately estimates the marginal rate of substitution (MRS) [31]. Following Menz [32], this study incorporates the happiness equation into analyzing residents' welfare in the context of energy transition. Individual utility, or subjective well-being, is assessed by life satisfaction. Considering the impact of environmental quality [33,34], cooking energy type [35], and energy cost [36] on life satisfaction, this study has developed the following life satisfaction equation:

$$LS = f(ET, I, P, F, C, X) \quad (1)$$

where  $LS$  represents residents' subjective life satisfaction,  $ET$  denotes the extent of the province's energy transition,  $I$  represents individual income,  $P$  represents environmental pollution,  $F$  represents the residents' cooking fuel,  $C$  is the energy cost, and  $X$  is the vector of control variables.

Taking into account that energy transition can enhance environmental quality [37], promote the transition to cleaner cooking energy [38], and increase the cost of living for residents [6], the following equations are established:

$$P = g(ET, X') \quad (2)$$

$$F = k(ET, X'') \quad (3)$$

$$C = h(ET, X''') \quad (4)$$

where  $X'$ ,  $X''$ , and  $X'''$  represent the vectors of control variables influencing  $P$ ,  $F$ , and  $C$ , respectively.

Taking the derivative of Equations (1)–(4) simultaneously, the marginal impact of the energy transition on life satisfaction can be calculated:

$$\frac{dLS}{dET} = \frac{\partial LS}{\partial ET} + \frac{\partial LS}{\partial P} \times \frac{\partial P}{\partial ET} + \frac{\partial LS}{\partial F} \times \frac{\partial F}{\partial ET} + \frac{\partial LS}{\partial C} \times \frac{\partial C}{\partial ET} \quad (5)$$

The right side is obtained by summing up four terms in Equation (5). The first term,  $\partial LS/\partial ET$ , represents the immediate influence of energy transition on life satisfaction. The symbolic meaning of this expression remains unclear due to the uncertainty surrounding the influence of energy transition on life satisfaction. The second expression,  $\partial LS/\partial P \times \partial P/\partial ET$ , signifies the indirect impact of environmental pollution. It is inferred that  $\partial LS/\partial P < 0$  because an increase in environmental pollution likely decreases life satisfaction [32]. Given that energy transition can enhance environmental quality [17], it is deduced that  $\partial P/\partial ET < 0$ . Combining these considerations, it can be concluded that the second term is positive. The third term,  $\partial LS/\partial F \times \partial F/\partial ET$ , represents the indirect impact of cooking fuel. It indicates that  $\partial LS/\partial F > 0$  since clean cooking fuels increase life satisfaction [21]. Residents are encouraged to opt for clean cooking fuels owing to the substantial progress in the energy transition [39]. Thus, it can be concluded that  $\partial F/\partial ET > 0$ . Therefore, this study anticipates that the sign of the third term is also positive. Drawing upon the assessment above, this research formulates the following hypotheses:

**Hypothesis 1.** Energy transition positively influences life satisfaction.

**Hypothesis 2.** Energy transition is expected to decrease environmental pollution, consequently increasing life satisfaction.

**Hypothesis 3.** Energy transition encourages residents to adopt clean cooking energy, which enhances life satisfaction.

The fourth term in Equation (5),  $\partial LS/\partial C \times \partial C/\partial ET$ , represents the indirect impact of energy costs. Given that high living costs are associated with lower life satisfaction [36], it follows that  $\partial LS/\partial C < 0$ . As energy transition leads to the adoption of cleaner but more expensive energy sources [6], it implies that  $\partial C/\partial ET > 0$ . Therefore, the fourth term is expected to be negative. Based on this, Hypothesis 4 is proposed.

**Hypothesis 4.** Energy transition will lead to an increase in energy costs, subsequently reducing life satisfaction.

In summary, Figure 1 presents the conceptual framework proposed in this research, illustrating the influence of energy transition on life satisfaction.

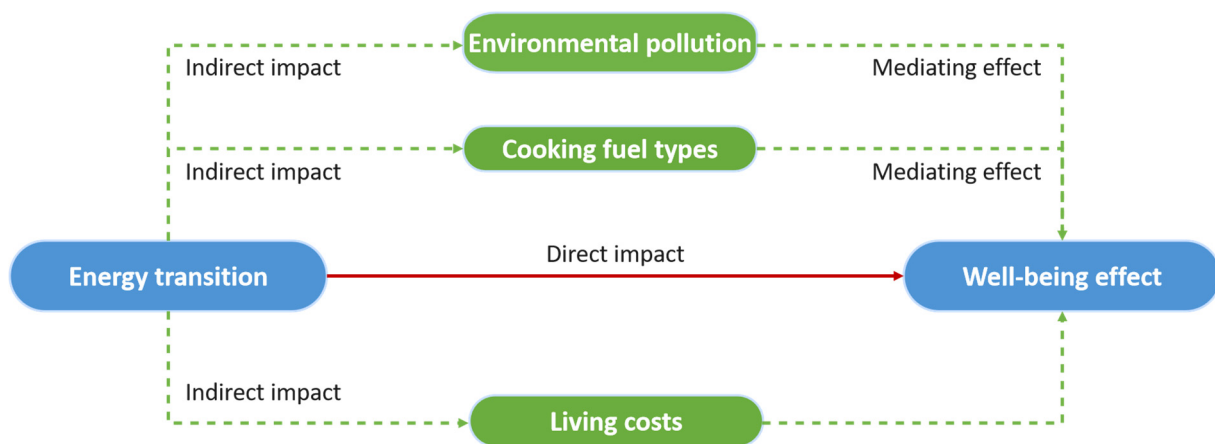


**Figure 1.** The conceptual model.

## 4. Methods

### 4.1. Empirical Models

Considering that the dependent variable, life satisfaction, is an ordinal variable ranging from 1 to 5, this study employs an ordered logistic regression model. To account for the influence of unobservable individual, temporal, and regional effects, as suggested by Baetschmann et al. [40], a fixed-effects ordered logistic regression model (FE-Ologit) is implemented to assess the impact caused by the energy transition on life satisfaction. Equations (6) and (7) represent the baseline regression model for this strategy.

$$Y_{it}^* = X_{it}^T \beta + \alpha_i + \varepsilon_{it} \quad (6)$$

$$Y_{it} = k \text{ if } \tau_{ik} < Y_{it}^* < \tau_{ik+1}, \text{ where } k = 1, \dots, 5 \quad (7)$$

where  $i$  represents the surveyed individual,  $t$  denotes the surveyed year,  $Y_{it}$  is the ordered variable for life satisfaction,  $Y_{it}^*$  is the latent variable for  $Y_{it}$ ,  $X_{it}$  is a vector of several covariates, including the core explanatory variables and various levels of control variables,  $\beta$  is the coefficient vector,  $\alpha_i$  is the unobservable individual fixed effect,  $\tau$  is the threshold, and  $\varepsilon$  is the error term.

Following Chen et al. [41], the current research implements the subsequent formula to investigate the potential mediating impacts of energy transition on life satisfaction:

$$LS_{it} = a_0 + a_1 ET_{it} + a_2 I_{it} + a_3 X_{it} + \mu_i + \gamma_t + \tau_p + \varepsilon_{it} \quad (8)$$

$$M_{it} = b_0 + b_1 ET_{it} + b_2 X_{it} + \mu_i + \gamma_t + \tau_p + \varepsilon_{it} \quad (9)$$

where  $M_{it}$  represents the mediating variables, including *envi*, *AQI*, *cookfuel*, and *C<sub>all</sub>*.  $X_{it}$  includes a group of control variables at the person, family, and regional levels.  $\mu_i$  denotes individual fixed effects,  $\gamma_t$  represents year fixed effects,  $\tau_p$  is regional fixed effects, and  $\varepsilon_{it}$  is the error term.

The estimated parameters can be used to derive the MRS between energy transition and income, representing the amount of money individuals are willing to forgo for energy transition while keeping the effect (here represented by life satisfaction) constant. Drawing on Menz [32], MRS can be calculated based on Equation (10), building upon the fundamental regression results obtained from Equation (8).

$$MRS = \frac{\frac{\partial LS_{it}}{\partial ET_{it}}}{\frac{\partial LS_{it}}{\partial I_{it}}} = \frac{a_1}{a_2} \quad (10)$$

#### 4.2. Data

This study examines the influence of energy transition on individual well-being by aligning provincial-level energy transition data in China with micro-level life satisfaction data. Utilizing data from six waves (2010–2020) of the China Family Panel Studies (CFPS), this study constructs an unbalanced panel dataset containing 9964 unique individuals and 43,980 individual-year observations. The measurement methods and data sources for all variables are outlined below.

Life satisfaction (denoted as *LS*) is the dependent variable in the current investigation, commonly employed in research on individual well-being [42,43]. Respondents aged 16 and above are required to select a number between 1 and 5 in response to the query “How satisfied are you with your life?” from the CFPS questionnaire, where 1 indicates very dissatisfied, and 5 represents very satisfied. Responses to this question capture a general and long-term perspective on life satisfaction, unrestricted by a specific time frame. Throughout all six rounds of CFPS surveys, the same question and response criteria were presented to participants, contributing to the compilation of a comprehensive long-term panel dataset.

Energy transition (denoted as *ET*) is chosen as the independent variable. The power sector consumed 59% of the world’s coal, 34% of natural gas, and 4% of oil in 2021 [44]. Furthermore, the prevailing energy transition is predominantly from fossil fuels to renewable sources [45]. Considering the role of the power sector’s energy transition in the overall energy transition [46] and the constraints in data availability, this study utilizes the proportion of non-fossil fuel electricity generation as a proxy variable to gauge the extent of the energy transition [47].

This indicator captures the upstream structural decarbonization of regional energy systems, which affects the availability, reliability, and affordability of electricity that households ultimately experience. Although it does not fully reflect household-level energy use patterns—for instance, access to clean cooking fuels or local grid stability—it provides a consistent and comparable measure across provinces and years. This limitation is acknowledged when interpreting the empirical results. The range of *ET* is between 0 and 1, with a higher *ET* indicating a more advanced stage of energy transition in the province.

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The mediating variables considered in this study comprise environmental pollution, cooking fuel choice, and energy costs. The study employs the Air Quality Index (AQI) and subjective environmental assessment (*envi*) to measure environmental pollution. The variable *envi* results from responses to the question “How do you perceive the severity of environmental protection issues in China?” in CFPS, with a scale ranging from 0 to 10, where 0 signifies minimal severity, and 10 indicates extreme seriousness. The cooking fuel (*cookfuel*) variable is derived from the response to the question, “What is the primary cooking fuel in your household?” with options encompassing wood, coal, gas, liquefied petroleum gas, natural gas, solar energy, biogas, and electricity. Responses to this question were re-encoded in this study, assigning a value of 0 to wood or coal and 1 to all other selections. Following Wang et al. [6], the total energy cost ( $C_{all}$ ) was constructed using data from the CFPS household survey. In the original survey, electricity ( $C_{elec}$ ) and fuel ( $C_{fuel}$ ) expenditures are reported monthly, while heating expenditure ( $C_{heat}$ ) is reported on an annual basis. To ensure consistency, monthly values are converted into annual terms, and total household energy expenditure is calculated as shown in Equation (11):

$$C_{all} = 12 \times (C_{elec} + C_{fuel}) + C_{heat} \quad (11)$$

Additionally, this study included controls for various variables to mitigate the potential impact of individual, household, and regional heterogeneity. Individual-level control variables encompass age, gender, years of education, ethnicity, political affiliation, occupation, type of residence, household registration type, marital status, self-rated health, and confidence in the future [48]. Household controls consist of family size and the logarithm of per capita net income. At the regional level, the primary control variable is per capita GDP.

Individual and household microdata are obtained from the CFPS survey questionnaire (<https://opendata.pku.edu.cn/dataverse/CFPS>, accessed on 9 March 2024). The data regarding the proportion of fossil fuel electricity generation is extracted from the *China Electric Power Yearbook*. AQI data is collected from the China Air Quality Online Monitoring and Analysis Platform (<http://www.aqistudy.cn/>), and provincial GDP data is derived from the *China Statistical Yearbook*. Table 1 presents an overview of all variables.

**Table 1.** Descriptive Statistics.

| Variables                                        | Definition                                                                  | Obs    | Mean      | Std. Dev. | Min   | Max       |
|--------------------------------------------------|-----------------------------------------------------------------------------|--------|-----------|-----------|-------|-----------|
| <i>LS</i>                                        | Life satisfaction, ranging from 1 (very dissatisfied) to 5 (very satisfied) | 43,980 | 3.788     | 1.047     | 1     | 5         |
| <i>ET</i>                                        | Energy transition, indicated by the share of non-fire power generation      | 43,980 | 0.248     | 0.228     | 0.006 | 0.911     |
| <b>Control variables at the individual level</b> |                                                                             |        |           |           |       |           |
| <i>income</i>                                    | Personal annual total income                                                | 43,356 | 61,167.37 | 91,953.55 | 0     | 6,033,600 |
| <i>age</i>                                       | >16                                                                         | 43,980 | 50.421    | 13.272    | 18    | 96        |
| <i>gender</i>                                    | 0 = female, 1 = male                                                        | 43,980 | 0.447     | 0.497     | 0     | 1         |
| <i>eduyear</i>                                   | Years of education                                                          | 43,774 | 6.879     | 4.558     | 0     | 19        |
| <i>ethnicity</i>                                 | 0 = others, 1 = Han nationality                                             | 43,980 | 0.934     | 0.248     | 0     | 1         |
| <i>party</i>                                     | 0 = others, 1 = Communist Party member                                      | 43,980 | 0.001     | 0.029     | 0     | 1         |
| <i>job</i>                                       | 0 = unemployed, 1 = employed                                                | 43,980 | 0.754     | 0.430     | 0     | 1         |
| <i>urban</i>                                     | 0 = rural, 1 = city                                                         | 43,980 | 0.447     | 0.497     | 0     | 1         |

Table 1. Cont.

| Variables                                        | Definition                                                                                                           | Obs    | Mean      | Std. Dev. | Min    | Max       |
|--------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------|-----------|-----------|--------|-----------|
| <i>household</i>                                 | Household type, 0 = agricultural registered permanent residence, 1 = non-agricultural registered permanent residence | 43,922 | 0.246     | 0.430     | 0      | 1         |
| <i>married</i>                                   | 0 = others, 1 = married                                                                                              | 43,980 | 0.893     | 0.309     | 0      | 1         |
| <i>unmarried</i>                                 | 0 = others, 1 = unmarried                                                                                            | 43,980 | 0.039     | 0.195     | 0      | 1         |
| <i>divorced_wid</i>                              | 0 = others, 1 = divorced or widowed                                                                                  | 43,980 | 0.068     | 0.251     | 0      | 1         |
| <i>health</i>                                    | Self-reported health status, ranging from 1 (unhealthy) to 5 (very healthy)                                          | 43,980 | 2.854     | 1.225     | 1      | 5         |
| <i>confidence</i>                                | Confidence for the future, ranging from 1 (very low) to 5 (very high)                                                | 43,980 | 3.984     | 1.038     | 1      | 5         |
| <b>Control variables at the household level</b>  |                                                                                                                      |        |           |           |        |           |
| <i>familysize</i>                                | Number of family members                                                                                             | 43,980 | 4.160     | 1.904     | 1      | 21        |
| <b>Control variables at the provincial level</b> |                                                                                                                      |        |           |           |        |           |
| <i>GDP</i>                                       | Provincial GDP per capita                                                                                            | 43,980 | 53,263.55 | 25,535.75 | 19,710 | 164,889.5 |
| <b>Mediating variables</b>                       |                                                                                                                      |        |           |           |        |           |
| <i>AQI</i>                                       | Air quality index                                                                                                    | 26,863 | 77.099    | 17.789    | 44.604 | 113.167   |
| <i>envi</i>                                      | Subjectively perceived level of environmental pollution, ranging from 0 (not serious) to 10 (very serious)           | 43,980 | 6.257     | 2.801     | 0      | 10        |
| <i>cookfuel</i>                                  | 0 = Firewood, coal, or others, 1 = Gas, LPG, natural gas, solar, biogas, or electricity                              | 43,980 | 0.651     | 0.477     | 0      | 1         |
| <i>C<sub>all</sub></i>                           | Total annual energy costs for households                                                                             | 43,154 | 2673.166  | 2891.327  | 0      | 84,400    |
| <i>C<sub>heat</sub></i>                          | Annual heating costs for households                                                                                  | 43,980 | 322.762   | 854.373   | 0      | 24,400    |
| <i>C<sub>elec</sub></i>                          | Annual electricity costs for households                                                                              | 43,980 | 104.239   | 120.519   | 0      | 3000      |
| <i>C<sub>fuel</sub></i>                          | Annual fuel costs for households                                                                                     | 43,980 | 93.781    | 178.213   | 0      | 5000      |

## 5. Results

### 5.1. Benchmark Regression

The current research examines how energy transition affects life satisfaction using Equations (6) and (7). Table 2 presents the findings. Findings are provided in Columns (1)–(2) without considering fixed effects, employing the Ologit model. Columns (3)–(5) display the results using the FE-Ologit model. The regression is gradually extended to include individual, year, and regional fixed effects. Column (6) incorporates all control variables and fixed effects.

The coefficient of *ET* is significantly positive in all models, as shown in Table 2. It illustrates that energy transition can effectively enhance residents' life satisfaction. Consequently, Hypothesis 1 is confirmed. The regression coefficients of the ordered logistic regression model do not directly represent marginal effects. Instead, they signify the rise in the ordered log-odds that, for every unit increase in the independent variable, the dependent variable will fall into a higher category. Therefore, it is necessary to follow Baetschmann et al. [40] and further obtain the marginal effects of energy transition on life satisfaction (refer to Table 3).

Table 3 illustrates that with the increase in *ET*, the likelihood of selecting 'very dissatisfied' ( $LS = 1$ ) diminishes by 3.8%, with a 95% confidence interval of  $[-0.068, -0.008]$ , whereas the likelihood of opting for 'very satisfied' ( $LS = 5$ ) rises by 25.3%, with a 95% confidence interval of  $[0.056, 0.449]$ . To provide a more intuitive interpretation of the effect

of energy transition (*ET*) on life satisfaction (*LS*), the expected change in *LS* for a one-unit increase in *ET* is calculated using the marginal effects from the FE-Ologit model, as shown in Equation (12):

$$E[\Delta LS] = \sum_{k=1}^5 \Delta P(LS = k) \cdot LS_k \quad (12)$$

where  $E[\Delta LS]$  is the expected change in life satisfaction,  $\Delta P(LS = k)$  is the change in the probability of reporting life satisfaction level  $k$  due to a one-unit increase in energy transition (*ET*), and  $LS_k$  is the numerical value of life satisfaction level  $k$  (1–5).

**Table 2.** Impact of energy transition on life satisfaction: benchmark model.

| Variables                  | Ologit               |                      | FE-Ologit            |                      |                      |                      |
|----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                            | (1)                  | (2)                  | (3)                  | (4)                  | (5)                  | (6)                  |
| <i>ET</i>                  | 0.166 ***<br>(0.037) | 0.449 ***<br>(0.043) | 1.506 ***<br>(0.400) | 1.089 ***<br>(0.470) | 1.651 ***<br>(0.482) | 1.216 **<br>(0.037)  |
| <i>Income</i> <sup>1</sup> |                      | 0.097 ***<br>(0.000) | 0.053 ***<br>(0.000) | 0.066 ***<br>(0.000) | 0.048 **<br>(0.000)  | 0.064 ***<br>(0.000) |
| Control variables          |                      | YES                  | YES                  | YES                  | YES                  | YES                  |
| Observations               | 43,980               | 43,096               | 73,711               | 73,711               | 73,711               | 73,711               |
| Person-fixed effects       |                      |                      | YES                  | YES                  | YES                  | YES                  |
| Province-fixed effects     |                      |                      |                      |                      | YES                  | YES                  |
| Year-fixed effects         |                      |                      |                      | YES                  |                      | YES                  |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ . <sup>1</sup> Considering the large absolute values of the *income* data, the regression coefficients are multiplied by 100,000 for processing.

**Table 3.** Marginal effects on life satisfaction: FE-ologit model estimates.

| Variables                  | Very Dissatisfied<br>( <i>LS</i> = 1) | Dissatisfied<br>( <i>LS</i> = 2) | Generally Satisfied<br>( <i>LS</i> = 3) | Satisfied<br>( <i>LS</i> = 4) | Very Satisfied<br>( <i>LS</i> = 5) |
|----------------------------|---------------------------------------|----------------------------------|-----------------------------------------|-------------------------------|------------------------------------|
| <i>ET</i>                  | −0.038 ***<br>(0.015)                 | −0.072 ***<br>(0.029)            | −0.183 ***<br>(0.072)                   | 0.040 ***<br>(0.016)          | 0.253 ***<br>(0.100)               |
| <i>Income</i> <sup>1</sup> | −0.002 ***<br>(0.000)                 | −0.004 ***<br>(0.000)            | −0.010 ***<br>(0.000)                   | 0.002 ***<br>(0.000)          | 0.013 ***<br>(0.000)               |
| <i>eduyear</i>             | 0.001 **<br>(0.000)                   | 0.002 **<br>(0.000)              | 0.004 **<br>(0.000)                     | −0.001 **<br>(0.000)          | −0.006 **<br>(0.000)               |
| <i>married</i>             | −0.011 ***<br>(0.003)                 | −0.021 ***<br>(0.006)            | −0.052 ***<br>(0.016)                   | 0.012 ***<br>(0.003)          | 0.073 ***<br>(0.022)               |
| <i>health</i>              | −0.005 ***<br>(0.000)                 | −0.010 ***<br>(0.001)            | −0.024 ***<br>(0.002)                   | 0.005 ***<br>(0.000)          | 0.034 ***<br>(0.003)               |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ . <sup>1</sup> Considering the large absolute values of the *income* data, the regression coefficients are multiplied by 100,000 for processing.

Using the reported marginal effects, the expected change can be calculated as follows: the probability changes for  $LS = 1, 2$ , and  $3$  are  $-0.038$ ,  $-0.072$ , and  $-0.183$ , respectively, while the probability changes for  $LS = 4$  and  $5$  are  $0.04$  and  $0.253$ , respectively. Multiplying each probability change by its corresponding  $LS$  value and summing across all levels yields an expected increase of  $0.694$  points in life satisfaction for a one-unit rise in *ET*. This indicates that, on average, a full-unit increase in the energy transition index is associated with an increase of approximately  $0.694$  points in the five-point life satisfaction scale, reflecting a substantial positive effect on individual well-being.

## 5.2. Robustness Checks

### 5.2.1. Alternative Regression Model: OLS Model

Existing studies frequently treat ordinal variables as continuous variables to account for fixed effects [33,42]. This approach is also employed for robustness testing in the present study, and Table 4 displays the outcomes of the OLS model regression.

**Table 4.** Robustness checks: Impact of energy transition on life satisfaction using the OLS model.

| Variables                  | (1)                  | (2)                   | (3)                  |
|----------------------------|----------------------|-----------------------|----------------------|
| <i>ET</i>                  | 0.435 ***<br>(0.142) | 0.677 ***<br>(0.165)  | 0.555 ***<br>(0.165) |
| <i>Income</i> <sup>1</sup> | 0.009 **<br>(0.000)  | 0.006<br>(0.000)      | 0.009 **<br>(0.000)  |
| Constant                   | 2.641 ***<br>(0.669) | −1.373 ***<br>(0.307) | 2.368 ***<br>(0.709) |
| Observations               | 43,096               | 43,096                | 43,096               |
| R-squared                  | 0.281                | 0.267                 | 0.281                |
| Number of pid              | 9952                 | 9952                  | 9952                 |
| Control variables          | YES                  | YES                   | YES                  |
| Person-fixed effects       | YES                  | YES                   | YES                  |
| Province-fixed effects     |                      | YES                   | YES                  |
| Year-fixed effects         | YES                  |                       | YES                  |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ . <sup>1</sup> Considering the large absolute values of the *income* data, the regression coefficients are multiplied by 100,000 for processing.

According to the findings in Table 4, while accounting for individual fixed effects, regional fixed effects, and year fixed effects, the estimated coefficient of *ET* is consistently positive and statistically significant. This indicates a significant positive influence of energy transition on life satisfaction. More precisely, the life satisfaction score increases by approximately 0.555 points for a one-unit increase in the degree of energy transition, based on the OLS estimate. Using the marginal effects from the FE-Ologit model (Table 3 and Equation (12)), the expected change in life satisfaction for a one-unit increase in *ET* is calculated to be 0.694 points. The comparison indicates that, although the FE-Ologit model is non-linear and the coefficients are on a different scale, the direction and approximate magnitude of the effect are consistent with the OLS estimate, supporting the robustness of the results.

### 5.2.2. Alternative Coding of Life Satisfaction

CFPS surveys require respondents to rate their level of overall life satisfaction using a 5-point rating system. However, ambiguity exists in respondents' assessments of score differences. For instance, the distinction between a score of 4 and 5 may not be inherently significant for respondents. To mitigate this measurement bias, drawing on Wang and Zhou [49], the *LS* variable was recoded to test the robustness of the results. Specifically, this study categorized values with  $LS > 3$  as 1 and the rest as 0. Subsequently, the binary variable was utilized as the dependent variable, and Logit and Xtlogit models were employed to investigate how the energy transition affected life satisfaction. The findings are detailed in Table 5.

As Table 5 shows, even after recoding the life satisfaction variable, the estimated coefficient of *ET* is still considerably positive. In line with earlier research, energy transition continues to have an immensely favorable influence on life satisfaction. These results reaffirm the robustness of the study's findings.

**Table 5.** Robustness checks: impact of energy transition on life satisfaction using recoded LS variables.

| Variables                  | Logit                |                       |                       | Xtlogit            |                      |                     |                      |
|----------------------------|----------------------|-----------------------|-----------------------|--------------------|----------------------|---------------------|----------------------|
|                            | (1)                  | (2)                   | (3)                   | (4)                | (5)                  | (6)                 | (7)                  |
| <i>ET</i>                  | 0.216 ***<br>(0.043) | 0.623 ***<br>(0.055)  | 0.170 ***<br>(0.058)  |                    | 1.257 ***<br>(0.483) | 0.988 **<br>(0.566) | 1.748 ***<br>(0.583) |
| <i>Income</i> <sup>1</sup> |                      | 0.242 ***<br>(0.000)  | 0.174 ***<br>(0.000)  | (0.472)<br>(0.000) | 0.055 **<br>(0.000)  | 0.071 **<br>(0.000) | 0.049 *<br>(0.000)   |
| Constant                   | 0.368 ***<br>(0.014) | −5.280 ***<br>(0.184) | −4.949 ***<br>(0.187) |                    |                      |                     |                      |
| Observations               | 43,980               | 43,096                | 43,096                | 30,440             | 30,440               | 30,440              | 30,440               |
| Control variables          |                      | YES                   | YES                   | YES                | YES                  | YES                 | YES                  |
| Number of pid              |                      |                       |                       | 6759               | 6759                 | 6759                | 6759                 |
| Person-fixed effects       |                      |                       |                       | YES                | YES                  | YES                 | YES                  |
| Province-fixed effects     |                      |                       |                       |                    |                      | YES                 | YES                  |
| Year-fixed effects         |                      |                       | YES                   |                    | YES                  |                     | YES                  |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . <sup>1</sup> Considering the large absolute values of the *income* data, the regression coefficients are multiplied by 100,000 for processing.

### 5.2.3. Implicit Marginal Rates of Substitution

Using Equation (10) and the regression results above, the MRS of the energy transition for income is computed. After employing the ordinal logistic regression with fixed effects (Column (6) in Table 2), the MRS of the energy transition for income is 1,900,000 CNY. In other words, measured by life satisfaction, the well-being effect of a 10% increase in the degree of energy transition is equivalent to the well-being effect of a 190,000 CNY increase in personal annual income.

### 5.3. Endogeneity Test

To address potential endogeneity concerns, two rigorous approaches are employed. First, the benchmark econometric model incorporates two-way fixed effects, controlling for both time-invariant individual heterogeneity and individual-invariant temporal effects, thereby effectively mitigating omitted variable bias. Second, an instrumental variable (IV) approach is implemented using two-stage least squares (2SLS) regression to account for potential reverse causality. Renewable energy installed capacity (*REcapacity*) is used as the instrument for the energy transition, proxied by the proportion of non-fossil fuel electricity generation. The validity of this instrument is supported by two considerations: (i) renewable energy installed capacity is strongly correlated with the energy transition measure, and (ii) it is plausibly exogenous with respect to individual-level self-reported well-being. Renewable energy installed capacity is defined as the sum of hydropower, wind, and solar power capacities, with data sourced from the *China Electricity Statistical Yearbook*. The 2SLS regression results are presented in Table 6.

As shown in Table 6, the first-stage 2SLS regression indicates that the instrument, renewable energy installed capacity (*recapacity*), has a positive and statistically significant effect on the endogenous explanatory variable *ET* at the 1% significance level, confirming the relevance of the instrument. A closer examination of instrument validity reveals a first-stage F-statistic of 9001.40, which is significant at the 1% level and far exceeds the commonly used threshold of 10, indicating that weak instrument bias is unlikely. The second-stage regression results show that *ET* has a coefficient of 0.095, which is significant at the 1% level, suggesting that energy transition increases well-being. These findings are consistent with the results obtained from the benchmark regression. Moreover, the robustness of these results is further supported by the consistency between the 2SLS estimates and the baseline fixed-effects model, highlighting the reliability of the empirical strategy.

**Table 6.** Endogeneity test results.

| Variables          | OLS                  | 2SLS                 |                     |
|--------------------|----------------------|----------------------|---------------------|
|                    | LS                   | First Stage          | Second Stage        |
| <i>ET</i>          | 0.555 ***<br>(0.165) |                      | 0.100 ***<br>(0.03) |
| <i>Recapacity</i>  |                      | 0.0001 ***<br>(0.00) |                     |
| Control Variables  | YES                  | YES                  | YES                 |
| Year-fixed effects | YES                  | YES                  | YES                 |
| F-statistic        |                      | 9001.40 ***          |                     |
| R-squared          | 0.281                | 0.720                | 0.342               |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ .

## 6. Additional Analyses

This study employed a two-step approach to examine the mediating effects outlined in Equations (8) and (9), and Table 7 presents the findings.

**Table 7.** Mediating effect test results.

| Variables                  | (1)<br><i>LS</i>     | (2)<br><i>AQI</i>      | (3)<br><i>Envi</i>    | (4)<br><i>Cookfuel</i> | (5)<br><i>C<sub>all</sub></i> |
|----------------------------|----------------------|------------------------|-----------------------|------------------------|-------------------------------|
| <i>ET</i>                  | 1.216 **<br>(0.482)  | −75.678 ***<br>(1.240) | −0.917 **<br>(0.411)  | 1.599 **<br>(0.743)    | 1413.823 **<br>(661.740)      |
| <i>Income</i> <sup>1</sup> | 0.064 ***<br>(0.000) | −0.032 ***<br>(0.000)  | −0.053 ***<br>(0.000) | 0.359 ***<br>(0.000)   | 70.190 ***<br>(0.000)         |
| Constant                   |                      | 113.217 ***<br>(1.014) |                       |                        | 5224.457 **<br>(2338.302)     |
| Observations               | 73,711               | 26,445                 | 220,852               | 15,272                 | 34,451                        |
| R-squared                  |                      |                        |                       |                        | 0.031                         |
| Control variables          | YES                  | YES                    | YES                   | YES                    | YES                           |
| Person-fixed effects       | YES                  | YES                    | YES                   | YES                    | YES                           |
| Year-fixed effects         | YES                  | YES                    | YES                   | YES                    | YES                           |
| Province-fixed effects     | YES                  | YES                    | YES                   | YES                    | YES                           |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ . <sup>1</sup> Considering the large absolute values of the *income* data, the regression coefficients are multiplied by 100,000 for processing.

Columns (2)–(3) in Table 7 indicate that an increase in *ET* significantly impacts *AQI* and *envi*. This suggests that a high degree of energy transition significantly improves air quality and enhances residents' environmental assessment, thereby increasing life satisfaction. Column (4) indicates that an increase in *ET* will significantly positively affect *cookfuel*, suggesting that those with a high energy transition are prone to switch to clean cooking fuels. Boosted self-reported health conditions and enhanced life satisfaction are potential rewards of using clean cooking fuels [21]. Therefore, Hypotheses 2 and 3 are confirmed.

According to column (5) in Table 7, the impact of *ET* on *C<sub>all</sub>* is significantly positive. This indicates that a greater degree of energy transition will substantially increase residents' overall energy expenses, decreasing life satisfaction. These findings confirm Hypothesis 4.

To further examine whether this effect varies across different groups, heterogeneity analyses are performed along three dimensions: income levels, urban versus rural residency, and regional differences. The results, summarized in Table 8, provide a more nuanced understanding of how the energy transition affects households under varying socio-economic and geographic conditions.

**Table 8.** Heterogeneous effects of energy transition on energy costs.

| Variables              | Income                     |                        |                           | Urban                     |                        | Region                |                           |                        |
|------------------------|----------------------------|------------------------|---------------------------|---------------------------|------------------------|-----------------------|---------------------------|------------------------|
|                        | (1)<br>Low                 | (2)<br>Middle          | (3)<br>High               | (4)<br>Rural              | (5)<br>Urban           | (6)<br>Eastern        | (7)<br>Central            | (8)<br>Western         |
| <i>ET</i>              | 3711.832 ***<br>(1208.621) | −723.895<br>(981.754)  | −2310.876 *<br>(1260.646) | 2149.801 ***<br>(765.772) | −802.569<br>(681.521)  | 30.621<br>(820.814)   | −1446.329 *<br>(867.890)  | −868.702<br>(1070.391) |
| Constant               | 1306.396<br>(4115.473)     | 1877.490<br>(3021.367) | 6423.409 **<br>(3105.298) | 2369.548<br>(1497.160)    | 8698.440<br>(5723.977) | 945.411<br>(2889.303) | 8741.785 **<br>(3935.267) | 3908.261<br>(2607.269) |
| Observations           | 13,976                     | 14,101                 | 14,222                    | 23,452                    | 18,847                 | 17,977                | 10,370                    | 11,447                 |
| R-squared              | 0.040                      | 0.047                  | 0.043                     | 0.045                     | 0.048                  | 0.072                 | 0.077                     | 0.019                  |
| Control variables      | YES                        | YES                    | YES                       | YES                       | YES                    | YES                   | YES                       | YES                    |
| Person-fixed effects   | YES                        | YES                    | YES                       | YES                       | YES                    | YES                   | YES                       | YES                    |
| Year-fixed effects     | YES                        | YES                    | YES                       | YES                       | YES                    | YES                   | YES                       | YES                    |
| Province-fixed effects | YES                        | YES                    | YES                       | YES                       | YES                    | YES                   | YES                       | YES                    |

Note: robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . The grouping of Chinese provinces by region follows the common practice used in [50].

The heterogeneity analysis results are presented in Table 8. When examining the effect of energy transition (*ET*) across income groups, *ET* significantly increases energy costs for low-income households (3711.832,  $p < 0.01$ ), while the effect is negative but not significant for middle-income households (−723.895) and significantly negative for high-income households (−2310.876,  $p < 0.1$ ). This indicates that low-income households bear a disproportionately higher energy cost burden during the energy transition, whereas high-income households may even benefit from cost reductions.

Considering urban-rural differences, *ET* significantly raises energy costs for rural residents (2149.801,  $p < 0.01$ ) but has no significant effect on urban residents (−802.569). This suggests that rural households are more vulnerable to the financial impacts of the energy transition, likely due to differences in energy infrastructure, energy efficiency, and income levels.

Regarding regional heterogeneity, *ET* shows no significant effect in the eastern region (30.621), while it significantly reduces energy costs in the central region (−1446.329,  $p < 0.1$ ) and has a negative but not significant effect in the western region (−868.702). These regional differences may reflect variations in energy resource endowment, regional development, and policy support for energy transition initiatives.

Overall, these findings reveal a clear regressive effect of energy transition: low-income, rural, and less economically developed regions tend to experience higher energy cost burdens, highlighting the need for targeted policies to mitigate the unequal financial impacts of the energy transition.

## 7. Discussion

Our findings present a nuanced picture of the energy transition as a major development intervention, highlighting a crucial tension between aggregate welfare gains and distributional equity. The Life Satisfaction Approach allows us to quantify a profound, non-market benefit of green development: a 10% increase in renewable energy use improves well-being by an amount comparable to a 190,000 CNY rise in annual income. This provides a strong counter-argument to development strategies that prioritize short-term economic growth at the expense of environmental quality. The discussion below translates our empirical results into insights for development theory and practice.

First, this study affirms that environmental quality is a critical, non-monetary component of human well-being in developing countries. The results show that cleaner air and a better environment are not luxury goods, but fundamental drivers of life satisfaction. This aligns with a growing body of literature in development economics that demonstrates the significant welfare and productivity costs of pollution [51]. For development practice, this

implies that investments in environmental public goods can deliver substantial welfare returns, justifying green policies not just on climate grounds, but as a direct contribution to human development. Moreover, it suggests that the poor, who often live in the most degraded environments, may be among the largest relative beneficiaries of such improvements, contributing to a form of environmental justice.

Second, our analysis reveals how macro-level energy policy can accelerate progress on a core development challenge: access to clean cooking fuel. The transition away from solid fuels is a global development priority due to its immense benefits for health, particularly for women and children [52]. Our findings suggest a powerful synergy: a systemic shift in the national electricity grid facilitates this transition at the household level. This highlights the importance of integrated development planning. Policies aimed at industrial decarbonization can have significant positive spillovers for household-level development goals, suggesting that energy, health, and rural development strategies should be designed in a coordinated manner to maximize these cross-cutting benefits. Crucially, this pathway often has a strong gender dimension; as women disproportionately bear the burden of solid fuel collection and suffer from indoor air pollution, the transition to clean cooking is a direct channel for enhancing female empowerment and well-being [53].

Conversely, and most critically for the development discourse, our results uncover the policy's regressive burden, which poses a significant threat to inclusive growth. The finding that rising energy costs disproportionately harm rural and low-income households is a classic example of how a well-intentioned policy can have unintended adverse consequences for the poor [54]. This rise in essential expenditure acts as a regressive tax, increasing the risk of households falling into, or deeper into, energy poverty. This is particularly acute in developing contexts where a large share of the population has insecure livelihoods and lacks access to formal safety nets or credit to smooth consumption. This presents a central dilemma for pro-poor development: how to pursue long-term structural transformation without imposing immediate hardship on the most vulnerable. It underscores that market-based environmental policies are not self-correcting in terms of equity. Without countervailing measures, they can exacerbate existing inequalities, undermining the broader goal of inclusive development.

The analytical framework created for this investigation supports a deeper understanding of this relationship. It is noteworthy that energy costs may be associated with the stage of development in the energy transition. In 2022, China's electricity generation comprised only 35.6% renewable energy, which falls below the global average of 39.4% [55]. With advancements in clean technologies, the energy transition is expected to become more economical and sustainable in the long term [56]. Additional investigation into the mediating impacts of energy costs is imperative, considering new temporal and spatial factors.

## 8. Conclusions

This study offers a holistic, welfare-based framework for assessing the distributional consequences of the energy transition in a major developing country. By applying this framework to China, we provide an empirical account of the complex trade-offs between environmental sustainability and social equity. Our results demonstrate that the transition yields significant well-being benefits by improving environmental quality and promoting access to clean cooking energy. However, these gains are threatened by rising energy costs, which disproportionately affect vulnerable households and can undermine the policy's social legitimacy.

These findings generate several critical implications for development policy, offering lessons that extend beyond China. First, the pursuit of green growth is not inherently pro-poor. Our analysis provides stark quantitative evidence that while the environmental

benefits of the energy transition are a public good, its economic costs function as a regressive tax, concentrated on those with the least capacity to bear them. This challenges the optimistic assumption that green policies will automatically lead to inclusive outcomes and highlights the risk of policy-induced poverty. It also speaks to the political economy of green transitions, where the costs are immediate and felt by households, while the benefits are diffuse and long-term, creating significant political hurdles for implementation.

Second, development planners must move beyond a siloed approach to policymaking. The strong synergistic effects we identify between industrial energy policy and household-level health outcomes (via clean cooking) underscore the immense potential for integrated strategies. This requires overcoming institutional barriers, for instance by establishing inter-ministerial task forces or joint budgeting mechanisms that align the objectives of energy, health, and social welfare ministries.

Third, and most critically, social protection policies are not a peripheral add-on but an essential, enabling component of a just and sustainable energy transition. Proactive, well-designed mechanisms are essential to shield vulnerable households from the price shocks associated with the energy transition. Drawing from international experiences, a combination of policy instruments—such as targeted ‘lifeline’ electricity tariffs, direct income support for low-income households, and subsidized energy efficiency upgrades—has been implemented to mitigate adverse impacts and promote equitable access to energy. For instance, in Lesotho, a lifeline tariff structure was introduced to provide affordable electricity to the poorest households, aiming to reduce energy poverty and enhance social equity [57]. Similarly, Brazil has implemented targeted electricity subsidies and energy efficiency programs to address energy poverty and improve household energy access, demonstrating the potential of such measures in reducing consumption and supporting vulnerable populations [58]. The implementation of such programs, however, is non-trivial and faces common challenges in developing countries, including issues of accurately targeting beneficiaries and building the administrative capacity for effective delivery. Acknowledging these challenges is a crucial first step. Without embedding such robust social safety nets into the core design of the energy transition, the policy risks becoming another driver of inequality, undermining the very development it seeks to promote.

The theoretical structure that this study develops provides an organized method for analyzing how energy transition affects individual well-being. Future research within the planning and management domain should continue to refine this approach. Owing to the lack of consensus on how to measure energy transition, this study employs the provincial share of non-fossil electricity generation as a practical proxy. However, this indicator primarily reflects the structural transformation of the power sector rather than household-level energy use patterns. Future research could explore more granular or multidimensional indicators—such as household access to clean fuels, grid reliability, and energy affordability—to provide a more comprehensive understanding of the complex connections between energy transition and household well-being. Due to data limitations, this study could not acquire long-term panel data on happiness. Subsequent research should aim to obtain and utilize longer sequences of micro-level survey data to observe dynamic changes over time. While the current analysis focuses on the observed panel data and captures short- to medium-term effects, exploring the long-term dynamics of energy transition impacts represents an important avenue for future research. Simultaneously, developing a science-based and widely accepted measurement method for energy transition is imperative to enable effective policy monitoring and evaluation. Moreover, this study examines the mediating channels independently. Future research could further investigate the potential interactions among these mechanisms to better capture the complex pathways linking energy transition to life satisfaction.

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