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# The Impact of Demographic Transition on Energy Poverty in China: Potential Challenges and Opportunities

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**Abstract:**

Energy poverty is a serious concern and an influential global determinant of subjective well-being (SWB). This paper seeks to explore the impact of demographic transition on energy poverty. Data for the study was obtained through panel data from 30 provinces of China from 2010 to 2022. The old dependency ratio is selected to address the shift in the total population. The negative population growth is anticipated to increase further and may not be easy to reverse. Demographic shifts also cause the gap to widen and alter the patterns of energy consumption. The energy poverty concept is measured through a multidimensional energy poverty index (MEPI) established on five key indicators: electricity consumption, clean cooking fuel like natural gas, telecommunication, heating, and cooling appliances. A Generalized Method of Moments (GMM) estimation technique is used to analyze the impact of the old dependency ratio (ODR) on energy poverty and a fixed effects model is performed to confirm the stability of the results. The outcome reveals that ODR and the demographic transition strongly contribute to worsening energy poverty. Effective policy implications regarding regional disparities among the elderly can change these challenges into opportunities and enhance clean energy access and infrastructure development across all regions.

**Keywords:** Energy Poverty; Demographic Transition; Old Dependency Ratio; Policy Implication; Social Security

## 1. Introduction:

Energy poverty defines the poverty level of individuals to meet the basic needs of energy consumption. Multi-dimensional energy poverty means the availability and affordability of clean sustainable energy. With a population of 1.417 billion, China is now the second-largest country in the world. Over the past 40 years, China has witnessed steady economic progress because of a competitive edge in the manufacturing industries due to excessive and cheap labor which attracts foreign direct investment. But now China faces serious challenges such as economic slowdown, demographic crisis, climate change, trade conflict, youth unemployment, and energy poverty. Since the beginning of the “12th Five-Year Plan” of the National Economic and Social Development (2011–2015), China has experienced economic decline after the global financial crisis. The energy industry will soon face three main issues, including climate change, security of supply, and energy poverty (González-Eguino, 2015). Energy poverty affects people’s quality of life and seriously impacts their health and life satisfaction (Nussbaumer et al., 2012). The World Bank maintains that the scarcity, inaccessibility, and unaffordability of sustainable energy and fuels lead to relying on nonrenewable fuel sources that pollute indoor air and endanger human health by emitting greenhouse gases (Group, 2020). International Energy Agency reveals that there will be 2.52 billion people in the world without access to clean energy by 2030, which means energy for daily life will still be dominated by burning fossil fuels for electricity, heat, and transportation and about 970 million people will be without access to electricity services. Most will be located in Asia and Africa. Demographic transformation has the worst impact on energy poverty in developing economies. In 2018, it was for the first time in history that the global population included more people aged over 64 than under 5 (United Nations, 2019).

### 1.1 Overview of China’s Energy Poverty:

China achieved 100% residential electricity coverage in 2015 (Hong et al., 2022). According to the International Energy Agency (IEA, 2020) studies, the proportion of the population with access to electricity and clean cooking facilities in China was 98.4% and 46.8% respectively, in 2002. By 2019, these figures rose to 100% and 71.3% respectively. China has achieved the above-specified high electricity access percentage but a substantial portion of the population still depends on solid fuels such as coal and firewood to meet their basic needs. (Tang & Liao, 2014). This is an alarming situation for health and the environment. Hence innovation and advanced technology will be required to deal with health issues and climate change risks. Around 51.88% of the population has access to clean cooking fuels and technologies. However, in rural areas, many households still depend on solid fuels like wood and other biomass, highlighting energy poverty. Additionally, households and industries in these regions have faced continuous energy shortages for years, as local energy demand continues to rise and rural areas struggle to meet their required demand (Kaygusuz, 2011). (Sesan, 2012) observes that energy poverty is inaccessible to modern energy sources for households in developing countries and their corresponding dependence on solid cooking biofuels.

### 1.2 An Overview of China’s Demographic Transition:

Changes in population demographics have a significant impact on energy poverty. China faces two major challenges during its demographic transition: low fertility rates and an aging population (Zhou et al., 2021). The National Bureau of Statistics forecasts that if the current situation persists, the number of individuals aged 20 to 34 will decrease by approximately 11 million annually from 2022 to 2025 (Li et al., 2024). The working-age population shortage means fewer people are available to support the larger population share, even as the overall number of people in China declines. During the past three decades of economic reforms, China's higher economic growth rate has greatly benefited from the nation's population dividend (Cai, 2013). But now this demographic dividend has changed into a burden because the aging population is more than 20%. The demographic shift may move more people to urban regions for jobs and better opportunities, leaving the aged population behind, and affecting the rural regions' development (Shi et al., 2023). On the one hand, aged people consume more electricity and heating systems because they spend more time inside residential buildings, increasing the demand and consumption of electricity. On the other hand, the government needs more energy to run the healthcare sector for the country's elderly. Faster aging and declining fertility rates would shift China from a source of cheap labor to an economy that will suffer from labor scarcity as it reaches the Lewis turning point between 2020 and 2030 (Cai, 2012). The energy sector will have difficulties in handling energy poverty. An economic perspective (Maestas et al., 2023) on the aging population shows that if the proportion of people over 60 years increases by 10%, the GDP growth rate would decrease by 5.5% because the retirement age for men is 60 years while women, 50-55 years. The old pension programs in China are designed to penalize employment in old age while retirement is encouraged. However, population aging requires an extension of working years to support escalating public health costs which will result in fewer employment opportunities for youth. It is anticipated that people over 60 will contribute 28% of the total population by 2040 (WHO China, 2024). China's retirement age has not been raised since the last decade and it is lowest in the world. The top officials have agreed that for male employees, the retirement age will be raised from 60 to 63 years while for females, it will be extended to 55 years for those retiring at 50 and to 58 years for those who now retire at 55. The Chinese youth unemployment rate was recorded at more than 20% a year ago, thus, negatively impacting economic growth and raising concerns about energy poverty among this group. One of the important ways to reduce energy poverty in China is to pay attention to the development of rural regions. Residents of rural regions identify, that there are more job opportunities in urban areas so they prefer to migrate to those regions. Low-income provinces also have high negative migrations because economic conditions and high-income opportunities are more attractive in other provinces (Chen et al., 2020). Income inequality and development disparities remain significant in some central and western provinces. It is necessary to address these issues to reduce their impact on the residents of these region's energy poverty (Dong et al., 2022). It has been pointed out that the floating population and the new generation of migrants that have played a significant part in the economic well-being of coastal areas, could also be useful in developing their hometowns and helping to reduce the problem of regional disparity in China (Cai, 1998). Many high-income provinces have introduced or will introduce population ceiling policies to tackle excessive concentration of population creating regional equality. However, poor infrastructure and relatively high energy costs tend to make some regions less attractive for business investment and energy-intensive industries located in rural areas, providing jobs and supporting the local economy. When these industries face high energy costs, they may reduce production, cause unemployment, or even relocate, which can hurt the broader rural economy (Prices). The demographic transition will worsen when rural elderly residents of China stay in regions with a smaller working-age population to support them.

### 1.3 The Drivers of China's Changing Demographics:

The Chinese government started to employ measures to regulate the population growth in the 1970s. The "later, longer, fewer" campaign (launched in 1973, increased the legal age of marriage for women to 23 years and men to 25 years) encouraged a gap of at least three years between two births and restricted births to two in rural areas and only one child in urban areas. Those who did not strictly follow the new rules faced severe penalties. This policy was very successful as the birth rate in China declined sharply from 6.1 in the 1970s to 2.7 in the 1980s. If a population is to reproduce at the same rate as the previous generation, the total fertility rate per woman has to be approximately 2.1. Due to the adoption of population control measures, fertility rates in China dropped to levels below this threshold. Official statistics show that China's fertility rate reduced to 1.5 in the nineties and was as low as 1.3 in 2020. Since 2013, if the parents themselves were the only child, they were allowed to have a second child. Then in 2016, the government expanded it for all couples thus discontinuing the one-child policy.

Technological innovation is essential for balancing the sustainable development of the environment and the economy. Environmental regulations can motivate large enterprises and governmental institutions to invest some of their funds in the R&D of green technologies to enhance energy efficiency and lower energy consumption fundamentally easing energy pressures (Liu et al., 2018). However, does technological advancement have any impact on energy poverty? There are many debates regarding the impact of this effect, and these academic discussions are undoubtedly supplementing the research.

This study also tries to make new contributions to the previous literature on environmental sustainability. This study's first empirical contribution is the application of comprehensive indicators to determine the energy poverty gap. The specific energy poverty gap analyzed in this paper encompasses affordability dimensions in China. Previous literature review on energy poverty mostly addresses the problem regarding the issue of income difference and urban-rural divide but this study addresses a new dimension of energy poverty. When analyzing the demographic transition, there is less focus on the consequences of low fertility on the economy and energy. As China has a large territory, regional differences are present and hence cannot be ignored. Secondly, the regression model used in this study is distinctly different from previous studies as it focuses on the effects of the demographic transition on energy poverty in China. Thirdly, from a practical perspective, the paper describes aspects contributing to China's energy poverty gap. Furthermore, it stresses the importance of assisting the Chinese authorities in formulating policies to bridge the energy poverty gap.

The remainder of the study is structured as follows. Section 2 provides a review of previous relevant literature. Section 3 discusses data and methodology. Section 4 discusses the main results of the study. Section 5 detailed discussion and in Section 6 Conclusions, we suggest the relevant policies to deal with the demographic and energy poverty issues.

## 2. Literature review:

Energy poverty is a critical problem regarding accessibility and affordability in developed and developing countries (J. Zhang et al., 2023). There is still no common definition of energy poverty and because conditions vary from region to region, there aren't any globally applied methods to determine the threshold of energy poverty. The International Energy Agency (IEA) spotlights energy poverty as the inaccessibility of clean energy for daily consumption and heavy dependence on solid fuels (IEA, 2002). Some classify energy poverty as "fuel poverty" when the daily basic need for energy, costs higher than the residential income (Hills, 2011; Zhang et al., 2019). Many researchers have conducted fragmented and detailed analyses at the sub-national level, examining differences between urban and rural populations and considering income/spending levels (Dong et al., 2022; Lin & Zhao, 2021; Ren et al., 2022). Poverty-targeted alleviation policies have made efforts to reduce the urban-rural income gap and energy poverty gap through the surveys of many provinces. The targeted poverty alleviation policy implemented from 2013 to 2020 has played an important role in eliminating China's absolute poverty and reducing the urban-rural income gap (Zhou et al., 2023). Social and economic factors such as family size, household income, age, education, and the household head role influence energy scarcity. Potential demographic transition is also a threat to energy availability and affordability in China.

Empirical research on energy poverty covers its social and economic effects on youth education, female workforce participation, and workforce efficiency (Adkins et al., 2010; González-Eguino, 2015; Leitão, 2021). After population urbanization (Sato & Yamamoto, 2005), population aging has also become one of the main indexes of global demographic transition because societies attain more technology, education, and economic development (Qi et al., 2022). Based on the global estimate, it was projected that 727 million people would age 65 years or over in 2020. The prevalence of obesity is also expected to increase and double by 2050 to over 1.5 billion people. The proportion of the oldest population is also predicted to rise from 9.3 percent in 2020 to 16.0 percent in 2050. Thus, by mid-century, people above sixty-five years will be in a ratio of one in six of the world's population. According to a World Health Organization report, China is one of the fastest-aging countries in the world and is expected to reach 28% by 2040, due to longer life expectancy and a declining fertility rate which create a huge demographic shift bringing opportunities and challenges at the same time (World Health Organization, 2021). The present estimated rate of energy poverty is 18.9 percent (Lin & Wang, 2020). Despite economic growth and rapid urbanization, energy poverty and inequality persist in China's urban areas. Studies indicate that 8% of urban households in China still rely on solid fuels (Hu et al., 2017), affecting around 72 million individuals (X. Wang et al., 2023). Although the Chinese government is implementing measures to reduce urban-rural disparities, many rural regions are underdeveloped and lack advanced infrastructure. Inequality and inaccessibility to opportunities will worsen the suffering of low-income households. Many researchers have discussed income inequality's impact on energy poverty (Igawa & Managi, 2022).

### 2.1 Measurement of Energy Poverty:

Many scholars have used the widely recognized tool, the 10% indicator for identifying energy poverty households. This indicator first introduced by (Boardman, 1991), defines an energy-poor household as one that "needs to spend 10% or more of its income to maintain a comfortable indoor temperature for survival". However, (Bollino & Botti, 2017) argue that the 10% indicator does not record the households that must remarkably reduce their energy consumption due to financial constraints. Despite this, many scientists prefer to use the "10% indicator" to measure energy poverty (Nussbaumer et al., 2012; Okushima, 2016). In developed countries, especially Europe, many studies have focused on the issue of energy poverty and its affordability (Tardy & Lee, 2019). Additionally, research on developing countries often aims at the accessibility of modern energy sources, such as electricity and non-solid fuels (Pachauri & Spreng, 2011; Sadath & Acharya, 2017; Tang & Liao, 2014). Therefore, affordability and accessibility were associated with energy poverty (Zhang et al., 2019). The Energy Development Index (EDI) by the International Energy Agency (IEA) is also used to calculate and understand energy poverty. It's a simple method that uses indicators like per capita residential electricity consumption, per capita commodity energy consumption, the proportion of commodity energy in total energy end-use, and the population of electricity users. However, the results obtained through EDI are more suitable for the comparative analysis of multiple regions. (Wang et al., 2017) upgraded the Energy Development Index (EDI), constructing a Clean Energy Development Index. This index includes additional indicators stressing clean energy supply and investment. The threshold point is established based on basic energy needs or energy expenses (Barnes et al., 2011; Foster et al., 2000). Households at or below this threshold consume only the minimum energy required and are considered to be living in energy poverty. Due to variations in climate across different countries and regions, accurate estimation of the minimum demand for energy is challenging. Consequently, this method is seldom used today.

### 2.2 Key Drivers of Energy Poverty:

Empiricists have discussed various key drivers that influence energy poverty in multiple ways both at micro and macro levels. Households' income directly and significantly affects energy poverty (Behera & Ali, 2016). As the household income increases, they can better afford the clean energy resources. Urbanization makes it possible for many rural residents to move to urban regions for job opportunities, often leaving their parents or grandparents behind. Elderly people living alone are vulnerable to energy poverty (Legendre & Ricci, 2015). Highly educated youth can improve innovation and fuel research and development in clean technologies to reduce energy poverty. Youth is a powerful asset and higher education has a greater potential for contributing to societal development. It is necessary to expand vocational and technological education to improve the quality of the youth population as a workforce (Zhuang et al., 2012). Government spending on research and development can effectively alleviate energy poverty. Subsidy on research and development and related education encourages youth to play their part. Moreover, the Chinese government initiated an "Internet plus" action plan to promote economic growth and to use Internet technology to raise awareness about the clean and efficient use of energy (S.-H. Zhang et al., 2023). Some other factors such as energy efficiency, financial development, increased urbanization, and proper infrastructure to supply energy are also crucial to reduce energy poverty in any country.

The existing literature on energy poverty covers many aspects both socially and economically. This research adds a new aspect; the impact of demographic transition on energy poverty. Few studies have covered the demographic transition impact on the energy consumption pattern and considered the old dependency ratio with the child dependency ratio. However, the present study covers the upcoming challenges for China that will affect its economic and social structure. The current scrutiny measures the demographic transition impact for rural-urban households and the conclusions and policy suggestions shed more light on the rural regions.

## 3. Theoretical Framework:

The theoretical framework is based on theories such as Dependency theory, Human Capital theory, and Population and Environmental theory. These theories provide key insights into how demographic shifts can change the energy consumption pattern and influence economic growth in China. The dependency theory stresses a high dependency ratio of the aged population to the working-age population. This shift changes the economic dividend of a large, young, and productive workforce to an economic burden due to the aging population and increased dependency on the labor force. On account of the low fertility rate and low mortality rate, China entered an aged society when people over 60 or above exceeded

131 million. This causes a high dependency ratio, indicating that a large elderly population needs more support from a shrinking workforce, further limiting the resources to invest in economic development, infrastructure, and technological innovation. High healthcare costs and pension programs also increase the government spending budget. Increasing demand for energy from the aged population in urban regions places additional burdens on energy infrastructure, potentially leading to energy poverty in rural regions. Economists like Gary Becker and Theodore Schultz developed the human capital theory in the 1960s. This theory identified the importance of an individual's education, training, and health as an economic investment. China has shifted from a manufacturing-based economy to a technology-oriented one that requires significant human capital investment to boost productivity. Improving education makes the workforce more skilled and capable of increasing productivity. Higher education means better job opportunities, which leads to higher incomes. Increasing income reduces energy poverty as households can afford more sustainable and clean energy. Equal educational opportunities remove the conflict between urban and rural disparities about income inequality. Equal job opportunities reduce income inequality and energy poverty, especially in rural regions. The IPAT theory (Holdren, 2018) (he environmental impact of human activities by considering three key factors: population size, economic affluence, and technological influence) consist of three main parts. First, the population of China faces rapid growth of the aging population that entered an "aged society" in 2022 and will become a "super-aged society" around 2033. Society is rapidly moving toward a super-aged society changing its energy consumption patterns as elderly people demand more energy because they spend more time inside their homes impacting more on the environment. A higher dependency ratio of the elderly population on youth results in less investment and saving plans. Second is affluence, which means an increase in GDP and income level automatically lifts the standard of living and consumption patterns of the households but not for the elderly because they depend on fixed incomes such as pensions. Third is the technological advancement that reduces energy consumption and costs through energy efficiency for households with limited resources to afford clean energy. Higher wages without matching advancement in technology could hurt China's international competitiveness in capital-intensive industries. The IPAT model helps policymakers understand how population growth, economic development, and technology choices affect environmental sustainability.

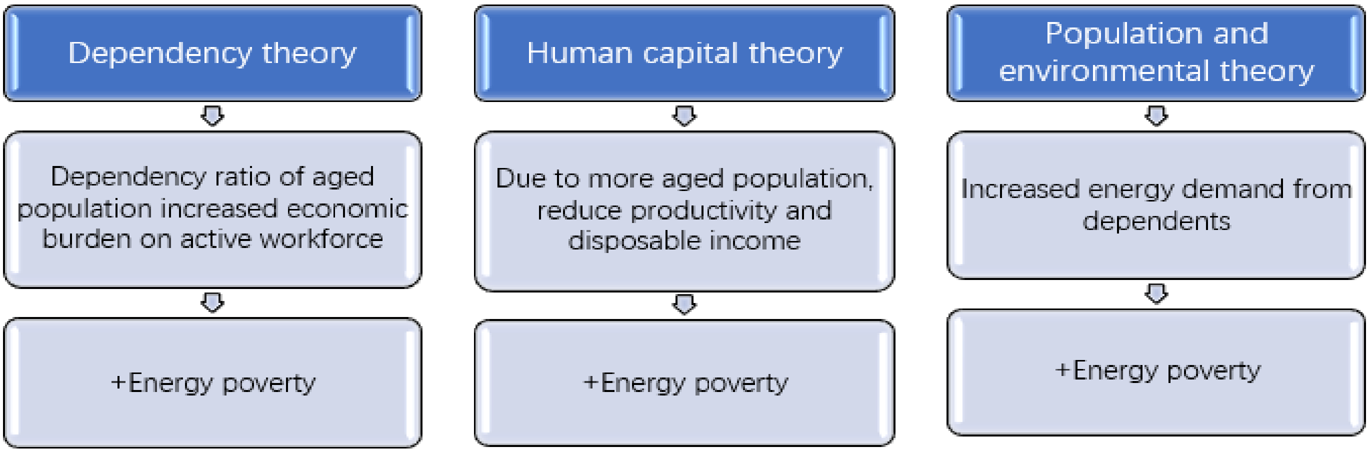

**Figure 1: Theoretical framework**

Figure 2 shows the population of China up to 2040. Age structure represents the proportion of children's age, working age, old age, and the total population. The increasing rate of the old-age proportion as compared to the working-age proportion emphasizes the increasing burden of the old-age population. The total population will start to decrease after 2035, and the demographic dividend of China will change into a demographic burden in the future.

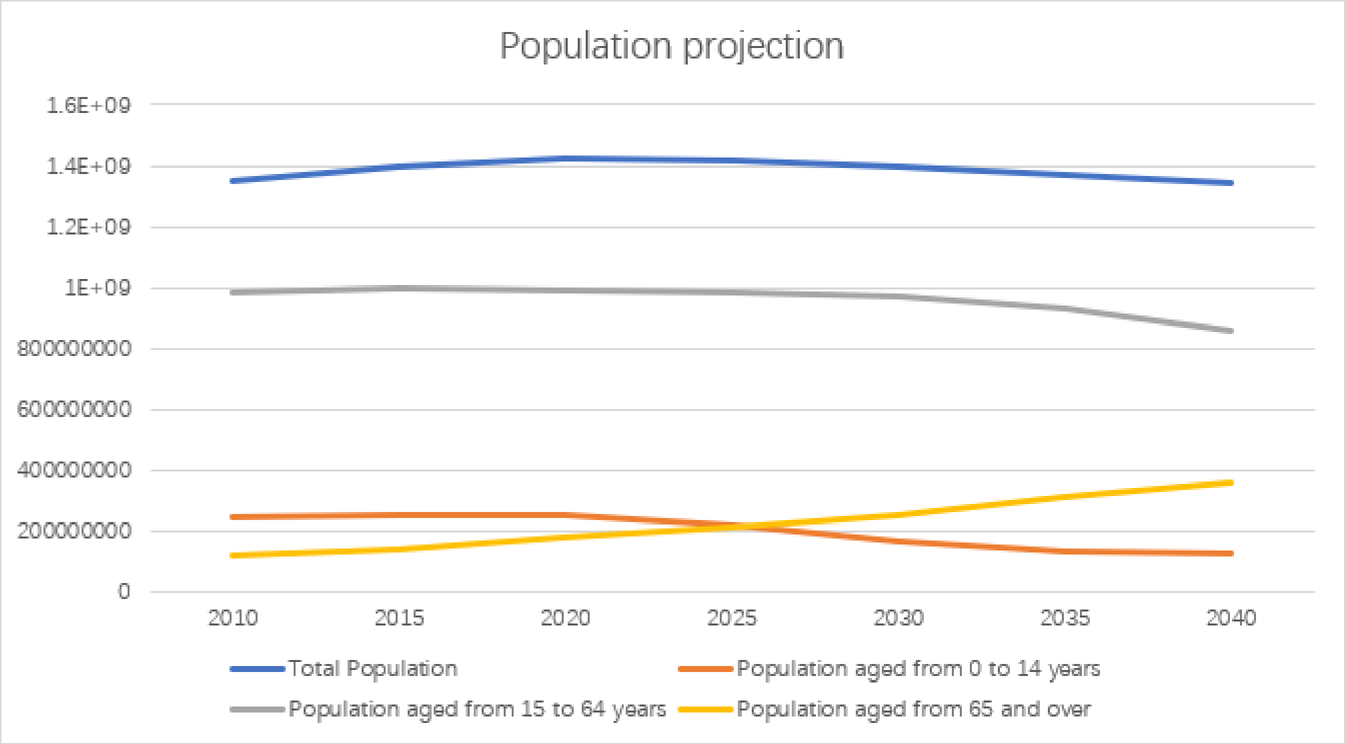

**Figure 2: Population projection of China's age structure**

Source: UN population prospect

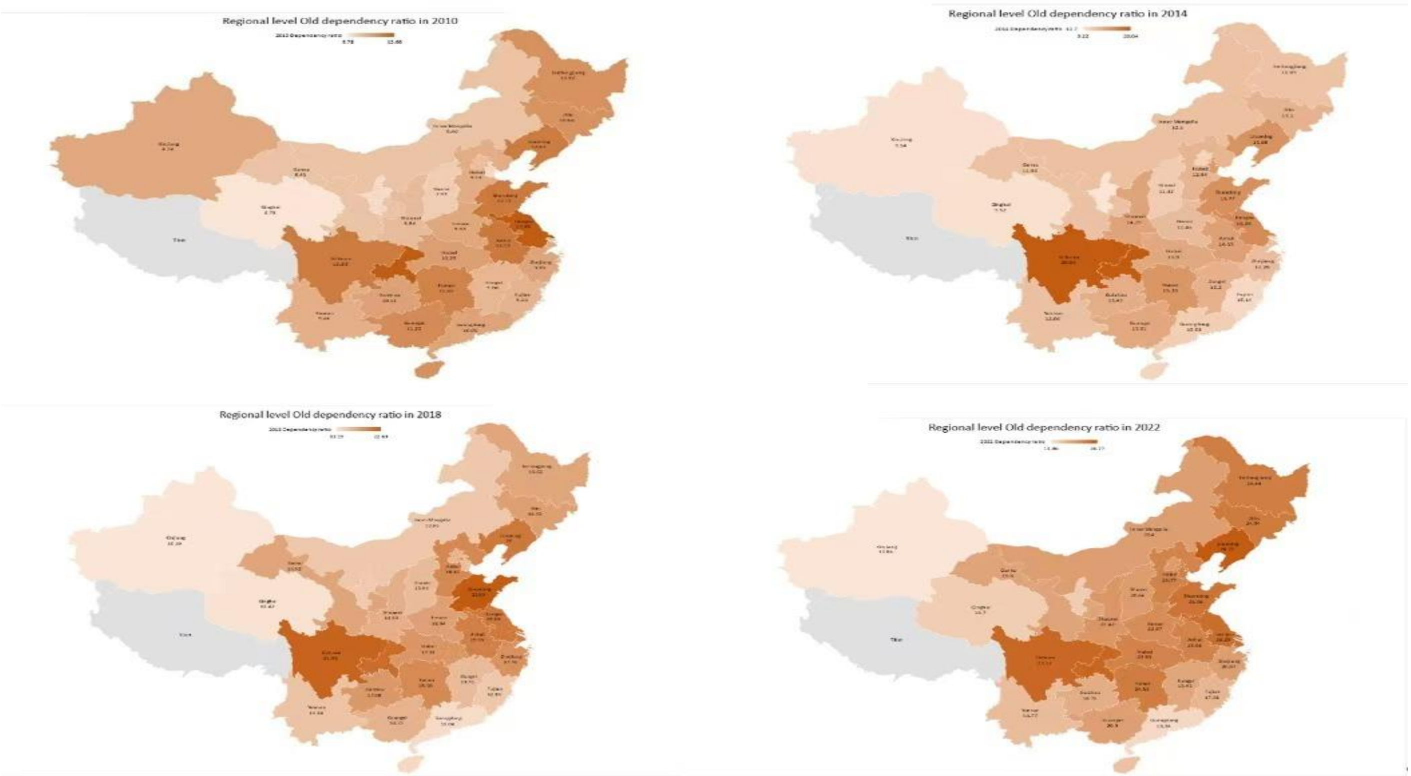

**Figure 3: Regional Level Old Dependency Ratio for Selected Years**

## 4. Methodology and Data:

### 4.1 GMM Estimation Technique:

The Generalized Method of Moments (GMM) is adopted as the estimation technique for energy poverty indicators. The GMM technique is chosen due to its flexibility in handling models with endogenous variables and its robustness in providing consistent and efficient parameter estimates. Previous literature often utilizes alternative proxies for energy poverty, depending on whether the data are examined from a micro or macroeconomic perspective. In a microeconomic context, various aspects of energy poverty are typically captured through surveys of households' socioeconomic conditions, including household income, household size, energy expenditure, and education level.

### Model Specification:

The basic model used to estimate is specified as:

$$EPit = \alpha + \beta 1ODRit + \beta 2GDPit + \beta 3EDUit + \beta 4CCit + \beta 5DILit + \beta 6HSit + \beta 7SSit + \epsilon it$$

Energy poverty is the independent variable in province i and year t. ODR is the old dependency ratio variable and series of control variables such as GDP (per capita GDP), education (EDU) based on primary, middle, college, and post-secondary, annual climate change (CC), disposable income level (DIL), household size (HS), social security of population (SS), and ϵit is the error term.

### 4.2 Variable description:

### 4.2.1 Explained variable:

This study is constructed on three dimensions and five indicators. Energy poverty arises when an individual or a society suffers from insufficient access to clean energy services, directly impacting the quality of life, health, and economic opportunities. Many factors are behind it such as low income levels or income inequality within the same country or region. High energy costs or substantial surges in energy prices are other factors that drive society towards energy poverty. Poor infrastructure, especially in developing countries' rural regions, is a major reason for energy poverty. In China, where residential energy prices are heavily regulated and subsidized by the government other factors such as regional disparities and changes in government policies can still impact energy affordability. Electrification of China is not the only solution because many rural regions presently rely on wood and coal for cooking.

**Table 1: Multidimensional Energy Poverty Key Dimensions and Indicators**

| Dimension | Indicators | Variables |
|---|---|---|
| Energy accessibility | Has electricity for lightening<br>Has access to clean fuel for cooking | Residential access to electricity by region<br>Residential access to clean cooking fuels by region |
| Energy-efficient appliances | Ownership of appliances for cooling and heating | Has air conditioner and water heater |
| Communication | Telecommunication means | Has a mobile phone |

### 4.2.1.1Establishment of index:

### Multiple Energy Poverty Index:

The MEPI comprises seven variables: air conditioning, water heater, mobile phone, computer, access to clean fuels, electricity consumption, and total volume of emission. Before PCA analysis, each indicator of the seven dimensions was normalized using the mix-max method. The formula is given below:

$$X_{i,d} = \frac{x_i - m_i}{M_i - m_i}$$

The variable $x_i$ represents the actual value of indicator i, while $m_i$ designates the minimum value of indicator I whereas $M_i$ signifies the maximum value of dimension i. The standardized value of indicator i in dimension d is denoted as $X_{i,d}$. After normalization, each indicator's KMO (Kaiser-Meyer-Olkin) values have been calculated, as shown in Table 2. The KMO was used to develop an adequate indicator to be included in the MEPI calculation. The item loading < 0.49 was excluded from the model. Two items; the total volume of emission (0.3737) and computer (0.3159) have been excluded from the model because their item loading was less than 0.49. The MEPI will be calculated using the remaining 5 indicators.

**Table 2: 5 indicators to calculate the MEPI**

| **Variables** | **KMO** |
|---|---|
| Access to clean fuels | 0.8974 |
| Electricity consumption | 0.9106 |
| Air conditioner | 0.9350 |
| Water heater | 0.8588 |
| Mobile Phone | 0.8939 |
| **Overall** | 0.8977 |

**Table 3. The results of the reliability and consistency analysis**

| | |
|---|---|
| **Average inter-item covariance** | 0.0819 |
| **Number of items in the scale** | 5 |
| **Scale reliability coefficient** | 0.9627 |

The value of the Cronbach alpha is > 0.60. The alpha value is good enough to conclude that the data is highly reliable.

In the first stage of PCA, the dimensions were estimated. The equation is given below:

$$\begin{aligned} MEPI_i = {} & \gamma_1 Fuel1 \\ & + \gamma_2 Electricity\ Consumption2 \\ & + \gamma_3 Air\ Conditioner3 \\ & + \gamma_4 Water\ Heater4 \\ & + \gamma_5 Mobile\ Phone5 + \varepsilon_i \end{aligned}$$

$$\begin{aligned} MEPI_i = {} & 0.4521 * Fuel1 + 0.4432 \\ & * Electricity\ Consumption2 \\ & + 0.4424 * Air\ Conditioner3 \\ & + 0.4582 * Water\ Heater4 \\ & + 0.4398 * Mobile\ Phone5 + \varepsilon_i \end{aligned}$$

The eigenvalue of each indicator was calculated using the PCA method. According to (Nguyen & Vo, 2020), the analysis focuses on the highest eigenvalue of the components, which is known to preserve a greater amount of standardized variance. Additionally, an eigenvalue greater than 1 is considered in this analysis. The results of the initial principal component analysis (PCA) are presented in Table 4. The first component has the highest eigenvalue; hence, the dimensions are approximated by utilizing the weights assigned to the principal component of each dimension. Table 5 contains the weights assigned to each indicator.

**Table 4. The results of the initial principal component analysis (PCA)**

| **Component** | **Eigenvalue** | **Difference** | **Proportion** | **Cumulative** |
|---|---|---|---|---|
| Access to clean fuels | 4.3569 | 4.1126 | 0.8714 | 0.8714 |
| Electricity consumption | 0.2442 | 0.0630 | 0.0488 | 0.9202 |
| Air conditioner | 0.1812 | 0.0502 | 0.0362 | 0.9564 |
| Water heater | 0.1309 | 0.0441 | 0.0262 | 0.9826 |
| Mobile phone | 0.0868 |  | 0.0174 | 1.0000 |

**Table 5. Weights of the indicators**

|  | Component 1 |
|---|---|
| Access to clean fuels | 0.4521 |
| Electricity consumption | 0.4432 |
| Air conditioner | 0.4424 |
| Water heater | 0.4582 |
| Mobile Phone | 0.4398 |

### 4.2.2 Explanatory variable:

The aging population is one of the significant challenges many countries face whether developed or developing. The rapidly increasing elderly population and low fertility rate have caused an alarming situation in many countries such as China, Japan, and Europe (Pais-Magalhães et al., 2022). The impact of the elderly population on economic growth, energy consumption patterns, and economic burden on the active workforce is not neglectable. The study measures the effect of the aged population on residential energy consumption and demand because the older population faces higher energy needs for heating, cooling, and medical care services. The variables used are directly linked to people aged 65 and over. Many existing literature reviews measure the impact of an aging population on energy consumption (Z. Wang et al., 2023) but the impact on energy poverty is still under-observed.

### 4.2.3 Control Variables:

All the variables employed in this study are collected from China's Panel data for 30 provinces and autonomous regions except Tibet, Hong Kong, Macao, and Taiwan from 2010 to 2022. The data set is extracted from the China Statistical Yearbook. The descriptive statistics of the control variables are presented in Table 6.

**Table 6. Description of the control variables**

| Name | Variable | Definition | Reference | Data source |
|---|---|---|---|---|
| Economic development | GDP | The per capita GDP | (Lee et al., 2022) | China statistical yearbook |
| Education | EDU | Education level<br>Primary<br>Secondary, College | (Shi et al., 2023) | China Educational Statistical Yearbook |

| | | | | |
|---|---|---|---|---|
| | | Post-secondary | | |
| Climate change | CC | Climate change in major cities by regions | (Tao et al., 2024)<br>(Lee et al., 2022) | Calculated by author |
| Disposable income level | DIL | Per capita disposable income of the household | (Chester & Morris, 2011) | China statistical yearbook |
| Household size | HS | Number of household members (from 1 to 10 Members/household) | (Z. Wang et al., 2023) | China statistical yearbook (2011 to 2023) |
| Social security | SS | Basic medical aid<br>Pension | (Li et al., 2022)<br>(Cheng et al., 2018) | China statistical yearbook |

## 5. Data analysis:

Table 7 presents the descriptive statistics of each research variable including the mean, standard deviation, minimum, and maximum values of the variables.

**Table 7. Representing the descriptive statistics of each indicator**

| **Variables** | **Mean** | **Standard deviation** | **Minimum** | **Maximum** |
|---|---|---|---|---|
| Multi-Dimension Energy Poverty Index | 1.226 | 0.653 | 0.000 | 2.236 |
| Disposal Income | 24480.370 | 12535.150 | 8306.000 | 79609.770 |
| Gross Domestic Product per capita | 58705.840 | 30481.020 | 13119.000 | 190313.000 |
| Dependency Ratio | 15.174 | 4.543 | 6.780 | 28.770 |
| Pension Expense | 94.409 | 105.261 | 1.100 | 489.500 |
| Education | | | | |
| Primary Education | 7126.436 | 1988.292 | 3174.000 | 11748.000 |
| Secondary Education | 6342.379 | 1507.115 | 2557.000 | 8440.000 |
| Higher Education | 2743.254 | 879.260 | 1082.000 | 6196.000 |
| Household | | | | |
| One to Five Households | 13467.380 | 8159.279 | 1260.000 | 28606.500 |
| Six to Ten Households | 978.442 | 835.293 | 75.000 | 2673.500 |
| Climate Change | 1.981 | 1.354 | 0.027 | 7.909 |

Before applying the main analysis for the generalized method of model and fixed effects model, it was ensured that data was normally distributed. Therefore, the Variance Inflation Factor model was applied to test multicollinearity. The problem of multicollinearity did not exist because the value was below 4. The heteroskedasticity analysis along with the serial autocorrelation analysis was also performed. The p-value of the Breusch Pagan test was above 0.05, hence, the heterogeneity problem did not appear either. The Durbin-Watson value was also found to be 2 which shows that the serial autocorrelation analysis problem did not arise. Lastly, heterogeneity was tested. The finding suggested the issue of heterogeneity did not emerge.

**Table 8. The results of the generalized method of the moment model**

| | Multiple Energy Poverty Index | Multiple Energy Poverty Index |
|---|---|---|
| | (1) | (2) |
| | | |
| L.MEPI | 0.745*** | 0.576*** |
| | (0.028) | (0.063) |
| | | |
| Dependency ratio | 0.036*** | 0.045*** |
| | (0.005) | (0.009) |
| | | |
| Gross Domestic Product per capita | | -0.000 |
| | | (0.000) |
| | | |
| Primary education | | -0.000* |
| | | (0.000) |
| | | |
| Secondary education | | 0.000 |
| | | (0.000) |
| | | |
| Higher education | | -0.000 |
| | | (0.000) |
| | | |
| Change in climate | | 0.032 |
| | | (0.043) |
| | | |
| Disposal income | | -0.000 |
| | | (0.000) |
| | | |
| 1 to 5 households | | -0.000*** |

| | | |
|---|---|---|
| | | (0.000) |
| | | |
| 6 to 10 households | | 0.000 |
| | | (0.000) |
| | | |
| Pension expense | | 0.004*** |
| | | (0.000) |
| | | |
| Direct medical aid | | 0.000** |
| | | (0.000) |
| | | |
| Observations | 330 | 330 |

***p < 0.01 **p < 0.05 *p < 0.10

The p-value < 0.01 of the dependency ratios indicates the significant impact of the variable on the multiple energy poverty index at a significance level of 1%. The influence is positive in direction. The positive effect of the dependency ratio on the multidimensional energy poverty index likely emerges from the budget and resource constraints associated with higher dependency burdens, i.e., the more the number of non-working aged people in a household, the lower the income or resources available to invest in energy access. Moving towards the controlling variable of the study, the p-value < 0.10 of primary education indicates a negative significant impact on the multidimensional energy poverty index at a 10% significance level. Other than this, the total number of people who fall within the range of 1 to 5 persons per household also exhibits a negative significant influence on the multidimensional energy poverty index at a 1% significance level. Pension expenses and direct medical aid also have a significant positive influence on the multidimensional energy poverty index at 1% and 5% significance levels, respectively. Other controlling variables, i.e., GDP per capita, secondary and higher education, change in climate, disposal income, and 6 to 10 people per household have insignificant influence on the multidimensional energy poverty index. However, in the presence of the controlling variables, the beta coefficient of the dependency ratio has improved showing the partial influence of controlling variables on the relationship between the dependency ratio and the multidimensional energy poverty index.

**Table 9. Robustness check**

| | | |
|---|---|---|
| | Multiple Energy Poverty Index | Multiple Energy Poverty Index |
| | (1) | (2) |
| | | |
| Old dependency ratio | 0.16063*** | 0.02140*** |
| | (0.00430) | (0.00670) |
| | | |
| GDP per capita | | 0.00000 |

| | | |
|---|---|---|
| | | (0.00000) |
| | | |
| Primary education | | -0.00003 |
| | | (0.00002) |
| | | |
| Secondary education | | -0.00017*** |
| | | (0.00002) |
| | | |
| Higher education | | 0.00056*** |
| | | (0.00004) |
| | | |
| Change in climate | | 0.02955 |
| | | (0.03308) |
| | | |
| Disposal income | | 0.00004*** |
| | | (0.00000) |
| | | |
| 1 to 5 persons per household | | -0.00000 |
| | | (0.00000) |
| | | |
| 6 to 10 persons per household | | -0.00003 |
| | | (0.00003) |
| | | |
| Pension expense | | -0.00059*** |
| | | (0.00012) |
| | | |
| Direct medical aid | | 0.00044*** |
| | | (0.00007) |
| | | |
| Constant | -1.21138*** | -0.15977 |
| | (0.06699) | (0.18525) |
| | | |
| Observations | 390 | 390 |
| R-squared | 0.796 | 0.930 |

***$p < 0.01$ **$p < 0.05$ *$p < 0.10$

For the robust analysis, the fixed effects model has been used to determine if the finding remains the same. According to the data, the dependency ratio has a significant positive influence of 1% on the multiple energy poverty index. The fixed effects model also confirmed that increasing the dependency ratio would increase the multiple energy poverty index. From the controlling variables, secondary education and pension expenses significantly negatively influence the multiple energy poverty index. However, higher education, disposal income, and direct medical aid significantly positively affect the multiple energy poverty index.

## 6. Conclusions and policy implications:

This research examines the effects of demographic transition on energy poverty in 30 provinces in China excluding Tibet, Hong Kong, Macao, and Taiwan. Quantitative information such as household energy consumption, old age dependency ratio, household size, etc., from the year 2010 to 2022 is gathered. China stepped into the aging society in the year 2000 when the percentage share of people aged 65 years old and above was defined as an aged society of 7 percent. By 2022, the total population of those aged 60 and over was expected to be more than 19% of the total population. An aging population in a nation implies that there will always be a shortage of working and youthful age groups to support the remaining population. Continuous rise in the aged population changes the consumer pattern and energy demand. Demographic transition not only reflects the increased burden on families but also shows that the burden can be considered a social burden.

The establishment and analysis of the Multiple Energy Poverty Index (MEPI) have provided valuable insights into the dimensions and indicators of energy poverty. The MEPI consists of three dimensions and five indicators, after the normalization and testing for sufficiency using the KMO test. Principal Component Analysis (PCA) was implemented to determine each indicator's weight and contribution. The findings manifested that the total volume of emission and computer indicators were excluded due to low KMO values (<0.49), resulting in a refined index composed of five key indicators: access to clean fuels, electricity consumption, air conditioning, water heater, and mobile phone.

The generalized method of the moments model and fixed effects model analyses revealed significant influences of various socio-economic factors on energy poverty. Key points include the positive impact of the dependency ratio. It clearly shows that a household with a high dependency burden faces challenges and to overcome that burden, avoids investment in clean and modern energy. Primary education has a negative effect but it is not very significant on energy poverty which shows that even basic educational attainment resulted in low energy poverty. Household size (1-5 persons) has a negative effect because smaller family sizes are more capable of managing their resources while pension expenses and direct medical aid show positive influence. Retired individuals, mostly aged 65 plus, suffer due to fixed income (pension) as they are unable to invest more in clean energy. Medical expenses in the elderly population are relatively high. Higher pension expenses force the government to allocate resources away from the investment in energy infrastructure or clean energy projects. Higher government expenses mean more taxes are imposed and energy prices are increased. Higher education and GDP per capita have insufficient influence on MEPI because these variables alone are insufficient to explain income inequality and disparities regarding energy infrastructure. The robustness of these findings is confirmed through multiple statistical tests, ensuring the reliability and consistency of the results.

These results provide significant implications for policymakers to address the persistent seriousness of energy poverty in developing nations including

China. First, policymakers should concentrate on the rural sector where there has been little or no investment in energy since 95% of users depend on solid fuels including; wood, coal, or fossil fuels. The income earned by farmers in rural regions is quite low compared to the urban regions, hence, the purchasing power of such households is inadequate.

### Three-Child Policy

After the two-child policy, the three-child policy was introduced in 2021 but due to previous restrictions on population control, it did not change the long-term societal attitudes toward marriage and family. Chinese people are less concerned about getting married on time and having more than one or two children. This policy has had little impact on reversing the fertility rate. Encouraging people through incentives and support such as adequate duration of maternity and parental paid leave might change the mindset. Consistency and continuous efforts to promote the three-child policy will give some positive results in the long run.

### Extending the Retirement Age:

The healthy life expectancy (HLE) rate for men and women was 70.53 and 73.78 in Beijing in 2015. Yunnan had the lowest HLE which was 60.44 for males in 2015 (Li et al., 2017)Still, China's official retirement age (60 for men and 50 & 55 for women) is the lowest in the world. The government is planning to gradually increase the retirement age in 2025. This will help citizens participate in an active workforce for more years and support their livelihood. The potential benefits of delaying retirement age are maintaining economic productivity, avoiding labor shortages, and better retirement savings. However, allowing older citizens to work for a few more years can create a job shortage for the younger generations. The government should make policies to create more jobs for the overall population with industrial modernization.

### State Government Pension Reforms:

Monthly pensions range from 3000 Yuan in less developed provinces to 6000 Yuan in more developed provinces like Beijing, Shanghai, etc. In 2009, the nationwide introduction of rural pension programs was insufficient. The basic pension program in China has increased by 20 to 123 Yuan per month, covering 170 million people nationally in 2024. Rural regions' pensions are less pronounced than those in the urban areas. According to China’s Academy of Social Sciences (CASS), it is estimated that the pension system will run out of funds by 2035. Hence gradually increasing the retirement age will reduce the pressure on pension fund deficit.

### Balanced Energy Infrastructure Development:

Regions with more resources and advanced technologies grow faster than regions with fewer resources and underdeveloped infrastructure. Inter-regional differences in China’s energy system are quite pronounced. With the collaboration of developed areas, this issue can be addressed and can successfully eliminate the regional disparities. The exchange of technologies, information, and digitalization can not only create energy justice but also contribute to the overall sustainability of China’s energy sector. This strategy will generate new jobs within those underdeveloped regions and deal with poverty (Wei et al.).

### Migrant Workers Rights:

The Ministry of Human Resources and Social Security collaborates with other authorities to issue guidelines for employment expansion, skill enhancement, and labor rights of migrant workers. Expanding employment benefits will provide stability for migrant workers and skill enhancement will provide competence to them in the labor market. Household Registration Reform can play a significant role in safeguarding the rights of migrant workers. The Chinese government is improving the urban household registration (Hukou) process to facilitate the settlement of migrant workers in cities with equal opportunities. Hukou is the internal passport system that draws lines between urban-rural populations. Many migrants leave their elderly parents and kids behind in the pursuit of better job opportunities. This further widens the energy poverty gap between rural and urban areas of China. Aging migrant workers face challenges in the form of inadequate pension payments due to the absence of Hukou. Better reforms in the Hukou system can overcome the extra burden on migrant workers.

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