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Gospel or curse: the impact of religious beliefs on energy poverty in rural China

Jie Dong ¹, Yanjun Ren^{2,3,4}  & Thomas Glauben³

Energy poverty, especially in rural areas, has become a central focus of scholarly and policy discussions. However, there is a significant gap in understanding the impact of religious beliefs on this phenomenon. This paper aims to fill this gap by utilizing household survey data from the China Labor-force Dynamics Survey (CLDS) spanning three waves (2012, 2014, and 2016) to examine the causal link between religious beliefs and energy poverty, covering clean energy accessibility and affordability among rural residents. Our analysis unveils a substantial positive influence of religious beliefs on the likelihood of experiencing energy poverty, especially concerning accessibility and affordability. This effect is notably pronounced among males, ethnic minorities, and low-income groups. Low income and education are recognized as pivotal mediating factors through which religious beliefs contribute to energy poverty. The findings of this study offer valuable insights for formulating strategies to mitigate energy poverty in rural China, with a particular emphasis on the role of religious beliefs.

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Introduction

Energy poverty constitutes not only an economic and social problem but also a cultural and historical one. Mainstream academia currently recognizes two dimensions in defining energy poverty: accessibility to clean energy and its affordability (Jones 2010; Leach 1992; Lin and Wang 2020; Zhang et al. 2019). The definition itself intuitively suggests that economic factors are primary causes of energy poverty, serving as the theoretical foundation for the energy ladder hypothesis proposed by Hosier and Dowd (1987). According to this hypothesis, domestic energy use tends to transition gradually towards clean, efficient, and modern energy sources as economic development and incomes increase, a phenomenon largely supported by the existing literature (Hanna and Oliva 2015; Rahut et al. 2017; van der Kroon et al. 2013). However, another body of literature empirically demonstrates that there is no significant association between household income and energy choices (Cooke et al. 2008; Sehjpal et al. 2014). For instance, recent literature from India suggests that with increasing income, households tend to opt for multiple fuel types simultaneously instead of solely replacing non-clean energy sources with modern energy. Consequently, it is concluded that attention must be paid to socio-cultural influences on energy choices (Yadav et al. 2021).

Religious belief, in itself, serves as the foundation of social structure and culture, establishing social norms and guiding individual behavior (Cooper and James 2017; Felix et al. 2018; Zemo and Nigus 2021). Approximately 84% of the world's population holds religious affiliations or spiritual beliefs (Hackett et al. 2012). Religious values, activities, and practices influence and permeate the daily lives of individuals, playing a mentoring role in shaping their attitudes and behaviors (Basedau et al. 2018; Kirchmaier et al. 2018). In recent years, economists have increasingly focused on religious beliefs to investigate their impact on income and economic growth (Bettendorf and Dijkgraaf, 2010; Durlauf et al. 2012; Squicciarini 2020), economic behavior and consumer preferences (Heiman et al. 2019; Kirchmaier et al. 2018), and innovation (Adhikari and Agrawal 2016; Bénabou et al. 2015). While a large body of literature has explored the relationship between religiosity and environmental behavior, few researchers have conducted systematic research into the impact of religious beliefs on energy poverty, with the notable exceptions of two studies by Ampofo and Mabefam (2021) and by Churchill and Smyth (2022), respectively. However, it is worth noting that neither of the aforementioned studies focuses on rural populations. Moreover, the two studies reach opposing conclusions: One study suggests that religious beliefs exacerbate energy poverty, while the other indicates that religious beliefs alleviate it. Therefore, the purpose of this study is to address this crucial gap in the literature by investigating how religiosity influences energy poverty in rural areas. However, it is worth noting that neither of the aforementioned studies focuses on rural populations.

Energy poverty is more prevalent and severe in rural areas compared to urban areas, particularly in developing countries. Scholars have also addressed the issue of rural energy poverty (Gafa and Egbendewe 2021; Kaygusuz, 2011; Nduka 2021; Wang et al. 2023b; Xie et al. 2022). Energy poverty in rural areas manifests in both availability and affordability. On the one hand, most rural residents are engaged in agricultural activities, leading to biomass, such as crop residues and fuelwood, being the primary energy source in rural areas. Furthermore, rural areas in less developed countries lack widespread access to the electricity grid, as seen in Bangladesh (Moniruzzaman and Day 2020), India (Yadav et al. 2019), and Sub-Saharan African nations (Gafa and Egbendewe 2021). On the other hand, rural areas have a higher proportion of impoverished individuals, rendering them unable to afford modern energy sources. Due to terrain and the absence

of economies of scale, the cost of electrification is significantly higher in rural areas. Even when modern energy services are available and affordable for impoverished households, the absence of roads, communication infrastructure, access to markets, and credit constitutes a significant barrier for them (Kaygusuz 2011). Rural energy services should not only fulfill the basic needs of rural households (such as cooking and lighting) but also provide substantial support for agricultural activities and rural industries. However, it is evident that rural energy services in developing countries have not yet fully achieved these two goals. Rural energy poverty adversely affects the physical and mental health of rural residents (Oum 2019; Robic and Ancic 2018), diminishes non-agricultural employment opportunities (Karpinska and Śmiech 2021; Rud 2012), reduces social capital (Lin and Okyere 2021; Middlemiss et al. 2019), and deprives children of education (Banerjee et al. 2021; Zhang et al. 2021). Rural energy poverty exerts a long-term detrimental effect on sustainable development in rural areas.

Religious belief is more widespread outside urban areas, particularly among rural and agricultural populations (Bouchard et al. 2020; Peach 2003). Likewise, in China, there is a significantly higher proportion of religious believers in rural areas compared to urban areas. The majority of religious adherents reside in rural areas (Miao et al. 2021). For instance, 80% of Protestants in China reside in rural areas. In recent years, China has witnessed an increase in its religious population, with the proportion of religious believers in the country rising by 120% from 2003 to 2010, as reported by the Chinese General Social Survey (CGSS) (Yang et al. 2019). Additionally, there is a diverse array of religious beliefs in China, with no single religion holding overwhelming dominance. While Buddhism currently constitutes the largest religious population in China, the Christian population is experiencing rapid growth. Furthermore, Islam is widely practiced, particularly in the northwest. Energy poverty is also more prevalent in rural China compared to urban areas. Many households in rural areas scarcely use modern energy, even when the power grid is fully accessible (Jiang et al. 2020). Additionally, religious believers are primarily concentrated in rural areas. There may be significant overlap between energy poverty and religious groups. However, to the best of our knowledge, no specific research has investigated the impact of religious beliefs on energy poverty in rural areas. Two articles have explored the relationship between religious belief and energy poverty, albeit not from a rural perspective (Ampofo and Mabefam 2021; Churchill and Smyth 2022). Thus, our primary research objective is to investigate whether religious beliefs exacerbate (i.e., curse) or alleviate (i.e., gospel) energy poverty in rural China, and to uncover the underlying mechanisms.

This paper contributes to the literature from multiple perspectives. Firstly, we investigate the causal relationship between religious beliefs and energy poverty using micro-level household data from rural areas. Secondly, we preliminarily explore the potential mechanisms through which religious beliefs influence energy poverty, focusing on low income and education. Thirdly, we examine the heterogeneous impact of various religions on energy poverty. Fourthly, we utilize data from a large national sample and employ instrumental variables and other econometric measures to mitigate endogeneity and rigorously explore the causal relationship between religious beliefs and energy poverty.

Literature review

Energy poverty in China. In some developing countries and economies in transition, energy poverty is often characterized by both availability and affordability, with the two dimensions

frequently coexisting rather than existing in isolation (Mendoza et al. 2019; Nguyen et al. 2019; Ozughalu and Ogwumike 2019). As the largest developing country, China exhibits a significant disparity between urban and rural areas, with energy poverty in rural regions manifesting in both accessibility and affordability challenges. For instance, a study conducted in rural China indicates that the gradual adoption of modern fuels has not resulted in substantial abandonment of fuelwood. Fuelwood continues to be the primary fuel for rural residents, suggesting that rural households in China are still in the initial phases of transitioning to modern energy sources (Song et al. 2018). Consequently, some scholars employ both measures when assessing household energy poverty. For instance, certain scholars define accessible energy poverty based on a household's access to modern energy. They utilize indicators such as "the ratio of household energy consumption to total income" and whether this ratio exceeds 10% to gauge the availability of household energy poverty (Nie et al. 2021; Zhang et al. 2019). Lin and Wang (2020) base their analysis on residential electricity consumption, determining that the threshold for basic household electricity demand is 113.8 KWH per family per month. They classify households with electricity consumption below this threshold as experiencing lifeline energy poverty. Likewise, another study has assessed the energy consumption threshold of Chinese residents focusing on electricity usage (He and Reiner 2016). In recent years, scholars have increasingly focused on researching energy poverty in China, particularly the challenges faced in rural areas (Li et al. 2023a; Li et al. 2024; Lin and Zhao 2021; Liu et al. 2023; Ren et al. 2022). Li et al. (2024), for example, show that nearly universal pension coverage significantly decreases the prevalence of energy poverty in rural areas.

Non-economic factors influencing energy poverty. While economic factors are commonly perceived to influence residents' energy poverty, some studies have observed that as income increases, households do not entirely forsake non-clean energy; instead, they blend clean energy with non-clean energy. This phenomenon is also conceptualized and labeled as the "energy accumulation" theory (Celik and Oktay 2019; Choumert-Nkolo et al. 2019). Within this theoretical framework, economists consider factors beyond the economy. They examine demographic characteristics of family members, such as education and gender, as well as social factors including social networks, cultural diversity, and ethnicity. For instance, a study from Pakistan demonstrates that householders with higher levels of education are less likely to report energy poverty (Qurat-ul-Ann and Mirza 2021). The inverse relationship between educational attainment and energy poverty has also been evidenced in other developing Asian countries (Abbas et al. 2020; Acharya and Sadath 2019). Moreover, studies examining the influence of the gender of the household head on household energy choice and energy poverty represent a frontier in energy economics (Listo 2018; Moniruzzaman and Day 2020). Besides gender differences, racial and ethnic disparities also contribute to energy poverty. Moreover, in some developed countries, research indicates that ethnic diversity within communities heightens the likelihood of energy poverty (Churchill and Smyth 2020; Wang et al. 2021). In certain developing countries, for instance, Nguyen et al. (2019) and Islar et al. (2017) examine residents in Vietnam and Nepal respectively, demonstrating that ethnic minority households face inherent barriers in selecting clean energy options, often preferring traditional non-clean energy sources. Energy poverty transcends economic boundaries and is also a social issue. Therefore, recent research has shed light on the correlation between energy poverty and social capital (Creutzfeldt et al. 2020; Middlemiss et al. 2019;

Searpellini et al. 2017). Recent literature has also delved into the correlation between culture and energy poverty (Chaudhry and Shafullah 2021; Li et al. 2023a). Moreover, two recent studies have examined the link between religious affiliation and energy poverty from a religious standpoint. Ampofo and Mabefam (2021) employing transnational macro data, analyze the impact of religious belief on energy poverty and find that it contributes to the phenomenon. Conversely, another recent study focusing on Australian residents suggests that Protestantism, to some extent, helps alleviate energy poverty (Churchill and Smyth 2022).

Religious belief and environmental behavior. Extensive studies have investigated the effects of religious beliefs on environmental behavior, categorizing them into three main groups: pessimism, optimism, and indifference. In the 1960s, the distinguished historian Lynn White developed a seminal theory that identifies religious beliefs as the cause of the ecological crisis (White 1967). White's theory suggests that the impact of Judeo-Christianity on nature dates back to the Middle Ages, leading to an exploitative attitude toward the environment within Western culture. Moreover, the Zen Buddhist approach to nature in Asia mirrors the Christian perspective on the natural environment in the Western world (White 1967). In line with White's theory, a substantial body of literature has subsequently argued for the adverse effects of religious beliefs on ecology and climate change. For instance, empirical evidence from the US suggests that the "greening of Christianity" has minimal positive effects on ordinary Christians (Clements et al. 2014a; Clements et al. 2014b). Moreover, several studies have demonstrated that religious individuals exhibit lower environmental concern compared to non-Christians and non-religious individuals in the US (Clements et al. 2014b; Danielsen 2013; Stoll 2015). Taylor et al. (2016) find that individuals with higher religiosity pay less attention to the environment than those with lower religiosity. Other scholars, however, attempt to challenge White's theory and are inclined to believe that religion fosters pro-environmental behavior and concern (Felix and Braunsberger 2016; Felix et al. 2018; Zemo and Nigus 2021). In certain developing countries with inadequate environmental protection systems and regulations, religion may prove to be more effective than institutions. For example, Appiah-Opoku (2007) finds that indigenous beliefs in Ghana facilitate environmental stewardship. Alternatively, in advanced countries, some scholars argue that there has been a "greening of Christianity" since the mid-1990s and assert that Christianity can enhance environmental awareness and education in the US (Hitzhusen 2007; Wilkinson 2010). Furthermore, additional studies have indicated a lack of significant association between religious beliefs and environmental concerns (Arbuckle and Konisky 2015; Djupe and Hunt 2009; Greeley 1993; Sherkat and Ellison 2007). For example, Konisky et al. (2008) argue that church attendance and the frequency of prayer are not correlated with environmental preferences.

In summary, as demonstrated by Zemo and Nigus (2021), religious beliefs exhibit heterogeneous or even opposite effects on the environment across various regions. This conclusion also appears to be supported by the two existing studies on the relationship between religiosity and energy poverty (see Ampofo and Mabefam 2021 and Churchill and Smyth 2022). The religious environment in rural China differs from that in Australia or Western countries, where Protestantism predominates. Moreover, energy poverty in rural China is more severe than in urban areas, with rural residents likely experiencing both accessible and affordable energy poverty. It remains unclear whether the religious environment in rural China influences the energy choices and energy poverty of residents. This paper aims to

estimate the causal relationship between religious beliefs and energy poverty in rural China using a large sample of micro-household data and instrumental variables, thereby contributing to the literature in this field.

Research hypothesis

Iannaccone (1998) introduces the economics of religion and proposes the theory of “trade-offs between time and money”. This theory predicts a substitution between time and money devoted to religion, highlighting that the more time families dedicate to religious activities, the less time they have available for secular production and consumption. Similarly, Azzi and Ehrenberg (1975), propose a theory that constructs models explaining how individuals allocate their time and possessions between religious and secular goods to maximize both lifetime and afterlife utility. Under the condition of constant total utility, the pursuit of “afterlife consumption” as the primary goal of religious participation will significantly constrain secular consumption during one’s lifetime (Azzi and Ehrenberg 1975). Consequently, it is reasonable to posit that in rural areas with limited economic conditions, frequent religious activities may displace time spent on productive economic activities, thus diminishing the purchasing power for energy acquisition or consumption (Martin 1993).

From another perspective, it can be argued that religious beliefs contribute to rural energy poverty, manifested as the issue of left-behind seniors and women in rural China (Liu et al. 2021; Ye et al. 2016). With China’s rapid economic development over the past two decades, a significant portion of the rural labor force has migrated to cities to engage in urbanization projects. Consequently, the rural elderly and some women, responsible for caring for young children, remain in rural areas. On the one hand, the elderly and women exhibit higher adherence to religious beliefs, while on the other hand, they face disadvantages in accessing clean energy options. On the other hand, domestic energy decisions are frequently made by women. The convergence of these three factors contributes to the prevalence of energy poverty in rural China.

Firstly, according to the theoretical model proposed by Iannaccone (1998), religious belief and religious activities are more prevalent among the elderly and women. Elderly individuals tend to be more invested in the concept of the “afterlife” due to the increased sunk costs associated with religious consumption. Secondly, families with a lower opportunity cost of time are more likely to engage in intensive religious activities, with lower-wage members, typically wives, allocating more time for religious pursuits. Secondly, it is the elderly and women who typically occupy the lower tiers of the energy consumption pyramid, particularly in rural areas. Research indicates that the elderly and women exhibit lower receptivity to new energy equipment, increasing the likelihood of experiencing energy poverty (Clancy et al. 2012; Ngarava et al. 2022; Wang et al. 2023a). Thirdly, and more importantly, in rural China, women often hold the decision-making power regarding household energy choices. Traditionally, families assign housework and child-rearing responsibilities to women, while men are expected to work outside the home (Ye 2016). Consequently, women, who primarily use cooking energy within households, play a pivotal role in energy decisions. Particularly in rural areas, women may prioritize firewood or coal in their energy consumption patterns (Li et al. 2023a).

Studies from other countries also indicate that energy poverty is more prevalent in highly religious areas. Acharya and Sadath (2019) conduct a qualitative analysis of the dynamic differences in energy poverty among various religions from 2004 to 2011.

They find that Muslims and Hindus tend to have relatively high average energy poverty scores, while individuals without any religious affiliation tend to score relatively low. Additionally, research suggests that individuals from lower caste backgrounds in India face greater challenges in ascending the energy ladder, with rural areas experiencing more severe energy poverty than urban areas (Poddar et al. 2020). Saxena and Bhattacharya (2018) observe serious inequalities in access to LPG among Muslim households. Consistent with several previous studies from India, a statistical analysis of Australian residents conducted by Leslie et al. (2022) indicates that communities with significant Hindu populations tend to consume less energy than the average. Additionally, Leslie et al. (2022) find that Islamic communities consume more energy than average, while Buddhist and Jewish communities consume energy at levels similar to the average. Based on these findings, this paper proposes Hypothesis 1(H1):

H1: Religious beliefs exacerbate rural energy poverty.

There exists a debate within the literature concerning the influence of religion on economic outcomes (Bryan et al. 2021; Gruber 2005; Weber 1976). However, certain scholarly sources delve into the positive correlation between religious belief and poverty, particularly within developing countries and regions (Berryman 1994; Marx and Engels 2012; Slade 1992). As Marx (1978) famously asserted, religion functions as the “opium of the people”. Religion can be metaphorically compared to a “black box” that distorts human perceptions of the social and material world. Moreover, religion serves as a coping mechanism amidst poverty, functioning as a conservative force that upholds the status quo and impedes calls for change (Rogers and Konieczny 2018). Slade (1992) examines the history of Latin America, contending that religion perpetuates a feudal system wherein extreme social inequalities become normalized, and attempts to enact change are perceived as rebellious acts against God. This phenomenon extends beyond Latin America, as scholars have observed religion legitimizing social inequality in regions like the Middle East (Mahmood 2011; Masoud 2014) and colonial South Africa (Comaroff and Comaroff 2008). Furthermore, Brown and Tierney (2009) discover that religious belief diminishes the subjective well-being of the elderly in China. Given the complex nature of religious belief, a dialectical examination of its impact on residents’ social and economic outcomes is warranted. In rural China, however, religious beliefs appear to hinder residents’ progress towards prosperity, despite the Chinese government’s advocacy for religious freedom and protection of the five major religious faiths: Buddhism, Taoism, Islam, Catholicism, and Protestantism. On the one hand, while every religion preaches the spirit of brotherhood, it inevitably imposes restrictions on its followers due to the exclusivity among religions. On the other hand, religion can dampen people’s competitive spirit, potentially diminishing their pursuit of wealth. This doctrine contributes to maintaining the stability of social order and facilitating the harmonious development of society to some extent. For believers themselves, it fosters physical and mental well-being amidst the competitive pressures of the market economy, enabling them to confront and endure various risks with a more positive attitude. However, in the long run, such psychological satisfaction may erode people’s drive for competition and advancement, and diminish their willpower. Additionally, it undermines the consciousness and behavior of believers in their utilitarian pursuit of wealth. Remarkably, conservatism is a prevalent characteristic of contemporary religions in China, evident across all major religious traditions. Particularly in rural China, the conservative nature of religion is particularly pronounced. Consequently, it is not challenging to comprehend that religion adversely affects the economic income of rural households.

Energy poverty stems from the active or passive choices regarding household energy, with low household income serving as its primary cause. As household income increases, energy consumption gradually shifts towards cleaner, more efficient, and modern sources, a trend corroborated by existing literature (Hanna and Oliva 2015; Rahut et al. 2017; Song et al. 2018; Van Cappellen et al. 2016). In essence, low income directly causes household energy poverty. From the above analysis, we infer that low income may serve as the conduit through which religious beliefs influence energy poverty. Based on the above analysis, Hypothesis 2 (H2) is obtained:

H2: Low income acts as a mediator in the relationship between religious beliefs and rural energy poverty.

The impact of religious belief on human capital, primarily education, manifests in two main aspects: First, the direct influence of religion on individual education (Becker and Woessmann 2009; Squicciarini 2020), and second, the indirect influence through intergenerational transmission (Fan 2008; Malik and Mihm 2022). Research by Glaeser and Sacerdote (2008), suggests a negative association between religious beliefs and education. Less educated individuals are more inclined to believe in miracles, heaven, demons, and biblical allusions. Additionally, religious belief exhibits a negative correlation with education, as secular education often contradicts religious teachings. Some renowned philosophers and economists argue that knowledge undermines religious belief (Freud 1907; Knight and Merriam 1946; Marx and Engels 2012). One significant factor is the distinctly anti-religious approach often associated with science-based secular education: Modern science and technology assert that human progress does not rely on gods of various denominations. Conversely, religious beliefs can impede the advancement of secular education. In certain developing countries, particularly in rural China, children from religious families also exhibit higher dropout rates (Li et al. 2017). Therefore, it also prompts relevant research on the intergenerational impact of faith on education. For instance, Malik and Mihm (2022) analyze how religious parents prioritize attending religious activities, which often detracts from their own working hours. Consequently, parents may encourage their children to work more to make up for this time, potentially leading to decreased academic performance or reduced study time for the offspring. The intergenerational effect of religious belief implies a social multiplier, which will cause the negative correlation between education and belief to become stronger at higher aggregation levels. Hence, the negative influence of religious belief on education becomes more deeply rooted.

Education plays a crucial role in mitigating energy poverty. Higher education enhances residents' proficiency in using modern kitchenware and heaters (such as induction cooktops, microwave ovens, and air conditioners). Additionally, education fosters environmental awareness, promoting the use of clean fuel. In rural and remote regions, religious individuals often have lower levels of education, which contributes to energy poverty (Chiswick 1983; Glaeser and Sacerdote 2008; Tomes 1984). Therefore, education is also considered to be one of the pathways through which religiosity influences energy poverty. Based on the above analysis, Hypothesis 3 (H3) is derived:

H3: Education mediates the relationship between religious beliefs and rural energy poverty.

Data and descriptive statistics

The sample. The data utilized in this study originate from the China Labor-force Dynamics Survey (CLDS), a nationally representative labor force questionnaire survey spanning 29 provinces in mainland China, excluding Tibet and Hainan. Conducted biennially, this survey was designed by Sun Yat-sen

University in Guangzhou, China, to longitudinally capture insights into Chinese communities, households, and individuals. We utilize three waves of data (2012, 2014, and 2016), which are available as mixed cross-section data. Following the matching of all variables and removal of observations with missing covariates, the final sample comprises 13,773 rural adults from three cross-sectional datasets.

Variables

Dependent variables. While there is no universally applicable definition of energy poverty, current academic discourse primarily defines it from one of two perspectives: accessibility, often emphasized in developing countries (Adusah-Poku and Takeuchi 2019; Sadath and Acharya 2017), or affordability, prioritized in advanced countries (Charlier and Kahouli 2019; Day et al. 2016). Despite achieving 100% electrification in 2014, encompassing both urban and rural areas, a significant proportion of rural households still rely on solid fuel as their primary energy source (Lin and Wang 2020; Zhang et al. 2019). Consequently, we define energy poverty from both the perspectives of accessibility and affordability. Firstly, regarding accessibility, we define whether a household uses solid fuels as its primary energy source as our independent variable. Secondly, based on the study by Zhang et al. (2019), we employ a continuous variable that divides energy expenditure by total income to define affordability.

Independent variable. According to the National Religious Affairs Administration of China (NRAAC), Protestantism, Catholicism, Islam, Taoism, and Buddhism are the primary religions in China. Consequently, the independent variable in this study is defined as whether individuals hold any religious beliefs. Specifically, the questionnaire inquires, "Do you have any religious beliefs?" with binary response options (1 = yes; 0 = no). Moreover, if the respondent acknowledges having religious beliefs, they are further queried about the specific type of religion.

Channel variables. To explore the underlying mechanism of religious beliefs influencing energy poverty, we introduce low income and education as mediating variables. Firstly, low income and energy poverty often coexist, with religious beliefs shown in several studies to diminish family income and impede economic development (Squicciarini 2020). We operationally define low-income individuals as those living below the poverty line¹. Secondly, compared with low income, a low educational level is considered to be a more fundamental cause of economic poverty (Squicciarini 2020); therefore, we also incorporate education into the mechanism of energy poverty. The preliminary statistical results are in line with our expectations and indicate that religious individuals are more likely to have low income and lower levels of education (Supplementary Table A1). We will delve deeper into these two mechanisms in mechanism analysis section.

Control variables. We include demographic variables (such as gender and age) and household-level characteristics (such as family size) as control variables, consistent with previous research. Additionally, we control for membership in the Communist Party of China (CPC), an atheist institution. Regional dummy variables are also incorporated to account for regional-fixed effects stemming from varying levels of regional development and religious atmosphere.

According to the statistical analysis (Supplementary Table A1), significant differences exist between the two groups. Specifically, compared to the control group (no religion), the treatment group (religion) exhibits a higher prevalence of energy poverty in terms of both accessibility and affordability. Additionally, individuals in

the treatment group are more likely to be female, younger, and of ethnic minority status compared to individuals in the control group. Furthermore, compared with non-religious individuals, those with religious beliefs are less likely to be members of the CPC, possess less agricultural experience, have smaller family sizes, and lower household incomes. Moreover, their villages are less likely to have cement pavements and are more likely to be situated in plain areas.

Descriptive statistics

Distribution of religious beliefs in rural China. According to the NRAAC, the five major religions in China are Buddhism, Protestantism, Islam, Catholicism, and Taoism. Based on the CLDS 2016 data, preliminary statistics indicate that in rural China, individuals with religious beliefs comprise 12.90% of the population. Subsequently, we analyze the distribution of specific religions in rural areas (Fig. 1). Buddhism remains the most prevalent religion in rural China, with 58.77% of individuals adhering to it. Protestantism and Islam have approximately equal numbers of followers, accounting for 17.94% and 17.18% of the population, respectively. Taoism, Catholicism, and other religions have fewer followers, constituting 2.62%, 1.81%, and 1.69% of the rural population, respectively.

The spatial distribution of energy poverty. To better illustrate the spatial and temporal distribution of rural energy poverty in China, we first map energy poverty concerning accessibility, as depicted in Fig. 2. Generally, compared with 2012, the energy poverty rate

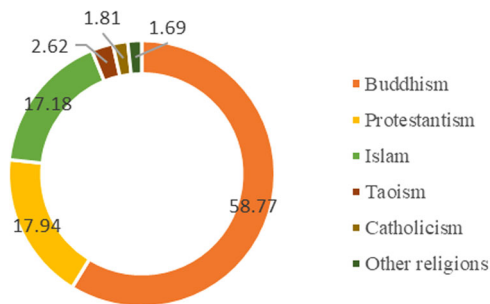


Fig. 1 Distribution of religious beliefs in rural China (%). This annular chart shows the proportion of religious groups to the total religious population in rural China.

decreased in most provinces by 2016 (the colors appear lighter in 2016 than in 2012). This trend indicates a significant increase in villagers' reliance on clean energy, particularly electricity, following the country's achievement of full power grid coverage in 2014. Additionally, the spatial distribution reveals that provinces with higher levels of development exhibit lower rates of energy poverty, as evidenced by lighter colors in the eastern coastal region.

When examining energy poverty based on affordability (Fig. 3)², the distribution differs from that of accessibility, with significant energy poverty issues observed even in developed provinces such as Guangdong and Fujian. This indicates a rising problem of energy poverty concerning affordability, mirroring challenges faced by developed countries. Furthermore, affordability-related energy poverty has not improved over time in several provinces. For instance, the issue has notably worsened in Henan province.

Methods

Model. We aim to estimate the effect of religious beliefs on the energy poverty of rural residents. Since the measures of energy poverty in this study are based on accessibility and affordability, we employ two models for our estimations. The accessibility model is set as follows:

$$Accessibility_h = F(\alpha + \beta Religion_i + \gamma X_{ih} + \epsilon_{ih}) \quad (1)$$

The affordability model is the following:

$$Affordability_h = F(\alpha + \beta Religion_i + \gamma X_{ih} + \epsilon_{ih}) \quad (2)$$

here, *Accessibility* is a binary variable indicating whether the household uses solid fuels (i.e., firewood and coal) for cooking and heating, where *Accessibility* = 1 indicates that household *h* suffers from accessibility energy poverty, and *Accessibility* = 0 indicates otherwise. *Affordability* is a continuous variable obtained by dividing energy expenditure by total income. *Religion* represents whether the individual is religious, with a value of 1 indicating a believer (of any religion) and 0 indicating an atheist. *X* is a vector of control variables at both the individual *i* and household *h* levels, β represents the estimated parameters of interest, and ϵ represents a random disturbance term.

Endogenous discussion. Furthermore, we are concerned with the potential endogeneity of religious beliefs in the aforementioned models. For instance, unobserved alterations in personal

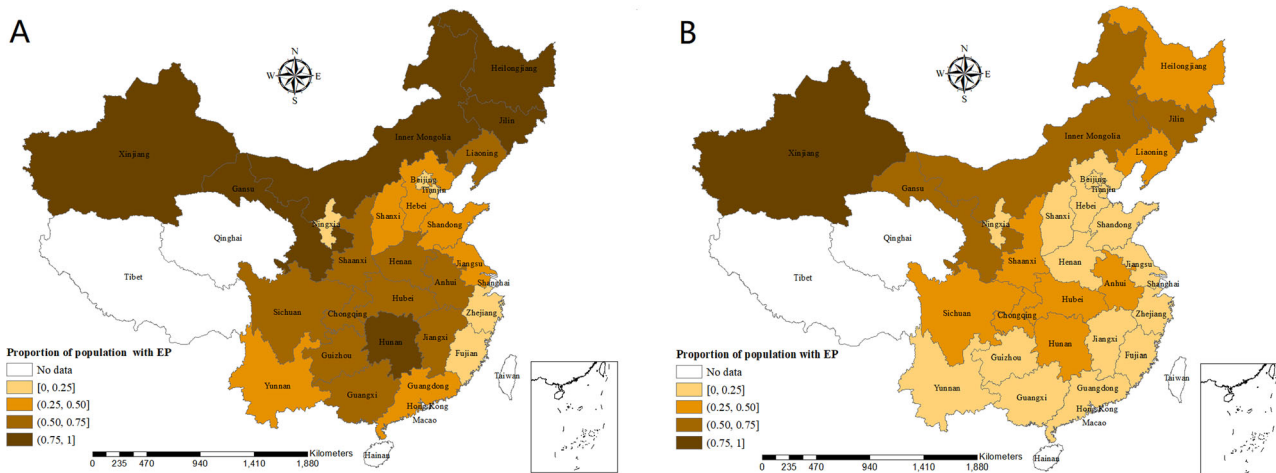


Fig. 2 Accessibility energy poverty in rural China. Figure A shows the spatial distribution of accessibility energy poverty in China in 2012, and Figure B shows the spatial distribution of accessibility energy poverty in China in 2016. The darker the color, the higher the proportion of people with accessibility energy poverty.

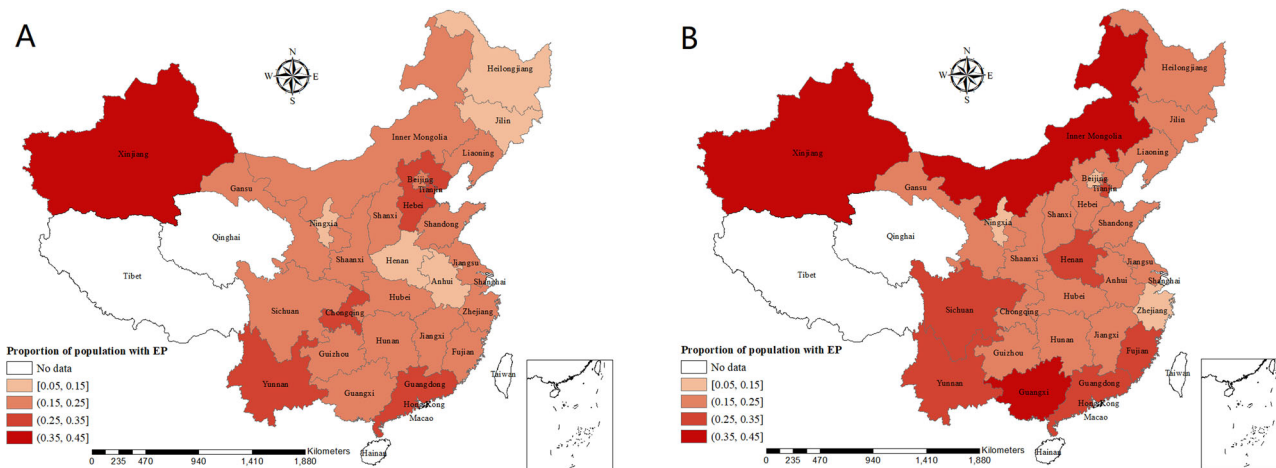


Fig. 3 Affordability energy poverty in rural China. Figure **A** shows the spatial distribution of affordability energy poverty in China in 2012, and Figure **B** shows the spatial distribution of affordability energy poverty in China in 2016. The darker the color, the higher the proportion of people with affordability energy poverty.

characteristics or household wealth may have exhibited correlation with changes in religious beliefs, even subsequent to controlling for demographic characteristics and household income. Alternatively, given that energy poverty impacts social relationships, it may likewise influence individuals’ religious beliefs (even after demographic characteristics and household income are controlled for). Alternatively, given that energy poverty impacts social relationships, it may also influence individuals’ religious beliefs (Middlemiss et al. 2019; Searpellini et al. 2017). Consequently, we utilize an instrumental variable to identify and estimate the impact of religious beliefs on energy poverty. This instrumental variable is represented by the density or count of places of worship (including churches, temples, and mosques) per thousand individuals in a village or community. For an instrument variable to be deemed valid, it must satisfy two requirements: correlation restriction and exclusion restriction. Firstly, in our scenario, the density of religious establishments exhibits a robust correlation with the religious convictions of individuals within the village/community. This correlation arises from the potential of a high density of religious establishments to significantly encourage nearby residents to engage in religious activities and embrace religious beliefs, either through the activities offered or through peer influence. Put differently, individual religious beliefs are influenced by factors such as the regional context, the quantity of local religious institutions, group dynamics, and generational influences. In essence, adherence to religious practices is intricately linked to the prevailing religious activity ambiance and traditions within the local community (Chunping et al. 2016). Moreover, in contrast to prior studies that utilized the density of religious establishments at the county or city levels, we employ the density of such establishments at the village/community level as our instrumental variable, thereby better fulfilling the correlation hypothesis. Secondly, it is unlikely to anticipate a direct impact on household energy habits and consumption since religious establishments were typically established before the survey period, thereby satisfying the pre-determined restriction. Moreover, the density of religious establishments in a village is not dictated by a single family but by the prevailing local religious milieu and culture, thereby fulfilling the exclusion restriction. Additionally, in certain studies, the density of religious establishments has been employed as an instrumental variable for individual religious beliefs (Chunping et al. 2016; Fruehwirth et al. 2019; Ruan et al. 2014b; Xu et al. 2022; Zhang and Liu, 2021).

Mediation effect model for mechanism test. This study employs the model proposed by Baron and Kenny (1986) to conduct a detailed analysis of the mechanism influencing the relationship between religious beliefs and energy poverty. Specifically, this study introduces two research hypotheses concerning the mechanism, focusing on the influence of low income and education. In this study, the subsequent formula is employed to provide a concise explanation of the causal pathway:

$$EP = i_1 + cReligion + \epsilon_1 \tag{3}$$

$$M = i_2 + aReligion + \epsilon_2 \tag{4}$$

$$EP = i_3 + c'Religion + bM + \epsilon_3 \tag{5}$$

here, *EP* represents the dependent variable, denoting energy poverty encompassing both availability and affordability aspects. *M* denotes two mediating variables. *Religion* the core explanatory variable in this study, is represented by a dummy variable indicating religious belief. As per Sobel (1982), the null hypothesis assumes that the product of coefficients *a* and *b* in Eqs. (4) and (5) equals zero, denoted as $ab = 0$. Rejecting this hypothesis implies the presence of a valid mediation effect. This test method is commonly referred to as the Sobel test in the assessment of mediation effects.

Empirical results

Baseline results. Table 1 presents the baseline estimations concerning the influence of religious beliefs on energy poverty, considering both accessibility (see column (1) and column (2)) and affordability (see column (3) and column (4)). Column (2) and column (4) display the results of instrumental variable estimation, with the initial stage estimation of instrumental variables provided in Supplementary Table A2. As demonstrated in Supplementary Table A2, the instrumental variable (IV) we employ exhibits a strong correlation with endogenous variables (with a coefficient of 0.016 and $P < 0.01$). Furthermore, the F-statistic is 10.969 (>10), rejecting the null hypothesis at the 1% significance level. In summary, these findings indicate the validity of our instrumental variable.

Initially, we examine the impact of religious beliefs on energy poverty in terms of accessibility. In column (2), the statistically significant Wald test of exogeneity indicates the endogeneity of the independent variable. Consequently, the IV-Probit model is deemed more effective than the general Probit model.

Table 1 The marginal effect of religious beliefs on energy poverty.

	Accessibility		Affordability	
	(1)	(2)	(3)	(4)
Religion	Probit 0.032** (0.015)	IV-Probit 0.564*** (0.149)	Tobit 0.012*** (0.005)	IV-Tobit 0.070** (0.030)
Sex	-0.001 (0.005)	0.012** (0.006)	-0.001 (0.002)	0.001 (0.002)
Age	-0.019*** (0.002)	-0.013*** (0.003)	-0.001* (0.001)	-0.001 (0.001)
Age ²	0.000*** (0.000)	0.000*** (0.000)	0.000** (0.000)	0.000** (0.000)
Ethnicity	0.043** (0.019)	-0.098** (0.046)	-0.004 (0.005)	-0.011 (0.009)
Marriage	0.036** (0.017)	0.041*** (0.015)	-0.006 (0.006)	-0.009* (0.006)
CPC	-0.057*** (0.018)	-0.025 (0.020)	0.005 (0.005)	0.001 (0.005)
A_experience	0.216*** (0.013)	0.192*** (0.023)	-0.018*** (0.004)	-0.009*** (0.004)
Fmnum	0.011*** (0.003)	0.009*** (0.003)	0.000 (0.001)	0.001 (0.001)
Ln_income	-0.021*** (0.004)	-0.017*** (0.004)	-0.032*** (0.002)	-0.013*** (0.000)
Cement	-0.002*** (0.000)	-0.002*** (0.000)	0.000*** (0.000)	0.000** (0.000)
Plain	-0.117*** (0.011)	-0.114*** (0.013)	0.001 (0.003)	-0.006** (0.003)
Year-fixed effects	Yes	Yes	Yes	Yes
Regional-fixed effects	Yes	Yes	Yes	Yes
Wald test of exogeneity		6.50***		4.32**
Observations	13,773	13,773	13,773	13,773

Standard errors are in parentheses (clustered at the household level). Year-fixed effects: 2012, 2014, and 2016. Regional-fixed effects: according to economic development and geographical factors, China is divided into: Eastern region, Central region, and Western region.
***p < 0.01; **p < 0.05; *p < 0.1.

Additionally, in column (2), the marginal effect value of interest is 0.564 at the 1% significance level, indicating a significant positive effect of religious beliefs on accessibility energy poverty in the IV-Probit estimation, as per Eq. (1). Moreover, from the perspective of affordability, the Wald test of exogeneity supports the validity of the IV-Tobit model. Additionally, in column (4), the estimated coefficient is 0.070 at the 5% significance level, as per Eq. (2), indicating that religious beliefs exacerbate the incidence of energy poverty in terms of affordability. Furthermore, the empirical findings of this study corroborate hypothesis 1, suggesting that religious beliefs contribute to energy poverty among rural households.

Additionally, this paper briefly examines the estimation results of control variables regarding accessibility energy poverty. In column (2) of Table 1, male respondents exhibit a higher propensity to report energy poverty. This finding aligns with the results of Li et al. (2023a) in the context of China. Within Chinese families influenced by traditional culture, the notion of “men working outside the home while women manage household affairs” promotes a division of labor model. Men typically do not participate in specific household tasks such as cooking and heating, leading to decreased interest in utilizing clean energy sources (Li et al. 2023a). The relationship between age and energy poverty exhibits a U-shaped curve, suggesting that both young and elderly individuals are more susceptible to energy poverty,

whereas middle-aged individuals are less susceptible. This pattern may be attributed to the fact that middle-aged individuals, who are typically in the prime of their working lives, possess higher labor value and income, and thus exhibit a greater inclination towards adopting clean energy sources. Vulnerable demographic groups, particularly the elderly, are more susceptible to experiencing energy inequality, with a specific focus on the issue of energy poverty among older adults, which has garnered considerable academic scrutiny (Jiang et al. 2024; Li et al. 2022). Married respondents and large households are at a higher risk of experiencing energy poverty. The increased cost of living in such households may lead them to prefer inexpensive, environmentally harmful energy sources. Additionally, our findings confirm that low income is a significant factor contributing to energy poverty. Moreover, individuals with experience in agricultural activities are at a higher risk of experiencing energy poverty. Chinese farmers perceive the use of straw as fuel as a deeply ingrained habit and tradition (Aunan et al. 2019; Sun et al. 2016; Wang and Jiang 2017). A higher proportion of concrete pavement correlates with a decreased likelihood of households experiencing energy poverty. Households situated on plains exhibit a reduced propensity to experience energy poverty. This is attributed to well-developed rural infrastructure and flat terrain, which create conducive conditions for establishing energy networks, such as power grids and photovoltaic systems (Li et al. 2023b; Lin and Zhao 2021).

Robustness check

Using selection on observables to assess the bias from unobservable. Despite efforts to control for certain observable factors (e.g., household income), the estimates presented in Table 1 may still be susceptible to influence from unobservable factors associated with religious beliefs and energy poverty. In this section, we will assess the potential bias introduced by unobservable factors. Our strategy draws upon the method introduced by Altonji et al. (2005) and refined by Oster (2019). It evaluates selectivity bias by comparing the ratio of selection on unobservable factors to that on observables. The methodology relies on the following two regression equations:

$$EP_h = F(\alpha + \beta^R Religion_i + \tau_i + \gamma_t + \epsilon_{ih}) \tag{6}$$

$$EP_h = F(\alpha + \beta^F Religion_i + Control_{ih} + \tau_i + \gamma_t + \epsilon_{ih}) \tag{7}$$

EP_h represents energy poverty based on both accessibility and affordability. In Eq. (6), only time and region are controlled for as a restricted set of variables, while Eq. (7) includes a full set of control variables. β^R and β^F represent the estimated coefficients for the variables of interest in Eqs. (6) and (7), respectively. Hence, the ratio can be computed as follows:

$$Ration = \beta^F / (\beta^R - \beta^F) \tag{8}$$

Equation (8) provides an intuitive perspective, indicating that the smaller the difference between $(\beta^R - \beta^F)$, the larger the ratio. Moreover, from an econometric standpoint, a smaller difference implies that the estimate is less influenced by selection on observables, and a stronger selection on unobservable factors (relative to observables) is required to entirely explain the effect. Following the methodology outlined by Nunn and Wantchekon (2011), we establish two restricted covariate groups: The first group lacks any controls, while the second group incorporates a limited number of demographic controls, encompassing sex, age, and age squared. The set of full controls comprises all control variables outlined in Eq. (1).

Table 2 presents the rates of three measures of energy poverty from two perspectives. None of the ratios in Table 2 exceed 1.

Table 2 Result of using selection on observables to assess the bias from unobservable.

		Accessibility	Affordability
		(1)	(2)
Controls in the restricted set	Controls in the full set		
None	Full set of controls	6.681	3.110
Sex, Age, Age ²	Full set of controls	29.742	3.643

In both regressions, the sample sizes are the same, and time- and regional-fixed effects are included.

Regarding accessibility, the minimum, maximum, and mean values are 6.681, 29.742, and 18.212, respectively. In terms of affordability, the rates range from 3.110 to 3.643, with a median ratio of 3.428. Therefore, for the entire estimate to be attributed to selection bias, the selection on unobservable factors would need to exceed the selection on observables by factors of 18.212 and 3.377 for accessibility and affordability, respectively. We contend that the estimated effect of religion is unlikely to be affected by such significant unobservable factors.

Historical instrumental variable. To address the potential endogeneity problem and enhance the robustness of our estimates, this study utilizes historical data as its instrumental variable. The selected historical instrumental variable for this study is the number of temples at the provincial level in 1820, developed by Harvard University. This instrumental variable has been employed in other studies within the field of economics (Banerjee et al. 2020; Ruan et al. 2014b). Specifically, the historical instrumental variable represents the number of religious sites in each province of China in 1820. Firstly, there exists a strong correlation between the number of temples and individuals' religious beliefs in 1820 due to the significant intergenerational transmission effect of religious beliefs. The intergenerational lock-in effect of religious beliefs is grounded in two theoretical frameworks in economics (Ruan et al. 2016). One theory pertains to religious human capital, while the other concerns the theory of cultural intergenerational transmission. The core tenet of the first theory posits that religious human capital primarily originates from past religious activities, and individuals' engagement in religious activities is influenced by their families, particularly their parents. The second theory posits that parents maximize their utility when their children adopt their beliefs. Consequently, parents are incentivized to mold their children's beliefs through vertical socialization. Hence, the intensity of historical religious beliefs significantly influences present-day religious beliefs. Additionally, empirical studies have demonstrated the robust intergenerational transmission of religious beliefs (Bar-El et al. 2013; Patacchini and Zenou 2016; Ruan et al. 2016).

Secondly, the number of temples in 1820 does not exhibit a correlation with current household energy poverty, satisfying stringent exogenous constraints. The number of places of worship in 1820 does not directly influence the energy choices of present-day rural residents. Moreover, in Chinese literature investigating the correlation between religious beliefs and outcome variables, similar historical instrumental variables are employed (Ruan et al. 2014a; Ruan et al. 2014b). Hence, the utilization of this historical instrumental variable is justified.

To further demonstrate the validity of this historical instrumental variable, we conduct the following analysis: Firstly, we present the results of the first-stage test for this historical instrumental variable in Table 3. The F-statistic is 39.622 (>10),

Table 3 Regression results from employing a historical instrumental variable.

	Accessibility	Affordability
	(1)	(2)
Religion	0.926*** (0.018)	0.233*** (0.066)
Control variables	Yes	Yes
Wald test of exogeneity	101.71*** ($P = 0.000$)	11.58*** ($P = 0.001$)
F-statistics	39.622	39.622
Observations	13,773	13,773

The values in the table are marginal effects. Standard errors are in parentheses (clustered at the household level). F-statistics are the first stage of the instrumental variable tests. *** $p < 0.01$, ** $p < 0.05$; * $p < 0.1$.

rejecting the null hypothesis of weak instrument problem at the 1% significance level. Secondly, following the methodology of Nunn and Wantchekon (2011), we perform a falsification test for the instrumental variable. The exclusion restriction condition for the instrumental variable stipulates that the historical instrumental variable can solely impact energy poverty through religious affiliation. In other words, in areas with a strong religious atmosphere, the historical instrumental variable influences residents' energy choices and energy poverty by influencing religious beliefs. Conversely, in regions with a high level of secularization, the historical instrumental variable does not affect the energy choices of contemporary residents. Consequently, we calculate the proportion of religious believers in each province based on the rural sample in the CLDS data (Supplementary Fig. A1). Using Supplementary Fig. A1 as a reference, we choose a sample consisting of the 10 provinces with the lowest religious atmosphere, listed in descending order: Shandong, Chongqing, Hunan, Hebei, Guangxi, Tianjin, Shanxi, Guangdong, Liaoning, and Hubei. Regression analyses are conducted on the historical instrumental variables for each of the two explained variables in these selected samples. As depicted in Supplementary Table A3, we observe that the coefficients of the instrumental variable are nearly zero in both models. Therefore, this estimation suggests that in regions with a high level of secularization, there exists no significant correlation between the number of places of worship in 1820 and contemporary rural household energy poverty. Hence, the falsification test suggests that the historical instrumental variable is reasonably dependable.

The estimated results using the historical instrumental variable are presented in Table 3. Similar to the baseline regression findings, we observe that the coefficients of the core explanatory variables are positive and statistically significant for both accessible and affordable energy poverty, suggesting the robustness of our results.

The policy shock of full coverage of rural areas in China in 2014. With the achievement of full electricity coverage in rural China in 2014, we augment the baseline model by incorporating the interaction term between the year 2014 and the religious belief variable. The estimated results are presented in Table 4. In Table 4, column (2) displays a negative coefficient for the interaction term, signifying that the policy implemented in this year mitigates availability energy poverty. Furthermore, in column (4) of Table 4, although the coefficient of the interaction term is negative, it lacks statistical significance. This suggests that the policy intervention in 2014 does not exert a significant influence on affordability energy poverty. These estimates further corroborate the findings of this paper. On the one hand, with full electricity grid coverage in rural areas, residents encounter no

physical obstacles in accessing clean energy. Consequently, accessibility energy poverty is mitigated to a certain degree. On the other hand, despite the attainment of electricity coverage, rural residents in China still face the expense associated with electricity in contrast to non-commodity energy sources like firewood, indicating that the impact of the 2014 policy shock on the affordability of energy poverty is relatively weak.

Further identification based on unobserved-factor heterogeneity. Leveraging insights from a recent study addressing endogeneity concerns (Churchill and Smyth 2022), we employ an alternative approach proposed by Lewbel (2012) to enhance the robustness of our estimation results. Specifically, this method is applied in scenarios where endogeneity arises due to unobserved-factor heterogeneity, and external valid instruments are unavailable. Consequently, the products of exogenous covariates and heteroskedastic errors can be utilized as valid instruments to identify the parameters of the endogenous variable, thereby constituting internally generated instruments. The estimation results are presented in Table 5. Firstly, we observe heteroscedasticity in the models for both accessible and affordable energy poverty, as evidenced by the rejection of the null hypothesis in both the BP test and White test. Secondly, the marginal effect values of interest are 0.936 and 0.047 at the 1% significance level, which closely resemble the estimated coefficients of the instrumental variable regression results presented in Table 1. Hence, this further underscores the relative robustness of our estimation results.

Table 4 The estimates of the policy impact of achieving full rural electrification coverage in 2014.

Variables	Accessibility		Affordability	
	(1) Probit	(2) IV-Probit	(3) Tobit	(4) IV-Tobit
Religion *2014	-0.089*** (0.029)	-0.695*** (0.206)	-0.022*** (0.008)	-0.045 (0.034)
Religion	0.070*** (0.020)	0.694*** (0.213)	0.021*** (0.008)	-0.045 (0.034)
Control variables	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Regional-fixed effects	Yes	Yes	Yes	Yes
Observations	13,773	13,773	13,773	13,773

The values in the table are marginal effects. Standard errors are in parentheses (clustered at the household level).
***p < 0.01; **p < 0.05; *p < 0.1.

Table 5 Robustness check based on heteroscedasticity identification with internally generated instrument.

Variable	Accessibility (1)	Affordability (2)
Religion	0.936*** (0.005)	0.047** (0.020)
Control variables	Yes	Yes
Regional fixed	Yes	Yes
Breusch-Pagan test for heteroskedasticity	21.05***	12149.06***
White test for heteroskedasticity	1536.41***	3564.01***
Observations	13,773	13,773

The values in the table are marginal effects. Standard errors in parentheses.
***p < 0.01; **p < 0.05; *p < 0.1.

Heterogeneity analysis. Research investigating the relationship between energy poverty and gender has garnered significant attention (Listo 2018; Moniruzzaman and Day 2020; Sanchez et al. 2020). In column (1) of Table 6, we observe a significantly positive coefficient for the interaction term between religious beliefs and gender, indicating that religious men, relative to women, are more prone to experiencing energy poverty based on accessibility. One plausible explanation is that men typically assume the role of household heads and exert influence over their households' energy preferences. In rural China, energy choices are predominantly made at the household level, where women typically do not hold the position of household heads. Women play a crucial role as users of fuels and specific energy services, particularly for cooking and heating. However, they often lack the bargaining power to make energy-related decisions, encompassing both purchasing and usage decisions (Fingleton-Smith 2018; Pachauri and Rao 2013). However, from the affordability perspective, there is no significant disparity in the impact of religion on energy poverty between men and women.

Inequality in energy services stemming from racial or ethnic disparities has garnered academic attention (Churchill and Smyth 2020; Reames 2016). In column (2) of Table 6, the interaction coefficient between religious beliefs and ethnic minorities is positively significant at the 1% level, indicating that believers in ethnic minorities are more susceptible to experiencing energy poverty compared to the Han nationality, the predominant ethnic

Table 6 Heterogeneity analysis.

	Accessibility			Affordability		
	(1)	(2)	(3)	(4)	(5)	(6)
Religion	-0.414*** (0.132)	-0.198*** (0.080)	-0.744*** (0.167)	-0.017*** (0.003)	-0.020*** (0.004)	-0.145*** (0.029)
Religion*Sex	0.961*** (0.278)			0.071 (0.049)		
Religion*Ethnicity		0.935*** (0.298)			0.092 (0.068)	
Religion*L_income			1.228*** (0.256)			0.254*** (0.045)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Wald test of exogeneity	6.75***	2.14*	8.84***	1.42	7.17***	13.19***
Observations	13,773	13,773	13,773	13,773	13,773	13,773

The instrumental variable of the endogenous cross-product term is IV*heterogeneity variable. Standard errors in parentheses.
***p < 0.01; **p < 0.05; *p < 0.1.

Table 7 Mechanism analysis results.

Panel A: the mediating effect of religious belief on accessibility energy poverty				
	(1)	(2)	(3)	(4)
Religion	L_income 0.048*** (0.012)	Accessibility 0.033*** (0.012)	Education -0.240*** (0.069)	Accessibility 0.039*** (0.013)
L_income		0.114*** (0.008)		
Education				-0.020*** (0.002)
Control variables	Yes	Yes	Yes	Yes
Observations	13,971	13,971	11,435	11,435
Sobel	0.005*** (0.001)		0.005*** (0.001)	
Panel B: the mediating effect of religious belief on affordability energy poverty				
	(1)	(2)	(3)	(4)
Religion	L_income 0.048*** (0.012)	Affordability 0.012*** (0.004)	Education -0.240*** (0.069)	Affordability 0.009** (0.004)
L_income		0.071*** (0.003)		
Education				-0.007*** (0.001)
Control variables	Yes	Yes	Yes	Yes
Observations	13,971	13,971	11,435	11,435
Sobel	0.003*** (0.001)		0.002*** (0.001)	

Standard errors in parentheses.
***p < 0.01; **p < 0.05; *p < 0.1.

group in China. This observation aligns with the findings of Reames (2016) for the US, which reveal that ethnic minorities (Black and Hispanic) are more prone to experiencing energy poverty. One potential explanation is that ethnic minorities in rural China may exhibit stronger religious tendencies, leading to a greater impact on energy poverty. Another plausible explanation is that ethnic minorities in rural China often reside in mountainous regions abundant in solid fuel resources (e.g., firewood and animal dung), thus predisposing them to rely more on non-clean energy sources.

Economic poverty and energy poverty are closely intertwined, with low income being a direct driver of energy poverty in rural China (Lin and Zhao 2021). In column (3) and column (6) of Table 6, the coefficients of the cross-terms between “Religion” and “L_income” are statistically significant at the 1% level, suggesting that low-income groups are also disproportionately affected by energy poverty in both accessibility and affordability. As anticipated, on the one hand, low-income households are primarily concerned about the cost of energy. Non-clean energy sources, such as crop straw, often come at a minimal cost or even no additional expense. On the other hand, lower incomes naturally contribute to affordability energy poverty. Our findings align with those of Mi et al. (2020), who demonstrate variations in the carbon footprint across income groups in China. Higher-income households typically exhibit more modern lifestyles and consequently have larger carbon footprints. Moreover, these households are inclined to consume more clean energy and low-carbon products. Consequently, the impact of religious belief on energy poverty is more pronounced in low-income families.

Mechanism analysis

We have demonstrated that religion positively influences energy poverty, but it is essential to investigate the mechanisms through

which religious beliefs affect energy poverty further. As depicted in Supplementary Table A1, we introduce two mediating variables. We explore the pathways of low income and education. Table 7 presents the results of the mechanism tests for low income and education. Panel 1 displays the outcomes concerning accessibility energy poverty, while panel 2 exhibits the results pertaining to affordability energy poverty.

Low income. Generally, energy poverty and poverty are intertwined, with poverty (inadequate household income) serving as the primary cause of energy poverty (Halkos and Gkampoura 2021). In both panel A and panel B, the Sobel values in column (1) are significant at the 1% level, suggesting that low income serves as the mediating variable through which religious belief influences energy poverty. Furthermore, we observe that religious beliefs significantly elevate the likelihood of low income, which amplifies the probability of energy poverty (see column (1) and column (2)). These results suggest that low income serves as the mechanism through which religion influences energy poverty. It should be noted that China is a predominantly secular country, lacking a widespread religious environment with universal values, and consequently, religion does not offer many positive aspects for residents. Despite a recent study showing that religious individuals report higher levels of happiness, religious affiliation also tends to reduce people’s income (Bentzen 2021). The impact of religion on low income can be elucidated through four main factors. Firstly, the involvement of religious individuals in religious activities, such as attending church, often reduces their working hours, resulting in lower incomes, particularly among the devout. Secondly, individuals may prioritize seeking God’s blessings and comfort through religion rather than pursuing material prosperity. For instance, religious individuals may be

Table 8 The impact of religious activity participation density on energy poverty.

	Accessibility		Affordability	
	(1)	(2)	(3)	(4)
R_activity	Probit 0.001*** (0.000)	Heteroscedasticity 0.002*** (0.000)	Tobit 0.001** (0.000)	Heteroscedasticity 0.001** (0.000)
Control variables	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Regional-fixed effects	Yes	Yes	Yes	Yes
Breusch-Pagan test for heteroscedasticity		15.42**		24.88***
Observations	13,773	13,773	13,773	13,773

Standard errors in parentheses (clustered at the household level).
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

more inclined to remain in their hometowns rather than migrate in search of employment, despite the potential for higher incomes from off-farm work compared to agricultural activities. Thirdly, religious beliefs may hinder the development of social capital, particularly trust (Ampofo and Mabefam 2021). Individuals who adhere to religious beliefs often find solace and trust in their faith, leading to decreased trust in individuals outside of their religious community. Consequently, religious beliefs diminish trust levels within communities, thereby decreasing the likelihood of accessing income, public goods, and opportunities. Fourthly, believers often donate generously to their religious institutions, believing that their contributions will enhance their well-being in the afterlife, thereby imposing constraints on their economic conditions. Consequently, religious beliefs heighten the risk of poverty, diminish people's income, and hinder their ability to access clean energy, consequently leading to energy poverty.

Education. The Sobel values in column (3) of both Panel A and Panel B are significant at the 1% level, suggesting that education serves as the mediating variable through which religious belief influences energy poverty. Additionally, there is a negative correlation between religious affiliation and years of education, coupled with a positive correlation between educational attainment and energy poverty (refer to column (3) and column (4)). In rural China, individuals who adhere to religious beliefs are less inclined to pursue further education and tend to have lower levels of educational attainment. Moreover, religious beliefs undergo significant intergenerational transmission; hence, when parents adhere to a particular religion, their children are more likely to adopt the same beliefs during their upbringing, exacerbating the lack of educational opportunities associated with religious beliefs.

In rural and remote areas, individuals who adhere to religious beliefs typically exhibit lower levels of education, which in turn contributes to energy poverty (Chiswick 1983; Glaeser and Sacerdote 2008; Tomes 1984). In terms of accessibility, education plays a crucial role in mitigating energy poverty as higher levels of education enhance residents' capacity to utilize modern kitchen appliances and heating systems (e.g., induction cooktops, microwave ovens, and air conditioners). Moreover, education can enhance people's awareness of environmental conservation, particularly concerning the use of clean fuels. Regarding affordability, higher education is perceived to enhance human capital with greater economic returns (Schultz 1961). Religious beliefs result in lower educational attainment among rural residents, consequently reducing their economic incomes. Reduced economic income directly contributes to affordability-based energy poverty. Hence, education emerges as the primary mechanism through which religious beliefs influence energy poverty.

Further discussion

Frequency of religious activities undertaken and energy poverty. We have examined the influence of religious affiliation on energy poverty through baseline regression analysis and have determined that religious individuals are more susceptible to experiencing energy poverty compared to non-religious individuals. Moreover, the frequency of religious activities reflects the depth of religious convictions. Leveraging insights from a recent study by Ampofo and Mabefam (2021), which investigates the relationship between religious intensity and energy poverty at the national level, we utilize the annual frequency of religious activities as a proxy for religious intensity. Table 8 illustrates that each additional religious activity corresponds to a 0.1% rise in the probability of energy poverty, as indicated by the Probit model for accessibility and the Tobit model for affordability (column (1) and column (3)). Nonetheless, the frequency of religious participation serves as an endogenous variable. To enhance the robustness of our findings, we apply the approach proposed by Lewbel (2012) to address endogeneity. Particularly, this method is employed in situations where endogeneity arises due to unobserved-factor heterogeneity, yet a valid external instrument is unavailable. Hence, the product of the central exogenous covariate and the heteroscedasticity error can serve as a potent instrument for identifying an endogenous variable.

Column (2) and column (4) present the results of the regression conducted using Lewbel's method. It is observed that for each additional religious activity, the probability of experiencing energy poverty increased by 0.2% and 0.1% for accessibility and affordability, respectively. Our finding aligns with that of Ampofo and Mabefam (2021), who demonstrate that increased intensity of religious activity attendance correlates with higher levels of energy poverty.

Three major religions on energy poverty. China exhibits a relatively diverse religious atmosphere, with no single religion holding overwhelming dominance. Presently, Buddhism, Protestantism, and Islam stand as the three largest religions, which are also among the world's major religions. While Eastern and Western religions share some commonalities in explaining the world, fostering settlement, regulating behavior, and impacting society, disparities exist in how religious beliefs influence individual and familial conduct. For instance, empirical studies indicate that varying religious beliefs yield distinct effects on individual economic behavior (Benjamin et al. 2016). Accessibility energy poverty reflects household energy choice behavior. Thus, we seek to analyze the distinct impacts of the three major religions on accessibility energy poverty. Table 9 presents our analysis, wherein we restrict the sample to religious groups and examine the effects of the three major religions on accessibility energy

Table 9 The marginal effect of three major religions on accessibility energy poverty.

	(1)	(2)	(3)
Protestantism	0.035 (0.030)		
Buddhism		-0.079*** (0.026)	
Islam			0.364*** (0.052)
Control variables	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes
Regional-fixed effects	Yes	Yes	Yes
Pseudo R ²	0.273	0.277	0.304
Observations	1893	1893	1893

Standard errors in parentheses (clustered at the household level).
 ***p < 0.01; **p < 0.05; *p < 0.1.

poverty. Intriguingly, the coefficients associated with belief in Protestantism fail to achieve statistical significance in relation to accessibility energy poverty (see column (1)). Next, we investigate the influence of Buddhism on poverty and find a coefficient of -0.079, significant at the 1% level (see column (2)). This indicates that belief in Buddhism decreases the likelihood of energy poverty, albeit with a relatively modest coefficient. Lastly, compared to other religions, the Islamic group exhibits a relatively high probability of experiencing energy poverty, evidenced by a coefficient of 0.364, significant at the 1% level (see column (3)). These findings align with those of the baseline regression.

Believers in Buddhism exhibit a decreased likelihood of experiencing accessibility energy poverty, suggesting a propensity towards clean energy usage. We provide insights into this intriguing phenomenon. On the one hand, in contrast to the debate surrounding the environmental impact of Western religions, scholarly investigations into the traditional wisdom of Eastern religions have largely concluded that an eco-friendly worldview is intrinsic to Buddhism (Ching 2016; Jenkins 2002). Woodhouse et al. (2015) identify two key factors contributing to Tibetan Buddhism’s favorable environmental stance based on field studies conducted in Tibetan regions of Sichuan Province, China, where Buddhism holds sway. Firstly, adherents of local religions intertwine deities with nature, venerating “sacred natural sites.” Secondly, the prohibition of killing animals and plants is regarded as a sin, carrying karmic consequences. On the other hand, local religions are officially endorsed as a means to foster ecological consciousness within Chinese society. The NRAAC has advocated for the concept of an “ecological temple”, which serves as a catalyst for ecological protection and education. Furthermore, the Chinese government regards traditional Chinese religion as a potent remedy for the nation’s environmental challenges (Pan 2016). Additionally, findings from the 2012 wave of the China Family Panel Studies (CFPS) reveal that Buddhists exhibit higher levels of education compared to adherents of foreign religions like Christianity. Increased education levels among believers correlate with greater awareness of indoor pollution’s health implications and a higher propensity to utilize modern kitchen appliances, thereby favouring clean energy adoption. Muslim households exhibit a higher propensity to experience energy poverty. This tendency can be attributed to Islam’s relatively conservative nature, particularly prevalent among ethnic minorities in rural China. Islam exhibits robust intergenerational transmission and familial continuity, often resulting in entire households adhering to the faith. Furthermore, the conservative norms within Islam contribute to the lower status of women, limiting their access to education and

opportunities for employment outside the home. Consequently, women primarily shoulder household responsibilities such as cooking and heating (Jaschok and Chan 2009). Protestantism, introduced relatively recently to China and considered a foreign religion, exerts minimal influence on family energy choices due to its limited intergenerational transmission and familial impact compared to indigenous religions.

Conclusions and remarks

Over the last two decades, China has experienced a profound economic metamorphosis and has earnestly endeavored to narrow the urban-rural disparity. Notably, in 2014, the nation accomplished universal electricity grid coverage. Nevertheless, empirical inquiries into rural energy poverty in China have unearthed a divergence: Despite income escalation, rural residents’ energy preferences do not conform to the conventional energy ladder theory (Han and Wu 2018; Niu et al. 2012). Thus, it becomes imperative to scrutinize factors beyond economic dimensions that contribute to energy poverty in rural China. In China’s rural areas, religious beliefs influence people’s ideologies and lifestyle choices to some extent. However, the relationship between religious beliefs and energy poverty in rural China remains poorly understood, including whether the impact is positive or negative. To address this knowledge gap, our study investigates the influence of religious beliefs on energy poverty in rural China. The primary findings are outlined below.

Our findings indicate that religious beliefs are associated with a higher likelihood of energy poverty, affecting both accessibility and affordability. In essence, religious beliefs hinder the energy development of rural communities. This result aligns with the recent study by Ampofo and Mabefam (2021), which also highlights the adverse impact of religious beliefs on energy poverty globally. Furthermore, our analysis of heterogeneity reveals that the influence of religious beliefs on energy poverty is particularly pronounced among males, ethnic minorities, and low-income individuals.

Our analysis identifies low income and education as pathways through which religious beliefs contribute to energy poverty. Firstly, low income serves as the principal mechanism linking religious beliefs to energy poverty. Religious individuals may seek solace and blessings from their deities, potentially perpetuating a cycle of “religion-sustenance-poverty”. Additionally, religious adherence often correlates with lower levels of trust in non-religious community members. In China, a secular nation, this lack of trust can diminish job prospects, access to public goods, and subsidies. Furthermore, donations made by devout individuals to churches can exacerbate their poverty. Secondly, education, serving as a mediator between religious beliefs and economic development (Squicciarini 2020), functions as an intermediary mechanism connecting religious beliefs to energy poverty. Religious beliefs curtail educational opportunities for rural residents, thereby exacerbating energy poverty. A lack of education diminishes residents’ capacity to adopt modern energy solutions, contributing to accessibility energy poverty. Furthermore, lower educational attainment correlates with reduced income, heightening the likelihood of affordability energy poverty. Additionally, our further analysis reveals a positive correlation between frequency of religious activities and energy poverty, enhancing the credibility of our research findings. Moreover, we observe divergent effects of different religions on energy poverty, with individuals adhering to Islam exhibiting a higher likelihood of experiencing accessibility energy poverty.

Based on these findings, we derive the following policy insights concerning energy poverty in rural China from a religious perspective. While the Chinese government upholds religious

freedom, enabling individuals to utilize religion as a means to enhance their welfare, certain rural areas witness a significant portion of living expenses allocated towards religious consumption and donations during religious festivals and activities. Hence, it becomes imperative, above all, to steer religious adherents towards cultivating a prudent concept of religious consumption. Avoiding poverty becomes a prerequisite for overcoming energy poverty. Secondly, policymakers should promote the integration of religions with modernity and technology. In the digital era, religions have increasingly embraced technology, enhancing the skills and perspectives of their followers. For instance, Chinese Buddhist leader Yongxin Shi visited Meta, an American Internet technology company, to discuss and explore the potential synergy between Zen philosophy and artificial intelligence³. Embracing technology encourages believers to enhance their literacy and skills, leading to better job opportunities and higher income. Ultimately, this fosters improved cognitive abilities and affords the capacity to invest in new energy facilities and clean energy sources. Thirdly, leveraging the ecological role of religion to alleviate energy poverty is crucial. Literature suggests that while religious belief in China may not always promote individual environmental behaviors, it can contribute positively to public environmental initiatives (Yang and Huang 2018). Therefore, religions should educate the public about the detrimental effects of unclean energy on the environment, encouraging believers to adopt and promote the use of clean energy. Once clean energy practices are embraced by believers, their peer influence can be significant, potentially leading to spillover effects on non-believers in rural areas. Finally, policymakers should prioritize addressing energy poverty among vulnerable groups. In rural areas, economically disadvantaged and ethnic minority groups are particularly vulnerable to energy poverty. Thus, the government should continue its efforts in targeted poverty alleviation, while also deepening reforms of the rural energy market system and prioritizing investment in clean energy infrastructure in ethnic minority areas.

Data availability

Please request access to the raw data from the official website of China Labor-force Dynamics Survey: <http://css.sysu.edu.cn>, and official email: cssdata@mail.sysu.edu.cn.

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Notes

- China's official national rural poverty standard is defined as a per capita annual net income of less than 2300 CNY (in 2010 constant prices). Source: https://en.wikipedia.org/wiki/Poverty_in_China.
- Energy poverty is defined as energy expenditure divided by the total income (ratio) greater than 10%.
- https://www.laitimes.com/en/article/65id9_6luod.html.

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JD: conceptualization, methodology, resources, writing—original draft. YR: conceptualization, supervision, writing—review, and editing. TG: supervision, writing—review, and editing. All authors read and approved the final manuscript.

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Competing interests

The authors declare no competing interests.

Ethical approval

There are no experiments on humans and/or the use of human tissue sample included in this study. We got the administrative permissions to access the raw data used in this study from the Center for Social Science Survey at Sun Yat-sen University. All methods are carried out in accordance with relevant guidelines and regulations of the Declaration of Helsinki.

Informed consent

The data used in this paper comes from the survey conducted by Sun Yat-sen University, which is a large-scale, anonymous survey at the national level with the informed consent of every participant.

Additional information

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