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Energy poverty and subjective well-being in China: New evidence from the China Family Panel Studies

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ABSTRACT

Using the 2012–2018 waves of the China Family Panel Studies, we investigate the impact of energy poverty (EP) on subjective well-being (SWB) among Chinese adults aged 18 and over. In addition to documenting EP rates in the range of 13.2% to 35.3% (dependent on measurement used), we show that EP leads to higher levels of depression. These results are robust to both alternative EP and SWB measures and to a series of estimation approaches that control for endogeneity. Structural equation modeling of the underlying mechanisms shows that individual self-reported health and household food expenditure mediate the EP-SWB relation.

1. Introduction

Not only has subjective well-being (SWB) long been a research focus in multiple social sciences, including psychology and economics (Clark, 2018; Diener, 2000; Dolan et al., 2008; Helliwell, 2003), but the 2021 World Happiness Report ranking of average national life evaluations in 149 countries (Helliwell et al., 2021) underscores the importance of SWB worldwide. It is therefore unsurprising that researchers increasingly advocate the use of SWB measures to assess the efficacy of public policies and quantify human progress through economic and social development (Diener et al., 2009; Diener and Seligman, 2018; Helliwell and Huang, 2014). A serious impediment to such development, however, is energy poverty (EP),[1] a lack of access to such modern energy services as electricity and clean cooking facilities (i.e., nonpolluting fuels and stoves, advanced biomass stoves, and biogas systems) (International Energy Agency (IEA), 2010). The United Nations Sustainable Development Goal seven (SDG 7) underscores the "access to affordable, reliable, sustainable, and modern energy for all" (United Nations, 2021). The fraction of the world population with access to electricity increased from 83% in 2010 to 90% in 2018. During the same time period, the proportion of the world population with clean cooking fuels and technologies increased from 56% to 63% (United Nations, 2021). Nevertheless, in 2018, 789 million people lacked electricity, and over 2.8 billion people did not have access to clean cooking fuels and technologies (United Nations, 2021). It is projected that 620 million people would still lack access to electricity, and 2.3 billion be deprived of access to clean cooking fuels and technologies in 2030 (United Nations, 2021). The resulting household air pollution is expected to engender over 1.5 million premature deaths annually, far more than from malaria, tuberculosis, or HIV/AIDS (International Energy Agency (IEA), 2010). Improving the poor's access to modern energy sources, therefore, could greatly improve their welfare while also serving as a catalyst for human developmental progress (Pachauri et al., 2004; World Bank, 2000; Zhang et al., 2019).

Although a large body of literature addresses the major SWB determinants of age (Bauer et al., 2017; Bittmann, 2020; Blanchflower and Oswald, 2008), gender (Inglehart, 2002; Tesch-Römer et al., 2008), income (Deaton, 2008; Diener and Biswas-Diener, 2002; Easterlin, 1995; Frijters et al., 2004), wealth (Lindqvist et al., 2020; Schyns, 2002), unemployment (Binder and Coad, 2015; Winkelmann, 2009), health

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[1] Because China's energy poverty has features of both fuel poverty and energy poverty (see Li et al., 2014, for a detailed discussion), the term "energy poverty" as used in this paper combines both concepts.

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(Gwozdz and Sousa-Poza, 2010; Herman et al., 2013), social capital (Bjørnskov, 2003; Kroll, 2011), religion and culture (Diener and Diener, 2009; Lim and Putnam, 2010; Schimmack et al., 2002; Tov and Diener, 2009), the evidence on how EP affects SWB remains scarce, especially in developing countries (Awaworyi Churchill et al., 2020). China offers an especially interesting case for filling this void because despite an unprecedented 1978–2019[2] increase in per capita GDP from 385 yuan to 70,725 yuan and a mushrooming urbanization rate from 18% to 61% (National Bureau of Statistics, 2020), an estimated 18.9% of Chinese are energy poor (Lin and Wang, 2020). At the same time, however, in contrast to the limited electricity availability in other developing nations (Lin and Wang, 2020), China has enjoyed 100% electricity access since 2013 (World Bank, 2020), with a per capita electricity consumption that surpasses the average in upper-middle income countries. Nonetheless, because China's resource distribution is unequal, its energy consumption unsustainable, and energy expenditures high, EP may still hinder progress in boosting citizen well-being, thereby impeding the nation's realization of its medium and long-term goals for social economic development (Wang et al., 2015).

Our paper contributes to the literature on EP-SWB relations in several important ways. In addition to being one of the first to investigate this relation among Chinese adults using nationally representative longitudinal data (i.e., the 2012–2018 China Family Panel Studies, (CFPS)), our study's rich set of EP measures yields a far broader picture of the EP-SWB linkage than currently available. To the best of our knowledge, only one recent study, using 2014–2018 CFPS data, confirms that EP reduces SWB in Chinese 10 to 15-year-olds (Zhang et al., 2021). Our study, however, is different from the work of Zhang et al. (2021) in three ways: First, Zhang et al. (2021) focus on how EP affects SWB of adolescents aged 10–15 year old, while we focus on adults aged 18+ (across most of the adult lifespan). Second, besides the cross-sectional design in Zhang et al. (2021), we make full use of CFPS's panel setting. Third, unlike Zhang et al. (2021)'s work that uses happiness as the main positive SWB measure, we mainly focus on the negative measures of SWB (i.e. depression index and depressive symptoms). As such, we extend prior work by employing both positive (life satisfaction) and negative (depression and depressive symptom) SWB measures to produce a more differentiated picture of the EP-SWB nexus. It is worth highlighting that most studies use positive measures of SWB such as life satisfaction (see, e.g. Biermann, 2016; Druică et al., 2019), however, we are unaware of any studies that use negative measures like depression. As one of the most populous developing countries, China has undergone both rapid economic growth and epidemiological transition from communicable to noncommunicable diseases (Nie et al., 2019). Depression is a common mental disorder in China and approximately 14.7% of total individual medical expenditures are a result of depression and depressive symptoms (Hsieh and Qin, 2018). Thus, depression places a heavy economic burden on Chinese society (Que et al., 2019). The introduction of depression in our study would thereby deepen our understanding of the potential impact of EP on mental well-being. Finally, rather than focusing solely on the impact of EP on SWB, we examine potential mediators in the EP-SWB association by employing a structural equation modeling (SEM) approach that introduces health and food expenditure as intervening variables. In doing so, we provide useful insights on the potential mechanisms through which EP operates on SWB.

The remainder of the paper is organized as follows: Section 2 reviews the relevant literature on EP measures and the EP-SWB relation, section 3 documents the possible heuristic mechanisms of the EP impact on SWB in China, and section 4 describes the dataset and empirical strategy. Section 5 then reports the results, after which section 6 concludes the paper with a discussion of major findings and their implications for policy.

[2] Following the 1978 Reform and Opening-Up Policy.

2. Relevant literature

2.1. EP measurement

Because a current lack of any unified definition of EP has prevented the development of generally accepted methods for measuring it, researchers tend to proxy it in several ways. After Lewis (1982) defined the first single indicator EP measure as household inability to afford adequate warmth, Boardman (1991) narrowed it to a total household fuel expenditure over 10% of income, with the 10% threshold being approximately twice the median energy expenditure (Liddell et al. 2012). Although Boardman (2010) later simplified his definition to household inability to afford adequate energy services, much recent literature (see, for instance, Awaworyi Churchill and Smyth, 2021; Awaworyi Churchill et al., 2020; Li et al., 2014; Lin and Wang, 2020) adopts Hills (2011) "low income high cost" (LIHC) measure, which combines residual income below the poverty line with basic energy requirement costs above the social average. Specifically, EP is defined as whether residual household income is below the official poverty line while basic energy costs for household living needs are higher than the average (Hills, 2011). This relative measure thereby rules out the inclusion of high-income and high-consumption households (Li et al., 2014).

Also popular in the EP literature are composite indices that incorporate several individual EP measures, such as the International Energy Agency (IEA) (2010) Energy Development Index (EDI), which comprises five indicators, namely, share of population with access to electricity, per capita commercial household energy consumption, per capita public sector electricity consumption, share of commercial energy to total final energy use, and share of productive energy to total final energy use. The EDI is particularly suitable for macrodata and regional comparative assessments (Lin and Wang, 2020). Another commonly used tool, the Multidimensional Energy Poverty Index (MEPI) (Nussbaumer et al., 2012), focuses specifically on deprivation of access to modern energy services, including modern cooking fuel, electricity, home appliances, entertainment, educational equipment, and communication tools (Li et al., 2014; Lin and Okyere, 2021; Lin and Wang, 2020).

Given the frequent unavailability of reliable EP macrodata for China, the extant literature on Chinese EP is limited and based primarily on microdata (Lin and Wang, 2020). For example, Jiang et al. (2020) draw on household survey data from rural Qinghai to identify a 57% EP rate in this area, while Tang and Liao (2014) use 2000 and 2010 national census data to document a dependency on solid cooking fuels in over 75% of all rural residents, with few rural households using clean alternatives. Wang et al. (2015) employ regional data to develop their own composite EP measure, which confirms a declining trend in EP from 2000 to 2011, although with large regional heterogeneities. Most relevant for our study, Zhang et al. (2019) use 2012–2016 CFPS household-level data to construct a composite EP measure of energy affordability and accessibility, which indicates improved EP during this period. In a subsequent study that applies the MEPI and 10% EP measure to 2014–2018 CFPS data, they further document that 3.1%, 3.5%, 23.9%, and 44.4% of those surveyed have no access to TV, mobile phones, refrigerators, and clean cooking fuels, respectively (Zhang et al., 2021).

2.2. Impact of EP on SWB

Although a small body of extant research on the EP-SWB linkage provides evidence of EP's detrimental effect on SWB, this corpus focuses almost exclusively on developed nations; most notably, Europe (see, e.g. Biermann, 2016; Mayer and Smith, 2019; Rodriguez-Alvarez et al., 2019; Thomson et al., 2017; Welsch and Biermann, 2017). For example, Welsch and Biermann (2014), drawing on data from 2002 to 2011 European Social Survey (ESS), find that a greater share of solar and wind power relative to nuclear power and electricity from coal and oil is linked with greater SWB in 25 European countries. Biermann (2016),

using 1984–2013 German Socioeconomic Panel (GSOEP) data, documents a significantly negative EP effect that Welsch and Biermann (2017) and Mayer and Smith (2019) also identify based on ESS data. Similarly, Druică et al. (2019), drawing on data from the 2016 Life in Transition Survey (LITS), shows that EP has a negative impact on life satisfaction in Central and Eastern European countries. Likewise, Thomson et al. (2017), employing 2012 European Quality of Life Survey (EQLS) data for 32 countries, link EP with poor SWB across Europe, but particular in the Eastern and Central areas, an observation confirmed by Robić and Ančić (2018) using data from 394 Croatian households, and Rodriguez-Alvarez et al. (2019) using 2013 Spanish Life Condition Survey (SLCS) data. Similarly, Deluga and Brau (2018) use data from the Italian version of the Survey on Income and Living Conditions and find that being energy poor at the highest severity level reduces by approximately one third the likelihood of being satisfied with life. More recently, Awaworyi Churchill et al. (2020), drawing on 13 waves of the Household, Income and Labour Dynamics in Australia (HILDA) survey, further show that EP lowers SWB dimensions such as life satisfaction.

Overall, several aspects of the existing literature on EP-SWB linkage are worth highlighting: First, most studies originate in developed countries, especially Europe, and provide strong evidence of a negative effect of EP on SWB. However, although EP has remained a key development issue, evidence for the EP-SWB relation in less-developed countries is very limited. Second, most extant studies focus on how EP affects positive aspects of SWB, in particular, life satisfaction. Yet, as Kahneman and Deaton (2010) underscore, life satisfaction refers to thoughts and feelings about life, and serves as a long-term measure of SWB (Pénard et al., 2013). As the commonly used negative measure of SWB, the rising prevalence of depression is not only a global public health concern but a significant concern for economic development and social welfare (Hsieh and Qin, 2018). Due to its rapid economic development and lifestyle changes in the past decades, China is now facing the challenge of a growing prevalence in depressions, which has become one of the leading causes of disability-adjusted life years in China (Hsieh and Qin, 2018; Phillips et al., 2009). Although the number of people with mental illness increases sharply, little is known about the impact of EP on depression. Our study aims to fill this gap by investigating the effect of EP on depression and depressive symptoms among Chinese adults. Finally, although most of the literature on the EP-SWB relation reports a clear negative association between EP and SWB, quite few studies have explored possible pathways through which EP operates on SWB with the exception of Druică et al. (2019) for Central and Eastern Europe and Zhang et al. (2021) for China. As such, our paper aims to extend this evidence through a comprehensive analysis of 2012–2018 CFPS data that both confirms the EP-SWB linkage and explores the potential mechanisms underlying this nexus.

3. Potential pathways for the EP impact on SWB

A burgeoning body of literature has examined the relationship between EP and health (see, for instance, Awaworyi Churchill and Smyth, 2021; Kahouli, 2020; Lacroix and Chaton, 2015; Llorca et al., 2020; Oliveras et al., 2020; Robić and Ančić, 2018; Zhang et al., 2019). For instance, Lacroix and Chaton (2015) find that experiencing EP (measured by self-reported perception of thermal discomfort) increases the likelihood of reporting poor health by 2.36% in France. Likewise, Robić and Ančić (2018) show that EP is associated with poorer health conditions among 394 Croatian households. This finding is reinforced by Kahouli (2020), showing that both objective and subjective EP[3] contributes to a lower probability of reporting good or very good SRH in France. Similarly, Oliveras et al. (2020) also shows that EP is significantly and positively associated with poor SRH in 27 European countries. This observation is further confirmed by Awaworyi Churchill and Smyth (2021), indicating that both objective and subjective indicators of EP lower SRH in Australia. Recently Banerjee et al. (2021) also shows that lower EP is correlated with higher life expectancy in 50 developing countries. In the case of China, Zhang et al. (2019) shows that EP decreases the likelihood of reporting good SRH. Additionally, the existing literature has consistently confirmed that better health enhances SWB (see several review studies, Clark, 2018; Deaton, 2008; Dolan et al., 2008; Frey and Stutzer, 2002). Based on all the above observations, we formulate the following hypothesis:

Hypothesis 1. *EP negatively affects SWB through health.*

The inability of poor households to access or afford both adequate nutrition and energy services leads to the "heat or eat" dilemma, which forces them to make tradeoffs (Anderson et al., 2012; Nord and Kantor, 2006). For example, among poor households in the UK, a temperature just two or more standard deviations (SD) colder than expected leads to a significant reduction in food spending (Beatty et al. (2014). Not only are these forced basic needs tradeoffs stressful, but reduced food expenditure frequently leads to decreased nutrient intake (Lee and Frongillo Jr, 2001; Park and Eicher-Miller, 2014), especially during the high-energy demand seasons of winter and summer (Nord and Kantor, 2006). As a result, household members of all ages are more likely to report poor health (Gundersen and Kreider, 2009; McIntyre et al., 2013). In particular, forced food expenditure reduction increases the risk of diabetes (Berkowitz et al., 2015; Fernández et al., 2018), hypertension (Stuff et al., 2004), hyperlipidemia (Seligman et al., 2010), and heart disease (Vozoris and Tarasuk, 2003), as well as declines in SWB factors like life satisfaction (see, for instance, Deleire and Kalil, 2010; Dumludag, 2015). In addition to diagraming the above factors as a simple heuristic of possible mechanisms for the EP impact on depression in China (see Fig. 1), we formalize the EP-food expenditure relation as our second hypothesis:

Hypothesis 2. *EP negatively affects SWB through food expenditure.*

It is, however, worth highlighting that due to data availability, we focus only on these two possible mechanisms. However, it is highly possible that there are other pathways through which EP operates on SWB. For instance, Zhang et al. (2019) find that academic performance is an important pathway through which EP lowers children's SWB in China. In addition, Druică et al. (2019) confirm that beside SRH, satisfaction with socioeconomic status (SES)[4] also mediates the relationship between EP and life satisfaction in 13 Central and Eastern European countries.

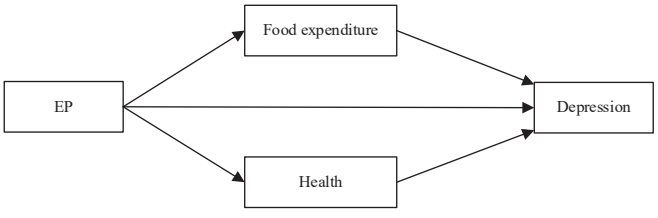

Fig. 1. Heuristic of potential mechanisms of the EP impact on depression.

[3] Use the 10% indicator as the objective EP measure and the difficulty that a household can encounter to heat its dwelling because of financial constraints or dwelling characteristics as the subjective EP measure.

[4] Satisfaction with SES is based on three questions: "my household lives better nowadays than around 4 years age", "all things considered, I am satisfied with my job as a whole" and "all things considered, I am satisfied with my financial situation as a whole", with responses ranging from 1 = strongly disagree to 5 = strongly agree (Druică et al., 2019).

4. Data and methods

4.1. Study design and population

We take our dataset from the CFPS, administered by Peking University's Institute of Social Science Survey, which currently encompasses five waves: 2010, 2012, 2014, 2016, and 2018. Because the survey covers 25 provinces, municipalities, or autonomous regions representing 95% of the Chinese population, it constitutes a nationally representative sample that captures both the socioeconomic development and the economic and noneconomic well-being of Chinese households (Xie, 2012). Productive use of the rich CFPS data in prior research confirms its ability to shed light on China's contemporary problems, including SWB (Nie et al., 2017; Zhang and Awaworyi Churchill, 2020) and health (Zhang et al., 2019). We restrict the study sample to adults aged 18+ for whom detailed demographic, socioeconomic, and SWB information is available in all waves but exclude family members who do not share the household oven. When calculating EP, we also exclude households whose income is zero. The resulting final sample is an unbalanced panel of 41,765 individuals and 109,406 observations.

4.2. SWB measures

Our main proxy of SWB is depression. The CFPS depression assessment is based on a 20-question version of the Center for Epidemiologic Studies Depression (CES-D) questionnaire (Radloff, 1977), which encompasses three negative aspects and one positive; namely, somatic-retarded activity, interpersonal relations, depressed affect, and positive affect (Hsieh and Qin, 2018). Respondents indicate how often in the preceding week they experienced the specified emotion on a 4-point scale of 0 = rarely, 1 = little, 2 = occasionally, and 3 = often. The CES-D score is then calculated as follows:

$$CES-D=\sum_{i} score_{i,somatic}+\sum_{j} score_{j,interpersonal}+\sum_{k} score_{k,depressed}+\sum_{m}\left(4-score_{m,positive}\right) \quad (1)$$

where $score_{i,\ somatic}$, $score_{j,\ interpersonal}$, $score_{k,\ depressed}$, and $score_{m,\ positive}$ denote the score for the ith question of the somatic-retarded activity, the jth question of interpersonal relations, the kth question of the depressed affect, and mth question of the positive affect, respectively. Given an overall CES-D score of 0 to 60, with higher scores indicating a higher probability of depression, we designate manifestation of depressive symptoms as a CES-D score equal to or over 16 as a robustness check (Radloff, 1977).

In addition, we also introduce one positive measure of SWB – life satisfaction as a robustness check. In the CFPS, life satisfaction is assessed by the question, "How satisfied are you with your life?" and measured on a 5-point scale from 1 = very unsatisfied to 5 = very satisfied.

4.3. EP variables

To evaluate EP, we employ six measures, EP4 in the main analysis and the remaining five in our robustness checks:

- EP 1: twice the median percentage of full income (EP1, Moore, 2012).
- EP 2: 10% measure (EP2, Boardman, 1991).
- EP 3: amended 10% measure (EP3, Kahouli, 2020). Because Boardman's original 10% measure might overestimate EP prevalence by including high-income households (Kahouli, 2020), we employ an amended 10% measure that only considers low-income households, those with an income below the third decile of the household income distribution (Kahouli, 2020).
- EP 4: LIHC measure.
- EP 5: solid fuel measure. Given the high prevalence of biomass use in China (see, e.g., Tang and Liao, 2014), we include an indicator for whether or not households use solid fuel as their primary fuel (1 = yes, 0 = no).
- EP 6: energy deprivation score. As in Awaworyi Churchill et al., 2020, we define this composite measure as follows:

$$EDS=W_1EP_1+W_3EP_3+W_4EP_4+W_5EP_5 \quad (2)$$

where EDS denotes energy deprivation score, $W_1 = W_3 = W_4 = W_5 = 0.25$, with EP2 omitted because EP3 is its derivative. We then generate EP6 as a dummy equal to one if the household energy deprivation score is 0.5 or above.

4.4. Control variables

Following Awaworyi Churchill et al. (2020), our models control for individual demographic and socioeconomic characteristics, including age, age squared, gender (1 = male, 0 = female), marital status (1 = married/living together, 0 = other), education (measured on a 6-point scale: 1 = illiterate, 2 = primary school, 3 = middle school, 4 = high school, 5 = vocational school, and 6 = university or higher, with illiterate as the reference group), employment status (1 = currently employed, 0 otherwise), household size, and home ownership (1 = complete or partial property owner, 0 otherwise). Lastly, given China's diverse physical geography and its major rural-urban divide, we add a provincial dummy to capture possible geographic heterogeneity together with a control for current residence location (1 = urban, 0 = rural).

4.5. Empirical strategy

4.5.1. Ordinary least squares (OLS) estimation

We adopt the standard OLS regression method applied in the majority of SWB studies. More specifically, we apply OLS estimation based on the following model:

$$SWB_i=\alpha_0+\alpha_1EP_i+\alpha_2X_i+\alpha_3F_i+\alpha_4P_i+\alpha_5W_i+\varepsilon_i \quad (3)$$

where SWB_i denotes the subjective well-being of individual i in terms of depression, and EP_i represents household EP. X_i is a vector of individual i's characteristics, F_i is a vector of household characteristics, P_i is a vector of provincial dummies (with Beijing as reference), W_i is a vector of wave dummies (with 2012 as reference), and ε_i is an error term.[5] The association between EP and individual SWB is captured by α_1.

4.5.2. Two-way fixed effects (FE) model

Given the potential for bias from individual time-invariant unobservables, we examine the EP-SWB relation by estimating the following two-way FE model:

[5] Rerunning the estimates using an ordered logit model yields quantitatively similar results.

$$SWB_{it} = \beta_0 EP_{it} + \beta_1 X_{it} + \beta_2 P_{it} + \beta_3 W_{it} + \mu_i + \delta_{it} \quad (4)$$

where SWB_{it} represents the SWB of individual i at time t, EP_{it} denotes individual i's EP status at time t, X_{it} is a set of time-variant controls, P_{it} and W_i denote provincial and wave dummies, respectively, and ε_{it} is the disturbance error. The unobservable time-invariant individual effects are captured by μ_i.

4.5.3. Instrumental variable estimation

In our baseline model, however, the use of OLS and FE estimators creates a potential for endogeneity in EP, including the possibility of omitted variable bias, measurement error and simultaneity bias. The bias of omitted variables will render the estimated coefficient of EP either to be biased upwards or downward. In particular, one key limitation of the FE estimate is that it cannot rule out some time-varying unobserved factors that may simultaneously impact EP and SWB. For instance, some unobservables such as individual expectations regarding income or job loss may not only affect EP but also SWB. In addition, because a higher level of social support is linked to better SWB (Gallagher and Vella-Brodrick, 2008; Siedlecki et al., 2014), any social support may lead to underestimation (Awaworyi Churchill et al. (2020) while also decreasing the likelihood of EP. Another potential endogeneity source – and one also likely to result in underestimation – is systematic measurement error in estimating EP, especially when households do not accurately recall their energy expenditure (Awaworyi Churchill et al., 2020) possibly due to their different levels of socioeconomic status and cognitive abilities. Furthermore, the magnitude of measure error might be substantial. For instance, Wilkins and Sun (2010) show that Australian respondents underestimate their annual energy expenditure by 13–20%. A final concern is simultaneity bias, such as when happier individuals earn higher incomes and decrease the fraction of energy expenditure in the household budget, which generates downward biases in both the OLS and FE estimates (Awaworyi Churchill et al., 2020).

To rule out these endogeneity issues, we run 2SLS estimations using provincial-level prices of electricity and natural gas as IV instruments under the implicit assumption that energy price increases raise energy bills and thus the likelihood of EP (Awaworyi Churchill et al., 2020; Zhang et al., 2021). This may in turn increase the probability of being mentally depressed. Yet if households with higher energy prices delay or even cancel household appliance purchases, this use of energy prices may not satisfy the exclusion restriction. Another threat to the exclusion restriction is that the increase in energy prices would result in the tradeoff between residential energy and health expenditures: after a shock in energy prices, there will be less expenditures for energy and health (Kahouli, 2020). The household may decide to maintain health expenditures but decrease residential energy expenditure or prefer thermal comfort at the expense of health expenditures (Kahouli, 2020), thereby affecting individuals' SWB. However, as highlighted by Awaworyi Churchill and Smyth (2021), expenditures on energy are unlikely to make up such a large share of the household budget that they would create an income effect large enough to significantly affect other items of the budget. This argument applies to the case of China where the average share of energy expenditure in household income is around 7–8% (Cheng et al., 2021). As such it is unlikely that Chinese residents would face dramatic changes in allocating household budgets to energy and health due to fluctuations in energy prices. In addition, it is also probable that energy prices might reflect economic performance (Awaworyi Churchill and Smyth, 2021). Existing studies have confirmed that fluctuations of energy prices are associated with economic growth in China (Nie and Yang, 2016; Shi and Sun, 2017), which would then influence individuals' SWB such as depression and life satisfaction (Easterlin et al., 2012; Lei et al., 2018; Qin et al., 2018). Thus, following Lewbel (2012), we combine the external IV (provincial prices) with internally generated instruments based on a heteroskedastic covariance restriction, a method widely used with or without external IVs to check the robustness of key findings (see, e.g. Mishra and Smyth, 2015; Prakash and Smyth, 2019). A precondition for identification in this method is the presence of heteroskedasticity, which we confirm using the Pagan-Hall and Breusch-Pagan tests (Breusch and Pagan, 1979).[6]

4.5.4. Structural equation modeling (SEM)

To explore the potential pathways through which EP4 impacts SWB, we use structural equation modeling (SEM) to analyze the effects of our two hypothesized mediators: individual health and household food expenditure (see Section 3). We proxy these latter by self-reported health (SRH, on a 5-point scale from 1 = very unhealthy to 5 = very healthy) and the yuan amount spent for food during the previous month, respectively. In addition to controlling for age, age squared, gender, education, employment status, marital status, household size, and home ownership, we assess each one's possible mediation on the EP-SWB relation. To evaluate the goodness-of-fit of our SEM estimations, we employ the comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA), whose acceptability criteria are $\geq$0.9, $\leq$ 0.1, and $\leq$ 0.08, respectively (Schermelleh-Engel et al., 2003).

5. Results

5.1. Descriptive statistics

As Appendix Table A1 shows, in terms of SWB, the average values of depression and life satisfaction in our sample are 13.1 and 3.7, respectively, with approximately 32% of respondents suffering from depressive symptoms (cf. Zhao et al. (2020). The share of EP ranges from 13.2% to 35.3%, depending on the measure used, with the 22.5% share derived using the 10% measure being very similar to that reported by Zhang et al. (2019) using a 2012–2016 CFPS sample. Fig. 2 shows that respondents who are energy poor are more likely to have higher depression scores compared to those who are not energy poor, irrespective of using EP1 to EP6.

5.2. Impact of EP on depression: OLS and FE estimates

According to Table 1, which reports the OLS and FE results for the

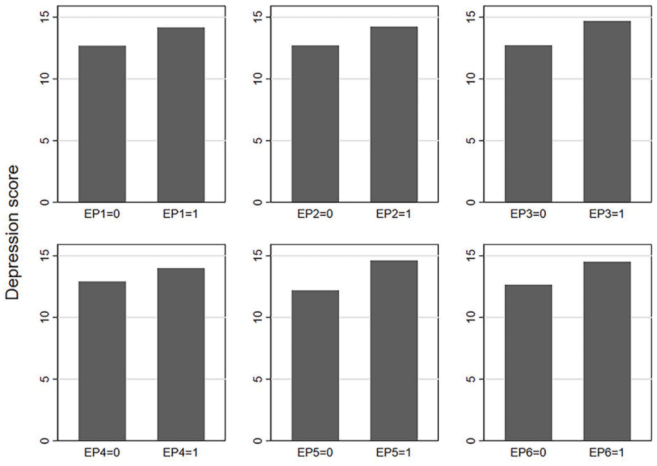

Fig. 2. Different measures of EP and depression.
Notes: Depression is measured as an overall CES-D score of 0 to 60, with higher scores indicating a higher probability of depression. EP1-EP6 denotes different six measures of energy poverty (1 = yes, 0 = no).

[6] See Lewbel (2012) for a detailed discussion.

Table 1
OLS/FE estimates of the EP impact on depression among Chinese adults in the 2012–2018 CFPS sample.

	(1)	(2)
	OLS	FE
EP4	0.657***	0.323***
	(0.079)	(0.083)
Age	0.153***	0.501***
	(0.013)	(0.076)
Age squared/100	−0.142***	−0.164***
	(0.014)	(0.036)
Gender	−1.461***	
	(0.065)	
Primary school	−1.495***	−0.383
	(0.101)	(0.281)
Middle school	−2.214***	−0.143
	(0.099)	(0.352)
High school	−2.661***	−0.344
	(0.114)	(0.432)
Vocational school	−2.652***	0.014
	(0.143)	(0.482)
University or higher	−2.863***	0.439
	(0.154)	(0.512)
Currently employed	−0.585***	−0.456***
	(0.078)	(0.090)
Married/living together	−1.978***	−1.859***
	(0.098)	(0.169)
Household size	−0.132***	−0.069***
	(0.016)	(0.025)
Home ownership	−0.611***	−0.117
	(0.099)	(0.120)
Urban	−0.730***	
	(0.068)	
Constant	13.478***	−3.346
	(0.443)	(3.263)
Observations	108,912	108,912
Number of Individuals		41,684
Wave FE	Yes	Yes
Provincial FE	Yes	Yes
Individual FE	No	Yes
Adj. R^2	0.079	

Notes: The dependent variable is depression/depressive symptom, with controls for age, age squared, educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = property is completely or partly owned, 0 = otherwise), wave dummies (with 2012 as reference) and provincial dummies (with Beijing as reference). The OLS estimates also control for gender (1 = male, 0 = female) and location type (1 = urban, 0 = rural). Individual-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

EP-depression relation based on EP4 (LIHC), EP is significantly associated with a higher level of the depression score, which is consistent with the results in Fig. 2. Admittedly, the FE estimate of an EP-associated increase in depression – at 32.3% – is far smaller than the OLS estimate of 65.7%, but this discrepancy results mainly from the former's controls of time-invariant individual fixed effects to partially mitigate any EP endogeneity from omitted unobserved factors. Overall, our findings are well in accordance with those of Biermann (2016) and Rodriguez-Alvarez et al. (2019) for Europe, Awaworyi Churchill et al. (2020) for Australia, and Zhang et al. (2021) for China.

As regards sociodemographic factors, we confirm another common finding in the SWB literature; namely, an inversed U-shape in the age-depression linkage that Nie et al. (2020) and Xu et al. (2021) document for China. Likewise, in line with Qin et al. (2018) and Ren et al. (2020), males in our sample have lower levels of depression than

Table 2
Lewbel's 2SLS estimates among Chinese adults in the 2012–2018 CFPS sample.

	(1)	(2)
	Lewbel internal IV	Lewbel internal & external IV
EP4	1.591***	1.571***
	(0.304)	(0.301)
Controls	Yes	Yes
Observations	108,909	108,909
First stage		
F-statistic	37.98	40.75
J P-value	0.538	0.183
Pagan-Hall test	3148.725	3152.616
Bresuch-Pagan test	5555.117	5561.436

Notes: Based on 2012–2018 CFPS data. The dependent variable is depression (score), with controls for age, age squared, gender (1 = male, 0 = female), educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), urban (1 = urban, 0 = rural), wave dummies (with 2012 as reference), and provincial dummies (with Beijing as reference). Individual-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

females.[7] Lower depression is also associated with larger households, a correlation documented in previous studies (Nie et al., 2020; Zhang et al., 2009). As is common in China (Lei et al., 2015; Nie et al., 2017; Xu et al., 2021), decreased depression is associated with being married or living together, perhaps suggesting that social support emanated from spouses reduces the risk of depression (St John and Montgomery, 2009) and marriage shields individuals from exposure to stress (Kessler and Essex, 1982).

5.3. *Impact of EP on depression: IV estimates*

Given the potential for EP endogeneity, we adopt the Lewbel (2012) 2SLS approach using first the internal IV only and then the internal IV combined with our external IV of provincial-level electricity and natural gas prices (see Table 2). The existence of heteroskedastictiy, confirmed by the Pagan-Hall test, marks this methodological choice as appropriate. Not only are the first-stage F statistics much larger than 10, suggesting no weak IV instrumentation, but the Hanson J test confirms IV exogeneity. As before, the results show that the effect of EP on depression is uniformly positive and statistically significant (see columns 1 and 2), which are generally in line with those reported in Table 1.

5.4. *Underlying mechanisms*

To test our two hypotheses that EP negatively affects SWB through poor health (H1) and/or household food expenditure (H2), we adopt an SEM approach that focuses solely on EP4 in our main analysis. The values from a goodness-of-fit test confirm the models' appropriateness: RMSEA = 0.035 (< 0.08), SRMR = 0.002 (< 0.08), and CFI = 0.998 (> 0.9). The resulting estimates (see Table 3) not only confirm our baseline results (see Table 1) that EP increases the depression score (standardized coefficient = 0.035, $p < 0.01$), but also show significant associations between EP and the two hypothesized mediators.

More specifically, those experiencing EP are more likely to report a lower health status (standardized coefficient = −0.005, $p < 0.1$) and spend less money on food (standardized coefficient = −0.011, $p < 0.01$). In turn, household food expenditure is negatively correlated with the

[7] Some theories like gender-role theory imply that the chronic stresses associated with traditional female roles result in a higher prevalence of depression among women compared with men (Xu et al., 2021).

Table 3
Path analysis: SEM with controls.

Dependent variable	Independent variable	Total effect	Direct effect	Indirect effect
Food expenditure	EP4	−0.011***	−0.011***	
Health	EP4	−0.005*	−0.005*	
Depression score	Food expenditure	−0.071***	−0.071***	
	Health	−0.313***	−0.313***	
	EP4	0.035***	0.033***	0.002**

Notes: Controls include age, age squared, gender (1 = male, 0 = female), educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), and an urban dummy (1 = urban, 0 = rural). We report the effects as standardized coefficients. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4
Indirect effects of EP on depression and their proportion to total effects: SEM with controls.

Mediator	Indirect effect	Standard error	*Z*-value	Indirect effect/total effect
Health	0.002*	0.001	1.751	0.045
Food expenditure	0.001***	0.000	3.819	0.023

Notes: Controls include age, age squared, gender (1 = male, 0 = female), educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), and an urban dummy (1 = urban, 0 = rural). We report the effects as standardized coefficients. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

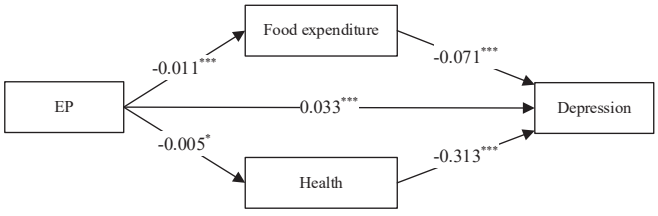

Fig. 3. Underlying mechanisms through which EP impacts LS.

depression score (standardized coefficient = −0.071, $p < 0.01$), implying that having more to spend on food is associated with a lower lever in emotional health. SRH is also negatively and significantly associated with the depression score (standardized coefficient = −0.313, $p < 0.01$). Household food expenditure mediates around 2.3% of EP's total negative effect on depression (standardized coefficient = 0.001, $p < 0.01$) compared with 4.5% for SRH (standardized coefficient = 0.002, $p < 0.1$) (see Table 4). These findings not only support our mediation hypotheses, whose mechanisms we detail in Fig. 3, but pinpoint SRH as the most important of the two mediators.

Notes: SEM estimates with all coefficients standardized. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.5. Robustness checks

Given the current lack of any consensual definition of EP, our robustness tests includes a battery of checks, the first of which employs our five remaining EP measures: EP1-EP3; EP5, the fraction of biomass use (Zhang et al., 2019); and EP6, our composite measure (Awaworyi Churchill et al., 2020). As Table 5 shows, FE results for all five EP measures indicate that EP is consistently positive and significant.

Second, when we then introduce our two SWB proxies of life satisfaction and depressive symptoms (see Table 6), EP lowers the first (except for the FE estimation) while raising the second, which accords not only with Table 1 but also Awaworyi Churchill et al. (2020) for

Table 5
FE estimates of the EP impact on depression among Chinese adults using alternative measures of EP.

	(1)	(2)	(3)	(4)	(5)
EP1	0.325*** (0.066)				
EP2		0.316*** (0.069)			
EP3			0.247*** (0.079)		
EP5				0.156* (0.085)	
EP6					0.349*** (0.071)
Observations	109,245	109,245	109,245	108,924	108,591
Number of Individuals	41,728	41,728	41,728	41,666	41,622
Wave FE	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes

Notes: Based on 2012–2018 CFPS data. The dependent variable is depression, with controls for age, age squared, educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), wave dummies (with 2012 as reference), and provincial dummies (with Beijing as reference). Individual-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6
OLS/FE estimates of the EP impact on the SWB factors of life satisfaction and depressive symptoms among Chinese adults in the 2012–2018 CFPS sample.

	(1)	(2)	(3)	(4)
	Life satisfaction		Depressive symptoms	
	OLS	FE	OLS	FE
EP4	−0.039*** (0.010)	0.006 (0.011)	0.026*** (0.004)	0.011** (0.005)
Observations	109,072	109,072	54,069	54,069
Number of Individuals		41,721		35,710
Wave FE	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes
Adj. R^2	0.091		0.060	

Notes: The dependent variables are life satisfaction and depressive symptoms, with controls for age, age squared, educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), wave dummies (with 2012 as reference) and provincial dummies (with Beijing as reference). OLS estimates also control for gender (1 = male, 0 = female) and urban (1 = urban, 0 = rural). Individual-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7
Logit estimates of the EP impact on depressive symptom among Chinese adults in the 2012–2018 CFPS sample.

	(1)	(2)	(3)	(4)	(5)	(6)
EP1	0.174***					
	(0.016)					
EP2		0.184***				
		(0.017)				
EP3			0.231***			
			(0.019)			
EP4				0.121***		
				(0.020)		
EP5					0.283***	
					(0.018)	
EP6						0.216***
						(0.017)
Observations	109,245	109,245	109,245	108,912	108,924	108,591
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	No	No	No	No	No
Pseudo R^2	0.050	0.050	0.050	0.049	0.051	0.050

Notes: The dependent variable is depressive symptom, with controls for age, age squared, gender (1 = male, 0 = female), educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), urban (1 = urban, 0 = rural), wave dummies (with 2012 as reference) and provincial dummies (with Beijing as reference). Individual-level adjusted standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8
Indirect effects of alternative EP measures on depression and their proportion to total effects: SEM with controls.

Mediator	Indirect effect	Standard error	*Z*-value	Indirect effect/total effect
Panel A: EP1				
Health	0.005***	0.001	5.268	0.097
Food expenditure	0.005***	0.000	16.543	0.100
Panel B: EP2				
Health	0.005***	0.001	5.081	0.097
Food expenditure	0.005***	0.000	16.553	0.102
Panel C: EP3				
Health	0.007***	0.001	7.438	0.147
Food expenditure	0.008***	0.000	18.851	0.173
Panel D: EP5				
Health	0.015***	0.001	15.230	0.191
Food expenditure	0.014***	0.001	16.968	0.180
Panel E: EP6				
Health	0.007***	0.001	7.196	0.121
Food expenditure	0.007***	0.000	18.252	0.128

Notes: Controls include age, age squared, gender (1 = male, 0 = female), educational level (illiterate, primary school, middle school, high school, vocational school, and university or higher, with illiterate as reference), marital status (1 = married/living together, 0 = otherwise), employment status (1 = currently employed, 0 = otherwise), household size, home ownership (1 = complete or part ownership of the property, 0 = otherwise), and an urban dummy (1 = urban, 0 = rural). We report the effects as standardized coefficients. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Australia, Welsch and Biermann (2014) for Europe and Zhang et al. (2021) for China.[8] Third, we also assess the association between EP and depressive symptoms by employing a logit estimation and alternative EP measures (EP1-EP3, and EP5 and EP6). Again, the outcomes, reported in Table 7, are quantitatively similar to those in the column 3 of Table 6.

As a final check, we also rerun the mechanism analysis using the alternative five EP measures. Once again, results, reported in Panel A-E of Table 8, support our mediation hypotheses. However, the relative contributions of household food expenditure (ranging from 10% to 18%) and SRH (ranging from 9.7% to 19.1%) to total effects are quite comparable, which might be attributable to the fact that unlike the other EP measures, EP4 (LIHC) considers both the high energy costs and the low-income status of households (Awaworyi Churchill and Smyth, 2021; Hills, 2011).

6. Conclusions

Despite much public attention to the detrimental effects of EP on social welfare and sustainable development (Wang et al., 2015), empirical research provides few insights into its impact on SWB in non-Western countries, particularly China. Our analysis of nationally representative data from the 2012–2018 CFPS is thus designed to shed light not only on the EP-SWB relation in China but also on the extent to which this relation is mediated by health and household food expenditure.

The analysis yields several key findings: First, although the share of EP identified differs by EP measure (ranging from 13.2% to 35.3%), the similarity of the 22.5% EP2 result to other seminal research (Zhang et al., 2019) and the 35% of respondents still cooking primarily with solid fuel indicate that despite China's substantial economic progress, EP remains a serious national concern. At the same time, as in Western countries (Awaworyi Churchill et al., 2020; Biermann, 2016; Rodriguez-Alvarez et al., 2019; Welsch and Biermann, 2014), EP contributes to an increased likelihood of depression and related symptoms. This EP-life satisfaction nexus is partially mediated by health and household food expenditure, which account for 4.5% and 2.3% of EP's total effect, respectively.

These findings, which echo those of previous research, have important implications for policy. Above all, they underscore the urgent need to guarantee energy accessibility and affordability to all Chinese by boosting investment in and access to modern energy services and technologies, a goal in line with China's current strategy for green and low-carbon development.[9] They also suggest that economic development can

[8] Although the 5-point scaling of our life satisfaction measure might suggest a latent variable estimation approach as the most appropriate, because the bias introduced by OLS is relatively small (Ferrer-i-Carbonell & Frijters, 2004), we employ an OLS estimation.

[9] This strategy is highlighted in China's 14th Five-Year Plan (2021–2025), as well as its Long-Term Goal of 2035.

effectively combat EP by promoting energy development and by providing financial support for the use of alternative energy sources. On June 18 of 2015, Chinese government released its National Mental Health Working Plan (2015–2020) and integrated the promotion of mental health into the Healthy China Action (2019–2030) since 2019, which aims to prevent depression and other mental diseases (Ren et al., 2020). The "*Basic Healthcare and Health Promotion Law*", which was enacted on June 1, 2020 (*Lancet,* 2020), also plans to develop mental health services, and build and improve mental health service systems, especially for vulnerable groups (e.g., minors, the disabled and the elderly). However, the implementation and effectiveness of those encouraging policies remain uncertain and depression still leads to a heavy social burden in China. As such mitigating EP might be an effective way of improving mental health in China.

Access to energy, being fundamental to improved quality of life, is a key imperative for economic development. Hence, while shedding useful light on the importance of EP in China and the mechanisms through which it affects well-being, our study also raises several worthwhile avenues for future research. One important possibility, especially given China's rapidly burgeoning older population, is to focus on this and other EP-susceptible subgroups for whom the SWB impacts may be more harmful (Kahouli, 2020). Likewise, given the limited research on EP's mid- to long-term effects on well-being, it would be fruitful (albeit challenging) to test for the speculated long-term scarring within a dynamic framework (Kahouli, 2020), a goal dependent on greater availability of detailed longitudinal microdata. Another promising path would be to explore increasing regional and gender inequities in both EP distribution and its impact on SWB. Lastly, based on our initial evidence that health and household food expenditure at least partially mediate the EP-SWB relation, there is an urgent need to investigate all possible mechanisms through which EP operates on SWB so as to better inform China's social economic and developmental policies.

Declaration of Competing Interest

None.

Acknowledgments

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Appendix A

Table A1
Descriptive statistics for Chinese adults in the 2012–2018 CFPS sample.

Variables	Obs.	Mean/percentage	S.D.
SWB measures			
Depression score (0–60)	109,245	13.050	8.077
Depressive symptom	109,245	0.320	0.466
Life satisfaction (1–5)	109,406	3.683	1.065
EP measures			
EP1	109,406	0.248	0.432
EP2	109,406	0.225	0.417
EP3	109,406	0.165	0.371
EP4	109,072	0.132	0.338
EP5	109,084	0.353	0.478
EP6	108,750	0.213	0.409
Individual characteristics			
Age	109,406	47.488	15.850
Gender	109,406	0.494	0.500
Educational levels			
Illiterate	109,406	0.273	0.446
Primary school	109,406	0.213	0.409
Middle school	109,406	0.278	0.448
High school	109,406	0.138	0.345
Vocational school	109,406	0.057	0.232
University or higher	109,406	0.041	0.197
Currently employed	109,406	0.740	0.439
Married/living together	109,406	0.836	0.370
Household characteristics			
Household size	109,406	4.292	1.996
Home ownership	109,406	0.907	0.290
Urban	109,406	0.474	0.499
Agricultural	109,261	0.724	0.447
Mechanism variables			
Log (food expenditure)	107,761	9.419	1.025
Self-reported health (SRH)			
Poor	109,398	0.171	0.376
Fair	109,398	0.165	0.371
Good	109,398	0.366	0.482
Very good	109,398	0.176	0.381
Excellent	109,398	0.122	0.327

Source: CFPS 2012–2018.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2021.105548.

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