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ABSTRACT

Energy Poverty and Subjective Well-Being in China: New Evidence from the China Family Panel Studies

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 lowers life satisfaction, with more pronounced impacts among males, the poor, and those residing in central regions. These results are robust to both alternative EP and SWB measures and to a series of estimation approaches that control for endogeneity. An additional structural equation modelling analysis of underlying mechanisms confirms that individual self-reported health, housing quality, and household food expenditure mediate the EP-SWB relation.

JEL Classification: I10, I12, R21
Keywords: energy poverty, life satisfaction, happiness, depression, China

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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 & Seligman, 2018; Helliwell & 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). EP is also a barrier to realizing multiple Millennium Sustainable Development Goals (SDGs), in particular, eradicating extreme poverty and hunger (goal 1) and ensuring environmental sustainability (goal 7) (Sesan et al., 2013; UNDP, 2010).[2] As of 2009, not only did 1.4 billion individuals -- mostly in developing countries (Li et al., 2014) -- lack access to electricity, but 2.7 billion were still cooking with traditional biomass in inefficient stoves. Given a projected increase to 2.8 billion traditional biomass users by 2030 (IEA, 2010), 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 (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).

Although a large body of literature addresses the major SWB determinants of age (Bauer et al., 2017; Bittmann, 2020; Blanchflower & Oswald, 2008), gender (Inglehart,

[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.

[2] The eight SDGs are eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowering women, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria, and other diseases, ensuring environmental sustainability, and developing a global partnership for development.

2002; Tesch-Römer et al., 2008), income (Deaton, 2008; Diener & Biswas-Diener, 2002; Easterlin, 1995; Frijters et al., 2004), wealth (Lindqvist et al., 2020; Schyns, 2002), unemployment (Binder & Coad, 2015; Winkelmann, 2009), health (Gwozdz & Sousa-Poza, 2010; Herman et al., 2013), social capital (Bjørnskov, 2003; Kroll, 2011), religion and culture (Diener & Diener, 2009; Lim & Putnam, 2010; Schimmack et al., 2002; Tov & 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[3] 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. At the same time, however, in contrast to the limited electricity availability in other developing nations (Lin & 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 in China 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, including potential heterogeneities within it. We also extend prior work by employing both positive (life satisfaction and happiness) and negative (depression and depressive symptom) SWB measures to produce a more differentiated picture of the EP-SWB nexus. In addition, unlike prior studies that ignore causality in the EP-SWB relation despite the omnipresence of reverse causality and selection issues, we purposefully conduct a causal analysis of the EP-SWB linkage.

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

Lastly, 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 modelling (SEM) approach that introduces poor housing quality, 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. 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 et al., 2020; Li et al., 2014; Lin & 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. This relative measure (Li et al., 2014) thereby rules out the inclusion of high-income and high-consumption households.

Also popular in the EP literature are composite indices that incorporate several individual EP measures, such as the IEA (2010) Energy Development Index (EDI), which comprises per capita consumption of commodity energy plus living electricity,

the share of commodity energy to total energy end-users, and the population of electricity users. The EDI is particularly suitable for macrodata and regional comparative assessments (Lin & 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 & Wang, 2020). We summarize these EP indicators and their measures and sources in Table 1.

Table 1 Commonly used energy poverty (EP) indicators and measures

Category	Indicator	Measure	Source
Single indicator	10% measure	A household spends more than 10% of its income on total household fuel costs.	Boardman (1991)
Two-dimensional indicator	Low income high cost (LIHC)	Residual household income is below the official poverty line while basic energy costs for household living needs are higher than the average.	Hills (2011)
Composite indicator	Energy Development Index (EDI)	Five indicators: 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.	IEA (2010)
	Multidimensional Energy Poverty Index (MEPI)	Six equally weighted indicators: cooking fuel, lighting, entertainment, household appliances, education, and communication tools.	Nussbaumer et al. (2012)

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.

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 (Awaworyi Churchill et al., 2020; Biermann, 2016; Mayer & Smith, 2019; Rodriguez-Alvarez et al., 2019; Thomson et al., 2017; Welsch & Biermann, 2017). For example, 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 European Social Survey (ESS) data. 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 Rodriguez-Alvarez et al. (2019) using 2013 Spanish Life Condition Survey (SLCS) data. 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.

Evidence for the EP-SWB relation in China, in contrast, is very limited, with our search identifying only the Zhang et al. (2021) analysis of 2014-2018 CFPS data, which pinpoints an association between EP and a declining SWB in 10 to 15-year-olds. The fact that this relation is further mediated by academic performance point to this latter as an important mechanism through which EP lowers SWB in youth. 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

Because poverty is generally associated with poor housing conditions, households experiencing EP often lack the resources for investment in their home, such as adequate sanitary installations or good insulation. Poor housing quality is also significantly related to individual health and SWB, with mortality increasing as housing property ages (Wilkinson et al., 2001). Living in an older house that does not have air conditioning, for instance, contributes to heat stress and excess deaths or hospitalizations (Knowlton et al., 2009; O'Neill et al., 2005). Conversely, living in cold housing increases the risk of colds and flu, and is associated with such illnesses as cardiovascular disease, respiratory problems, arthritis, and rheumatism (Dear & McMichael, 2011). When poor housing also has limited ventilation, it poses the additional risk of dampness (Howden-Chapman, 2004), which can promote mold growth, dust mites, and cockroach feces (Jacobs et al., 2014), thereby increasing the risk of allergies, eczema, and respiratory morbidity such as asthma (Barton et al., 2007; Boomsma et al., 2017). Such poor housing conditions are also strongly associated with mental health issues and negative SWB, including more psychological symptoms in children (Gifford & Lacombe, 2006) and adolescents living in cold housing (Barnes et

al., 2008). Based on all the above observations, we formulate the following two hypotheses:

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

Hypothesis 2: *EP negatively affects SWB through poor housing quality or conditions*.

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 & 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 & Frongillo Jr, 2001; Park & Eicher-Miller, 2014), especially during the high-energy demand seasons of winter and summer (Nord & Kantor, 2006). As a result, household members of all ages are more likely to report poor health (Gundersen & 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 & Tarasuk, 2003), as well as declines in SWB factors like life satisfaction (see, for instance, Deleire & Kalil, 2010; Dumludag, 2015). In addition to diagraming the above factors as a simple heuristic of possible mechanisms for the EP impact on SWB in China (see Figure 1), we formalize the EP-food expenditure relation as our third hypothesis:

Hypothesis 3: *EP negatively affects SWB through food expenditure.*

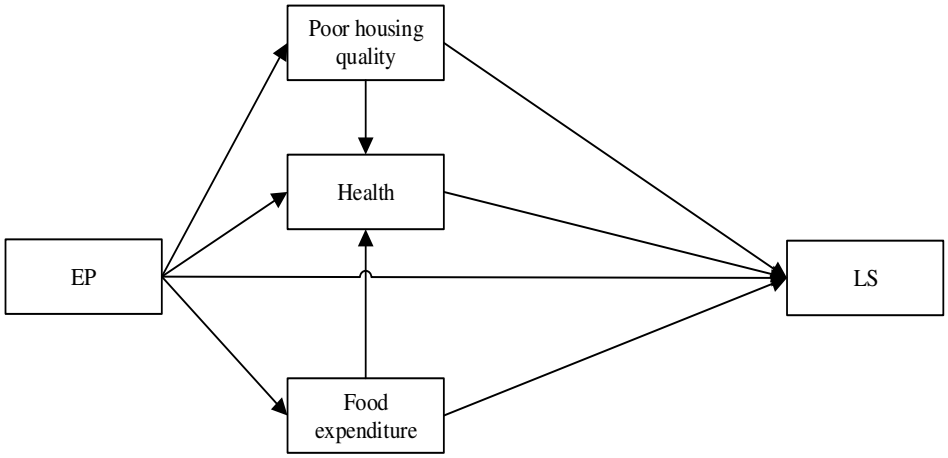

Figure 1 Heuristic of potential mechanisms of the EP impact on SWB

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 & 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

Following Awaworyi Churchill et al. (2020), our main proxy of SWB is life satisfaction 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. In our robustness checks, we also introduce the two additional SWB measures of happiness and depression, with the first measured by responses to "How happy are you?", asked only in the 2014 and 2018 CFPS waves and measured on a 10-point scale ranging from 1 = very unhappy to 10 = very happy.

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 & 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:

$$CES-D = \sum_i score_{i,somatic} + \sum_j score_{j,interpersonal} + \sum_k score_{k,depressed} + \sum_m (4 - score_{m,positive}) \quad (1)$$

where $score_{i,somatic}$, $score_{j,interpersonal}$, $score_{k,depressed}$, and $score_{m,positive}$ denote the score for the *i*th question of the somatic-retarded activity, the *j*th question of interpersonal relations, the *k*th question of the depressed affect, and *m*th 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 (Radloff, 1977).

4.3 EP variables

To evaluate EP, we employ six measures, the first three in the main analysis and the remaining three 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:

$$EDS = W_1 EP_1 + W_3 EP_3 + W_4 EP_4 + W_5 EP_5 \quad (2)$$

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

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

$$SWB_i = \alpha_0 + \alpha_1 EP_i + \alpha_2 X_i + \alpha_3 F_i + \alpha_4 P_i + \alpha_5 W_i + \varepsilon_i \qquad (3)$$

where SWB_i denotes the subjective well-being of individual i in terms of life satisfaction, 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.[4] 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:

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

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. As a robustness check, we also employ the Baetschmann et al. (2015) blow-up and cluster (BUC) estimator for fixed-effects ordered logit models (FEOLM), which calculates all possible dichotomizations jointly while using observation-specific cutoff points.

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

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. For instance, because a higher level of social support is linked to better SWB (Gallagher & Vella-Brodrick, 2008; Siedlecki et al., 2014), any social support may lead to underestimation (cf. 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 measurement error in estimating EP, especially when households do not accurately recall their energy expenditure (Awaworyi Churchill et al., 2020). 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). 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. 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 & Smyth, 2015; Prakash & 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 & Pagan, 1979).[5]

4.5.3 Structural equation modeling (SEM)

To explore the potential pathways through which EP impacts SWB, we use structural equation modeling (SEM) to analyze the effects of our three hypothesized mediators:

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

individual health, poor housing quality, and household food expenditure (see Section 3). We proxy these latter by self-reported health (on a 5-point scale from 1 = very unhealthy to 5 = very healthy), housing property age, 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 ≥ 0.9, ≤ 0.1, and ≤ 0.08, respectively (Schermelleh-Engel et al., 2003).

5. Results

5.1 Descriptive statistics

As Table 2 shows, the mean age in our sample is about 47 years, with an almost equal distribution of gender (49.4% male). Most respondents are employed (74%) and married or living together (83.6%). The majority (72.4%) have a *hukou*[6] designation of agricultural versus approximately 47.4% denoted as urban, with over one third of all respondents using solid fuel as their main cooking medium. In terms of SWB, the average values of life satisfaction, happiness, and depression in our sample are 3.7, 7.5 and 13.1, respectively (see Table 2), 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.

Table 2 Descriptive statistics for Chinese adults in the 2012-2018 CFPS sample

Variables	Obs.	Mean/percentage	S.D.
SWB measures			
Life satisfaction (1-5)	109406	3.683	1.065

[6] *Hukou* is a formal household registration system implemented in mainland China to control internal migration, ensure social safety, and maintain social stability.

Happiness (1-10)	54530	7.497	2.182
Depression score (0-60)	109245	13.050	8.077
Depressive symptom	109245	0.320	0.466
EP measures			
EP1	109406	0.248	0.432
EP2	109406	0.225	0.417
EP3	109406	0.165	0.371
EP4	109072	0.132	0.338
EP5	109084	0.353	0.478
EP6	108750	0.213	0.409
Individual characteristics			
Age	109406	47.488	15.850
Gender	109406	0.494	0.500
Educational levels			
Illiterate	109406	0.273	0.446
Primary school	109406	0.213	0.409
Middle school	109406	0.278	0.448
High school	109406	0.138	0.345
Vocational school	109406	0.057	0.232
University or higher	109406	0.041	0.197
Currently employed	109406	0.740	0.439
Married/living together	109406	0.836	0.370
Household characteristics			
Household size	109406	4.292	1.996
Home ownership	109406	0.907	0.290
Urban	109406	0.474	0.499
Agricultural	109261	0.724	0.447
Mechanism variables			
Log (food expenditure)	107761	9.419	1.025
Age of housing property	89757	15.946	11.797
Self-reported health (SRH)			
Poor	109398	0.171	0.376
Fair	109398	0.165	0.371
Good	109398	0.366	0.482
Very good	109398	0.176	0.381
Excellent	109398	0.122	0.327

5.2 Impact of EP on LS

According to Table 3, which reports the OLS and FE results for the EP-LS relation based on EP1 (median share of income x 2), EP2 (10% measure), and EP3 (amended 10% measure), respectively, EP lowers LS irrespective of the indicator used. Admittedly, the FE estimates of an EP-associated decline in life satisfaction − at 2.1%, 2.3%, and

2.5% for EP1-EP3, respectively − are far smaller than the OLS estimates of 7.4%, 7.6%, and 10.6%, but this discrepancy results mainly from the former's controls for 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, a U-shape in the age-life satisfaction linkage (Blanchflower & Oswald, 2008) that Nie et al. (2020) also document for China. Likewise, in line with Lei et al. (2015), males in our sample have lower levels of life satisfaction than females, which lower life satisfaction is also associated with larger households, a correlation documented (Nie et al., 2020; Zhang et al., 2009). Conversely, as is common in China (Lei et al., 2015; Nie et al., 2017), increased life satisfaction is associated with being married or living together.

Table 3 OLS/FE estimates of the EP impact on LS among Chinese adults in the 2012-2018 CFPS sample

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	FE	OLS	FE	OLS	FE
EP1	-0.074***	-0.021**				
	(0.008)	(0.009)				
EP2			-0.076***	-0.023**		
			(0.008)	(0.010)		
EP3					-0.106***	-0.025**
					(0.010)	(0.011)
Age	-0.027***	-0.070***	-0.027***	-0.070***	-0.027***	-0.070***
	(0.002)	(0.010)	(0.002)	(0.010)	(0.002)	(0.010)
Age squared/100	0.035***	0.054***	0.035***	0.054***	0.035***	0.054***
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)
Gender	-0.067***		-0.067***		-0.067***	
	(0.008)		(0.008)		(0.008)	
Primary school	0.000	0.048	0.000	0.048	-0.002	0.047
	(0.012)	(0.040)	(0.012)	(0.040)	(0.012)	(0.040)
Middle school	-0.011	0.108**	-0.011	0.108**	-0.015	0.107**
	(0.012)	(0.053)	(0.012)	(0.053)	(0.012)	(0.053)
High school	-0.015	0.003	-0.015	0.003	-0.020	0.002
	(0.014)	(0.064)	(0.014)	(0.064)	(0.014)	(0.064)

Vocational school	0.030	-0.143**	0.030	-0.143**	0.025	-0.143**
	(0.018)	(0.070)	(0.018)	(0.070)	(0.018)	(0.070)
University or higher	0.064***	-0.242***	0.065***	-0.242***	0.061***	-0.242***
	(0.019)	(0.076)	(0.019)	(0.076)	(0.019)	(0.076)
Currently employed	0.029***	0.028**	0.029***	0.028**	0.029***	0.028**
	(0.009)	(0.012)	(0.009)	(0.012)	(0.009)	(0.012)
Married/living together	0.195***	0.074***	0.195***	0.075***	0.194***	0.074***
	(0.011)	(0.022)	(0.011)	(0.022)	(0.011)	(0.022)
Household size	0.011***	-0.000	0.011***	-0.000	0.010***	-0.000
	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)
Home ownership	0.125***	0.062***	0.125***	0.062***	0.125***	0.062***
	(0.013)	(0.017)	(0.013)	(0.017)	(0.013)	(0.017)
Urban	0.027***		0.027***		0.023***	
	(0.008)		(0.008)		(0.008)	
Constant	3.515***	4.940***	3.515***	4.939***	3.524***	4.942***
	(0.056)	(0.423)	(0.056)	(0.423)	(0.056)	(0.423)
Observations	109406	109406	109406	109406	109406	109406
Number of individuals		41765		41765		41765
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes
Adj. R^2	0.092	0.110	0.092	0.110	0.093	0.110

Notes: The dependent variable is life satisfaction, 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3 Robustness checks

Given the current lack of any consensual definition of energy poverty, our robustness testing includes a battery of checks (detailed in the Appendix), the first of which employs our three remaining EP measures: EP4, the LIHC (EP4, Hills, 2011); EP5, the fraction of biomass use (EP5, Zhang et al., 2019); and EP6, our composite measure (EP6, Awaworyi Churchill et al., 2020). As Table A1 shows, both the OLS and FE results for all three measure are consistent with those reported in Table 3.

When we then introduce our three SWB proxies of happiness, depression score, and depressive symptoms (see Table A2), EP lowers the first while raising the second and third, which accords not only with Table 2 but also Awaworyi Churchill et al. (2020) for Australia and Welsch and Biermann (2014) for Europe. We assess the sensitivity of these results by first employing the ordered logit estimation used by Awaworyi Churchill et al. (2020) and then rerunning the estimates using FEOLM (cf. Baetschmann et al. (2015). Again, the outcomes, reported in Table A3, are quantitatively similar to those in Table 3.

Lastly, 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 A4). 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 are generally in line with those reported in Table 3.

5.4 Heterogeneity analysis

To increase understanding of EP's impact on life satisfaction and provide useful guidance on appropriate policies to reduce EP and boost SWB in China, we break our analysis out by the sociodemographic characteristics of poverty, gender, region, and rural versus urban, reporting the outcomes separately for each subgroup in the discussion below. We define households as poor if their annual income is below the mean annual household income for the full sample.

5.4.1 Results by poverty

The FE estimates based on poverty level underscore the greater vulnerability of the poor to EP relative to the nonpoor. Regardless of the primary measure used (EP1, EP2, or EP3), EP lowers life satisfaction among poor households.

Table 4 FE estimates of EP's impact on LS among Chinese adults in poor versus nonpoor households

	Nonpoor			Poor		
	(1)	(2)	(3)	(4)	(5)	(6)
EP1	0.023			-0.030***		
	(0.040)			(0.011)		
EP2		0.038			-0.032***	
		(0.044)			(0.011)	
EP3[a]			-			-0.025**
						(0.012)
Age	-0.047***	-0.047***	-0.047***	-0.070***	-0.070***	-0.071***
	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)	(0.016)
Age squared/100	0.037***	0.037***	0.037***	0.053***	0.053***	0.053***
	(0.010)	(0.010)	(0.010)	(0.007)	(0.007)	(0.007)
Primary school	0.105	0.106	0.105	0.034	0.034	0.033
	(0.088)	(0.088)	(0.088)	(0.051)	(0.051)	(0.051)
Middle school	0.274**	0.275**	0.274**	0.005	0.005	0.004
	(0.107)	(0.107)	(0.107)	(0.071)	(0.071)	(0.071)
High school	0.200	0.200	0.200	-0.130	-0.130	-0.131
	(0.124)	(0.124)	(0.124)	(0.091)	(0.091)	(0.091)
Vocational school	0.168	0.169	0.168	-0.401***	-0.401***	-0.400***
	(0.132)	(0.132)	(0.132)	(0.105)	(0.105)	(0.105)
University or higher	0.051	0.052	0.051	-0.415***	-0.415***	-0.415***
	(0.141)	(0.141)	(0.141)	(0.119)	(0.119)	(0.119)
Currently employed	0.040*	0.040*	0.040	0.045***	0.045***	0.045***
	(0.024)	(0.024)	(0.024)	(0.016)	(0.016)	(0.016)
Married/living together	0.128***	0.127***	0.128***	0.033	0.033	0.032
	(0.044)	(0.044)	(0.044)	(0.030)	(0.030)	(0.030)
Household size	0.003	0.003	0.003	-0.002	-0.002	-0.002
	(0.007)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)
Home ownership	0.005	0.005	0.004	0.057**	0.057**	0.056**
	(0.032)	(0.032)	(0.032)	(0.024)	(0.024)	(0.024)
Constant	4.290***	4.289***	4.286***	5.082***	5.084***	5.084***
	(0.596)	(0.596)	(0.596)	(0.710)	(0.711)	(0.711)
Observations	34602	34602	34602	74804	74804	74804
Number of individuals	20475	20475	20475	34335	34335	34335
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.095	0.095	0.095	0.114	0.114	0.114

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[a] Because EP3 is defined as including only low-income households, it is inapplicable to the nonpoor.

5.3.2 Results by gender

When we break the results out by gender, however, EP has a negative impact on life satisfaction only among males (Table 5), a finding consistent with Zhang et al. (2021) for Chinese children. In Europe, in contrast, although the research too often ignores the unequal distributional impact of energy vulnerability by gender, it is females that are more likely to be affected by energy affordability and energy efficiency (Bollino & Botti, 2017). This difference in our finding is likely to be sociocultural: in China, males generally serve as the household breadwinner and are thus more likely to face EP's economic burden directly, increasing its negative impact on their SWB.

Table 5 FE estimates of EP's impact on LS among male versus female Chinese adults

	Female			Male		
	(1)	(2)	(3)	(4)	(5)	(6)
EP1	-0.009			-0.033**		
	(0.013)			(0.013)		
EP2		-0.012			-0.035***	
		(0.014)			(0.014)	
EP3			-0.015			-0.036**
			(0.016)			(0.016)
Age	-0.102***	-0.102***	-0.103***	-0.046***	-0.046***	-0.046***
	(0.016)	(0.016)	(0.016)	(0.012)	(0.012)	(0.012)
Age squared/100	0.069***	0.069***	0.069***	0.039***	0.039***	0.039***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Primary school	-0.016	-0.016	-0.017	0.103*	0.103*	0.102*
	(0.060)	(0.060)	(0.060)	(0.053)	(0.053)	(0.053)
Middle school	0.083	0.082	0.082	0.132*	0.132*	0.131*
	(0.077)	(0.077)	(0.077)	(0.073)	(0.073)	(0.073)
High school	-0.082	-0.082	-0.082	0.071	0.071	0.070
	(0.093)	(0.093)	(0.093)	(0.087)	(0.087)	(0.088)
Vocational school	-0.190*	-0.190*	-0.191*	-0.115	-0.115	-0.115
	(0.100)	(0.100)	(0.100)	(0.097)	(0.097)	(0.097)
University or higher	-0.229**	-0.229**	-0.229**	-0.270**	-0.270**	-0.269**
	(0.107)	(0.107)	(0.107)	(0.108)	(0.108)	(0.108)

Currently employed	0.023	0.023	0.023	0.032	0.031	0.031
	(0.015)	(0.015)	(0.015)	(0.020)	(0.020)	(0.020)
Married/living together	0.044	0.044	0.044	0.105***	0.105***	0.105***
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Household size	-0.005	-0.005	-0.005	0.004	0.004	0.004
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Home ownership	0.090***	0.090***	0.090***	0.033	0.033	0.033
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Constant	5.907***	5.906***	5.914***	4.349***	4.348***	4.345***
	(0.711)	(0.711)	(0.711)	(0.517)	(0.516)	(0.516)
Observations	55350	55350	55350	54056	54056	54056
Number of individuals	20917	20917	20917	20848	20848	20848
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.102	0.102	0.102	0.120	0.120	0.120

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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), 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3.3 Results by region

When we separate our results by the four main economic regions,[7] EP only significantly discourages life satisfaction in the central region (Table 6), an observation well in line with evidence that, relative to other regions, this area has the highest rate of EP (Lin & Wang, 2020; Wang et al., 2015). This regional heterogeneity may be attributable to a recognized disparity in economic growth and development (Lin & Wang, 2020; Yang & Mukhopadhaya, 2017) by which the central region is poorer than the east. Its financial revenue may thus be lower, leading to less financial expenditure on energy infrastructure construction and reduced availability of the modern energy services so popular in the east. Because to some extent, economic development contributes to such popularity and investment in energy development (Wang et al., 2017), our results imply that economic development may play a pivotal role in energy

[7] We base our regional division on the socioeconomically determined delineation by China's National Bureau of Statistics: East (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan), Northeast (Liaoning, Jilin and Heilongjiang), Central (Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan), and Western (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang).

poverty alleviation.

Table 6 FE estimates of EP's impact on LS among Chinese adults in different geographic regions

	EP1	EP2	EP3
	(1)	(2)	(3)
Panel A: East			
EP	-0.011	-0.016	-0.026
	(0.017)	(0.017)	(0.021)
Observations	35298	35298	35298
Number of individuals	13928	13928	13928
Wave FE	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Adj. R^2	0.116	0.116	0.116
Panel B: Central			
EP	-0.056***	-0.056***	-0.045**
	(0.018)	(0.019)	(0.021)
Observations	27242	27242	27242
Number of individuals	10409	10409	10409
Wave FE	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Adj. R^2	0.099	0.099	0.099
Panel C: West			
EP	-0.003	-0.003	-0.011
	(0.017)	(0.017)	(0.019)
Observations	31348	31348	31348
Number of individuals	12331	12331	12331
Wave FE	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Adj. R^2	0.106	0.106	0.106
Panel D: Northeast			
EP	-0.019	-0.026	-0.030
	(0.025)	(0.026)	(0.030)
Observations	15518	15518	15518
Number of individuals	5609	5609	5609
Wave FE	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Adj. R^2	0.128	0.128	0.128

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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), 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3.4 Results by rural versus urban

As regards EP's different effects on rural versus urban populations, our results initially appear to indicate a 2.4% (EP1) or 2.5% (EP2) decline in life satisfaction among rural residents (Table 7, columns 1-3) but a significant impact on those in urban areas (column 6). This observed difference, however, results from EP1 and EP2 overestimating the extent of EP by including high-income households. When we drop these latter to include low-income households only (i.e., EP3), EP lowers life satisfaction in both rural and urban areas, albeit with a higher prevalence in the former (10.4% versus 6.1%, see Figure 2). At the same time, the larger fraction of rural-urban disparity in the EP3 calculations relative to the EP1 and EP2 measures implies that urban residents have higher energy expenditures than their rural counterparts. Hence, when the focus is solely on low-income groups (EP3), the negative impact of the EP affordability problem on life satisfaction is far larger for urban than for rural residents.

Table 7 FE estimates of EP's impact on LS among Chinese adults in rural versus urban households

	Rural			Urban		
	(1)	(2)	(3)	(4)	(5)	(6)
EP1	-0.024*			-0.018		
	(0.012)			(0.014)		
EP2		-0.025*			-0.019	
		(0.013)			(0.015)	
EP3			-0.013			-0.042**
			(0.014)			(0.018)
Age	-0.089***	-0.089***	-0.089***	-0.050***	-0.050***	-0.051***
	(0.012)	(0.012)	(0.012)	(0.018)	(0.018)	(0.018)
Age squared/100	0.069***	0.069***	0.069***	0.044***	0.044***	0.044***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Primary school	0.036	0.036	0.036	0.056	0.056	0.055
	(0.051)	(0.051)	(0.051)	(0.069)	(0.069)	(0.069)
Middle school	0.023	0.022	0.022	0.238***	0.239***	0.237***
	(0.070)	(0.070)	(0.070)	(0.088)	(0.088)	(0.088)

High school	-0.038	-0.039	-0.039	0.144	0.144	0.143
	(0.093)	(0.093)	(0.093)	(0.098)	(0.098)	(0.098)
Vocational school	-0.289***	-0.290***	-0.289***	0.071	0.071	0.071
	(0.107)	(0.107)	(0.107)	(0.105)	(0.105)	(0.105)
University or higher	-0.231*	-0.232*	-0.233*	-0.056	-0.056	-0.055
	(0.125)	(0.125)	(0.125)	(0.111)	(0.111)	(0.111)
Currently employed	0.026	0.026	0.027	0.027	0.027	0.026
	(0.018)	(0.018)	(0.018)	(0.017)	(0.017)	(0.017)
Married/living together	0.099***	0.099***	0.098***	0.059*	0.059*	0.059*
	(0.033)	(0.033)	(0.033)	(0.032)	(0.032)	(0.032)
Household size	0.002	0.002	0.002	-0.007	-0.007	-0.007
	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)
Home ownership	0.097***	0.097***	0.097***	0.034	0.034	0.034
	(0.031)	(0.031)	(0.031)	(0.021)	(0.021)	(0.021)
Constant	5.256***	5.259***	5.252***	4.409***	4.407***	4.421***
	(0.557)	(0.557)	(0.557)	(0.782)	(0.782)	(0.782)
Observations	57576	57576	57576	51830	51830	51830
Number of individuals	23005	23005	23005	21662	21662	21662
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.113	0.113	0.112	0.104	0.104	0.104

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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), 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

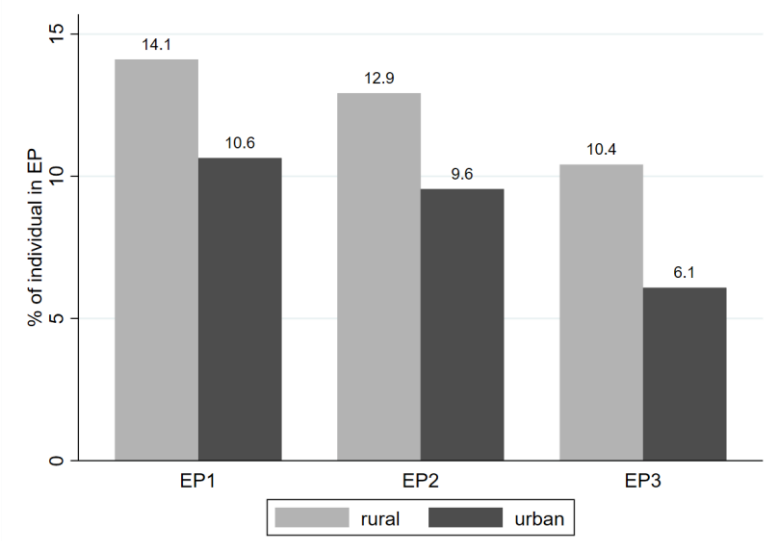

Figure 2 Fraction of EP by rural and urban area

Notes: EP1-EP3 represent the following three indicators, respectively: twice the median percentage of full income (Moore, 2012), the 10% measure (Boardman, 1991), and the amended 10% measure (Kahouli, 2020), which considers low-income households only.

5.5 Underlying mechanisms

To test our three hypotheses that EP negatively affects SEB through poor health (H1), poor housing quality or conditions (H2), and/or food expenditure (H3), we adopt an SEM modeling approach that focuses solely on EP3, the strongest of the three indicators in our main analysis. The values from a goodness-of-fit test confirm the models' appropriateness: RMSEA = 0.057 (< 0.08), SRMR = 0.023 (< 0.08), and CFI = 0.922 (> 0.9). The resulting estimates (see Table 8) not only confirm our baseline result (see Table 3) that EP lowers life satisfaction (standardized coefficient = -0.037, $p<0.01$) but show significant associations between EP and all three of our hypothesized mediators.

More specifically, those experiencing EP are more likely to report a lower health status (standardized coefficient = -0.017, $p<0.01$), live in poor-quality housing (standardized coefficient = 0.049, $p<0.01$), and expend less money on food (standardized coefficient = -0.122, $p<0.01$). In turn, poor housing quality is negatively associated with both SRH (standardized coefficient = -0.010, $p<0.01$) and life satisfaction (standardized coefficient = -0.017, $p<0.01$), suggesting that living in inferior housing raises the likelihood of poor SRH and lower life satisfaction. Conversely, household food expenditure is positively correlated with both SRH

(standardized coefficient = 0.033, p<0.01) and life satisfaction (standardized coefficient = 0.046, p<0.01), implying that having little to spend on food is associated with corresponding deficiencies in physical and emotional health. In fact, household food expenditure mediates around 13.2% of EP's total negative effect on LS (standardized coefficient = -0.004, p<0.01) compared with 9% for SRH (standardized coefficient = -0.001, p<0.01) and 2.2% for poor housing quality (standardized coefficient = -0.006, p<0.01) (see Table 9).[8] These findings not only support all three of our mediation hypotheses, whose mechanisms we detail in Figure 3, but pinpoint household food expenditure as the most important of the three mediators.

Table 8 Path analysis: SEM with controls

Dependent variable	Independent variable	Total effect	Direct effect	Indirect effect
Poor housing	EP3	0.049***	0.049***	
Food expenditure	EP3	-0.122***	-0.122***	
Health	Poor housing	-0.010***	-0.010***	
	Food expenditure	0.033***	0.033***	
	EP3	-0.021***	-0.017***	-0.005***
Life satisfaction	Poor housing	-0.019***	-0.017***	-0.002***
	Food expenditure	0.053***	0.046***	0.007***
	Health	0.221***	0.221***	
	EP3	-0.048***	-0.037***	-0.011***

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

[8] As a robustness check, we redefine poor housing quality using a dummy variable of housing hardship defined as whether a household lives with at least one of the following conditions: (i) children aged over 12 and parents n the same room ; (ii) family members of three generations in the same room; (iii) children over 12 of different genders in the same room; (iv) beds laid out at night and folded up during the daytime; (v) beds laid out in the living room. Rerunning the SEM estimates yields similar results to those reported in Table 9, with around 8% of EP's direct effect on life satisfaction mediated by health, 4% by housing hardship, and 14% by household food expenditure (results available from the authors upon request).

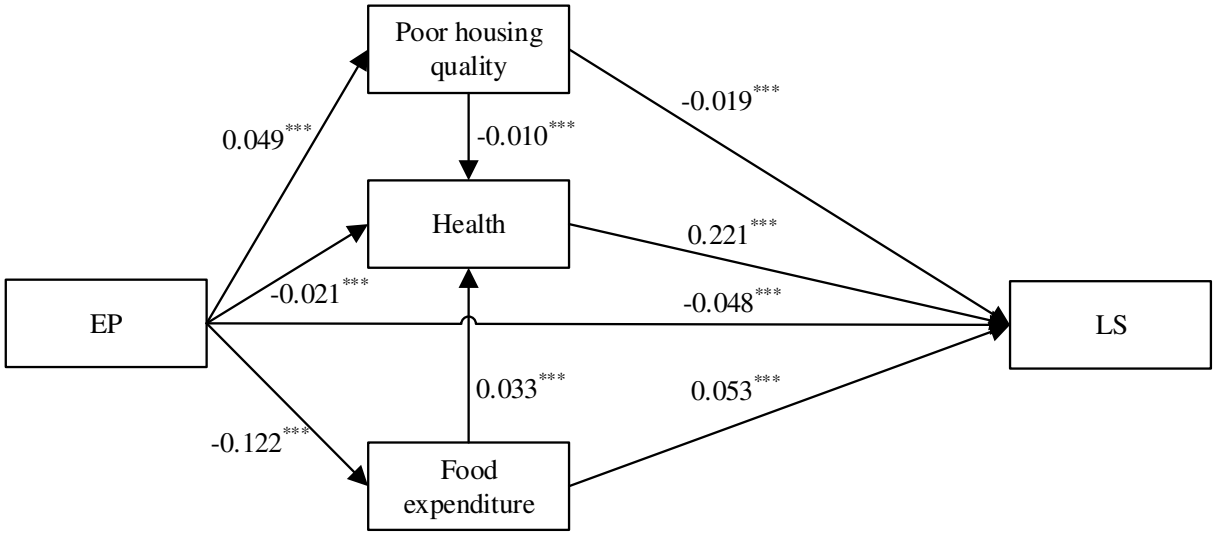

Figure 3 Underlying mechanisms through which EP impacts LS

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

Table 9 Indirect effects of EP on LS and their proportion to total effects: SEM with controls

Mediator	Indirect effect	Standard error	Z-value	Indirect effect/total effect
Health	-0.004***	0.001	-5.103	0.090
Poor housing quality	-0.001***	0.000	-4.728	0.022
Food expenditure	-0.006***	0.000	-12.055	0.132

Notes: The controls are 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, and an urban dummy (1 = urban, 0 = rural). We report the effects as standardized coefficients. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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 subjective well-being 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 housing quality, 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 & Biermann, 2014), EP reduces life satisfaction while contributing to a decline in happiness and an increased likelihood of depression and related symptoms. According to our heterogeneity analysis, this negative impact on life satisfaction is more pronounced among the poor, males, and those residing in China's central regions, whose high EP rate corresponds to the area's slower economic development (Lin & Wang, 2020). This EP-life satisfaction nexus is partially mediated by poor housing quality, health, and household food expenditure, which account for 2.2%, 9%, and 13.2% 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 effectively combat EP by promoting energy development and by providing financial support for the use of alternative energy sources. Lastly, given the sociodemographic heterogeneity in the linkage between EP and life satisfaction, policies aimed at alleviating EP should prioritize the poor, males, and those living in the central 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

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

scarring within a dynamic framework (Kahouli, 2020), a goal dependent on greater availability of detailed longitudinal microdata. Another promising path, given our finding of regional and gender heterogeneities in EP's effects, 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 poor housing quality, 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.

Conflicts of interest

None.

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Appendix:

Table A1 OLS/FE estimates of the EP impact on SWB among Chinese adults: Robustness check using alternative measures

	(1) OLS	(2) FE	(3) OLS	(4) FE	(5) OLS	(6) FE
EP4	-0.039***	0.006				
	(0.010)	(0.011)				
EP5			-0.097***	-0.017		
			(0.009)	(0.012)		
EP6					-0.096***	-0.026***
					(0.009)	(0.010)
Age	-0.027***	-0.069***	-0.028***	-0.070***	-0.028***	-0.070***
	(0.002)	(0.010)	(0.002)	(0.010)	(0.002)	(0.010)
Age squared/100	0.035***	0.054***	0.036***	0.054***	0.035***	0.054***
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)
Gender	-0.068***		-0.065***		-0.067***	
	(0.008)		(0.008)		(0.008)	
Primary school	0.003	0.048	-0.006	0.046	-0.001	0.047
	(0.012)	(0.040)	(0.012)	(0.040)	(0.012)	(0.040)
Middle school	-0.008	0.112**	-0.022*	0.107**	-0.014	0.113**
	(0.012)	(0.053)	(0.012)	(0.053)	(0.012)	(0.053)
High school	-0.011	0.005	-0.029**	-0.001	-0.020	0.002
	(0.014)	(0.064)	(0.014)	(0.064)	(0.014)	(0.064)
Vocational school	0.038**	-0.137**	0.018	-0.142**	0.026	-0.137*
	(0.018)	(0.070)	(0.018)	(0.070)	(0.018)	(0.070)
University or higher	0.074***	-0.235***	0.052***	-0.245***	0.060***	-0.237***
	(0.019)	(0.076)	(0.019)	(0.077)	(0.019)	(0.077)
Currently employed	0.031***	0.029**	0.039***	0.029**	0.030***	0.028**
	(0.009)	(0.012)	(0.009)	(0.012)	(0.009)	(0.012)
Married/living together	0.195***	0.077***	0.194***	0.074***	0.196***	0.078***
	(0.012)	(0.022)	(0.011)	(0.022)	(0.012)	(0.022)
Household size	0.013***	0.000	0.014***	0.000	0.011***	-0.001
	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.004)
Home ownership	0.124***	0.060***	0.129***	0.058***	0.121***	0.055***
	(0.013)	(0.017)	(0.013)	(0.017)	(0.013)	(0.017)
Urban	0.027***		0.004		0.025***	
	(0.008)		(0.009)		(0.008)	
Constant	3.491***	4.903***	3.539***	5.023***	3.524***	5.003***
	(0.056)	(0.423)	(0.057)	(0.426)	(0.057)	(0.426)
Observations	109072	109072	109084	109084	108750	108750
Number of Individuals		41721		41703		41659
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes

Adj. R^2	0.091	0.109	0.093	0.110	0.092	0.110

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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 A2 OLS/FE estimates of the EP impact of EP on the SWB factors of happiness, depression, and depressive symptoms among Chinese adults in the 2012-2018 CFPS sample

	(1) OLS	(2) FE	(3) OLS	(4) FE	(5) OLS	(6) FE
Panel A: Happiness						
EP1	-0.151***	0.008				
	(0.024)	(0.035)				
EP2			-0.164***	-0.003		
			(0.025)	(0.037)		
EP3					-0.272***	-0.039
					(0.029)	(0.043)
Observations	54069	54069	54069	54069	54069	54069
Number of individuals		35710		35710		35710
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes
Adj. R^2	0.050	0.010	0.050	0.010	0.051	0.010
Panel B: Depression (score)						
EP1	0.835***	0.325***				
	(0.063)	(0.066)				
EP2			0.854***	0.316***		
			(0.066)	(0.069)		
EP3					1.056***	0.247***
					(0.077)	(0.079)
Observations	109245	109245	109245	109245	109245	109245
Number of individuals		41728		41728		41728
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes
Adj. R^2	0.081	0.005	0.081	0.005	0.081	0.005
Panel C: Depressive symptoms						
EP1	0.037***	0.012***				
	(0.004)	(0.004)				
EP2			0.039***	0.014***		
			(0.004)	(0.004)		
EP3					0.050***	0.010**
					(0.004)	(0.005)
Observations	109245	109245	109245	109245	109245	109245
Number of individuals		41728		41728		41728
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes

Adj. R^2	0.061	0.013	0.061	0.013	0.062	0.013

Notes: The dependent variables are happiness, depression 9score), 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 A3 Ordered logit/FE ordered logit estimates of the EP impact of EP on LS among Chinese adults in the 2012-2018 CFPS sample

	(1)	(2)	(3)	(4)	(5)	(6)
	OL	FEOLM	OL	FEOLM	OL	FEOLM
EP1	-0.114***	-0.064***				
	(0.015)	(0.021)				
EP2			-0.118***	-0.070***		
			(0.015)	(0.022)		
EP3					-0.171***	-0.060**
					(0.018)	(0.024)
Age	-0.050***	-0.166***	-0.050***	-0.166***	-0.050***	-0.166***
	(0.003)	(0.028)	(0.003)	(0.028)	(0.003)	(0.028)
Age squared/100	0.064***	0.125***	0.065***	0.125***	0.065***	0.125***
	(0.003)	(0.012)	(0.003)	(0.012)	(0.003)	(0.012)
Gender	-0.120***		-0.120***		-0.120***	
	(0.014)		(0.014)		(0.014)	
Primary school	-0.036*	0.025	-0.036*	0.025	-0.040*	0.024
	(0.022)	(0.093)	(0.022)	(0.093)	(0.022)	(0.093)
Middle school	-0.077***	0.106	-0.077***	0.105	-0.083***	0.103
	(0.022)	(0.122)	(0.022)	(0.122)	(0.022)	(0.122)
High school	-0.091***	-0.145	-0.092***	-0.146	-0.100***	-0.147
	(0.025)	(0.151)	(0.025)	(0.151)	(0.025)	(0.151)
Vocational school	-0.025	-0.477***	-0.025	-0.477***	-0.033	-0.477***
	(0.032)	(0.173)	(0.032)	(0.173)	(0.032)	(0.173)
University or higher	0.021	-0.622***	0.022	-0.623***	0.016	-0.621***
	(0.034)	(0.195)	(0.034)	(0.195)	(0.034)	(0.195)
Currently employed	0.041**	0.050*	0.042**	0.050*	0.042**	0.051*
	(0.017)	(0.028)	(0.017)	(0.028)	(0.017)	(0.028)
Married/living together	0.338***	0.220***	0.338***	0.220***	0.336***	0.220***
	(0.021)	(0.051)	(0.021)	(0.051)	(0.021)	(0.051)
Household size	0.019***	-0.003	0.019***	-0.003	0.017***	-0.003
	(0.004)	(0.008)	(0.004)	(0.008)	(0.004)	(0.008)
Home ownership	0.216***	0.139***	0.216***	0.139***	0.216***	0.139***
	(0.022)	(0.040)	(0.022)	(0.040)	(0.022)	(0.040)
Urban	0.046***		0.046***		0.041***	
	(0.015)		(0.015)		(0.015)	
Observations	109406	145612	109406	145612	109406	145612
Number of individuals		83388		83388		83388
Wave FE	Yes	Yes	Yes	Yes	Yes	Yes
Provincial FE	Yes	Yes	Yes	Yes	Yes	Yes

Individual FE	No	Yes	No	Yes	No	Yes
Pseudo R^2	0.036	0.129	0.036	0.129	0.036	0.129

Notes: The dependent variable is life satisfaction, 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). OL 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 A4 Lewbel's 2SLS estimates among Chinese adults

	(1)	(2)	(3)	(4)	(5)	(6)
	Lewbel internal IV			Lewbel internal & external IV		
EP1	-0.077**			-0.071**		
	(0.036)			(0.036)		
EP2		-0.066*			-0.061*	
		(0.034)			(0.034)	
EP3			-0.094***			-0.092***
			(0.024)			(0.024)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	109403	109403	109403	109403	109403	109403
First stage						
F-statistic	36.320	39.300	108.530	32.690	35.550	88.480
J P-value	7.395	4.070	5.948	10.169	6.729	8.623
Pagan-Hall test	2327.392***	2506.905***	2517.982***	2506.838***	2511.847***	2523.478***
Bresuch-Pagan test	2293.838***	2296.385***	2305.005***	2299.122***	2301.449***	2309.901***

Notes: Based on 2012-2018 CFPS data. The dependent variable is life satisfaction, 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), 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.