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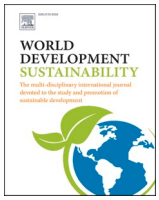

Energy poverty and mental distress in South Africa: Assessing linkages and potential pathways

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ABSTRACT

Despite the increasing attention on energy poverty due to its health implications, the South African story is yet to be told, while pathways of influence have received little empirical investigation in the extant literature. This study examines how energy poverty affects mental distress in post-apartheid South Africa and explores gender and locational heterogeneities in outcomes as well as potential pathways. We use five years of longitudinal data extracted from the National Income Dynamics Survey (NIDS). We employ the Lewbel instrumental variable method to resolve endogeneity and apply causal mediation analysis to identify potential channels of effect. The findings suggest that energy poverty is associated with an increase in mental distress. This outcome is consistent across different estimation methods and conceptualisations of energy poverty. The deteriorating effect of energy poverty on mental distress is more pronounced among females and rural residents. We further establish that experiences of persistent cough and chest pains/tightness serve as potential pathways in the link between energy poverty and mental distress. We encourage the South African government to increase budgetary allocations to the free basic electricity policy and provide connection subsidies to poor households, which have the potential to alleviate energy poverty and reduce mental distress as a result.

Introduction

Energy poverty is a multifaceted issue that has far-reaching socio-economic implications and arises from a lack of access to reliable, affordable, and clean energy services [5,21,36]. In addition to its immediate implications on living conditions, energy poverty can have significant, yet underexplored impacts on mental health or distress [42,46]. Mental distress refers to "a state of emotional suffering characterised by symptoms of depression (e.g., loss of interest; unhappiness; desperateness) and anxiety (e.g., restlessness; feeling tense)" ([6], p. 1). Similarly, Mboya et al. [28] depict mental distress to be symptomized by anxiety, depression and somatic symptoms such as sleeping problems, fatigue and headache. Some studies have been undertaken to examine the energy poverty–mental health nexus in Asia [24,48], Europe [31], Australia [7], and in some African countries [26,41]. The connection between energy poverty and mental health can operate through several interrelated pathways. First, reduced comfort from inadequate heating, cooling, and lighting has been linked to elevated levels of stress and anxiety [9,46]. Second, financial stress resulting from high energy costs can exacerbate feelings of insecurity and worsen mental distress [25]. Third, energy deprivations may constrain communication, cooking, and entertainment, resulting in social isolation and worse mental health [15]. Furthermore, indoor air pollution increases the risk of headache, cough, respiratory irritations, chest pains, dizziness, watery eyes and other health complications [12,39,43], which can increase mental distress. According to a Canadian study, chronic productive cough is associated with an estimated 49 % increased risk of mortality [40]. Cardiovascular diseases, which are characterised by chest pain/tightness, account for 38.3 % of deaths attributed to non-communicable diseases [30]. Existing studies have also shown that gender and spatial disparities exist in energy related deprivations and mental distress experiences [11,16,27,34].

After a critical assessment of the literature, we identify three main gaps that motivate the current study. First, although the energy poverty–mental health nexus continues to attract scholarly attention in Asia, Europe, Australia and some other African countries, the South African story is yet to be examined, despite South Africa's high rate of energy poverty [19,20] and increasing prevalence of mental distress or depression [14,16]. Second, most of the existing studies anecdotally discuss health complications as possible reasons for the deteriorating effect of energy poverty on mental health but do not empirically analyse such mediation effects [7,26,48]. Third, despite the socio-demographic

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disparities in energy poverty and mental distress identified in the extant literature, majority of the studies have not engaged in gender and rural-urban analysis to assess the differential impact of energy poverty on mental distress (e.g., [7,24,26]).

In response to the gaps identified, this study examines the effect of energy poverty on mental distress in South Africa, using longitudinal data extracted from the National Income Dynamics Survey (NIDS). We assess heterogeneities in our findings by engaging in gender and location-specific analyses. The potential roles of respondent's coughing and chest pain/tightness experiences as pathways in the energy poverty–mental distress nexus are also explored. Overall, our findings suggest that energy poverty worsens mental distress, with the effects being greater among women and rural residents. Persistent cough and chest pain/tightness experiences among respondents are identified as important pathways through which energy poverty affects mental distress.

The South African context

We explore the link between energy poverty and mental distress within the South African context for two main reasons.

Available statistics overtime shows that energy poverty in South Africa is considerably high. Olawumi Israel-Akinbo et al. [35] found multidimensional energy poverty in South Africa to be between 39 % and 61 % among low-income households in rural and urban areas respectively. Another study by Ye and Koch [47], using the Foster–Greer–Thorbecke (FGT) approach to poverty measurement, identified 58 % of the households in South Africa as experiencing energy poverty. Considering the gendered perspective, Longe [27] discovered that 57 % of those living in energy poverty were women, who are responsible for gathering firewood and traditional 'dirty' cooking fuels. To alleviate energy poverty, the South African government has set a target to achieve universal access to electricity for households by 2025. To achieve this target, the government has initiated programs such as Integrated National Electrification Programme (INEP), Free Basic Electricity Policy (FBE), Free Basic Alternative Energy Policy (FBAE), and Inclining Block Tariff (IBT) [37]. From 2023, the government has allocated funding of around R17 billion per year for 50 kgwatt-hours of FBE to reach 11.2 million low-income homes [37].

With regard to mental health, a recent study considers South Africans as having greater depression and anxiety rates than other countries [14]. Craig et al. [14] found 25.7 % of South Africans to be depressed compared to the Australian rate of 10 % in 2014, 6.9 % in the US (2011), and 5.6 % in Germany (2013). Racial and locational disparities exist in the rate of psychological distress in South Africa. Harriman et al. [16] posit that psychological distress varies by race, with Africans feeling more distressed than Whites and Coloured people. Among Africans, those located in urban areas experience higher mental distress compared to their counterparts in rural localities [16]. Gender-wise, female South Africans are more likely to experience mental distress [34], which is consistent with findings from a study undertaken across 73 countries [11]. The prevalence of persistent cough is as high as 24.8 % in urban South Africa [4]. According to some reports, the nation's biggest cause of mortality is cardiovascular disorders (i.e., 18.9 % of all deaths) [44], while chest pains/tightness (i.e., Angina) was found to be 9.5 % among adults [38].

Considering the high rates of energy poverty and mental distress in South Africa, using South Africa as a case study is apt. The socio-demographic and locational disparities in energy deprivations and mental distress experiences also provide a reasonable basis to explore heterogeneities in findings along gender and locational lines.

Based on inferences from the body of existing research, Fig. 1 illustrates the hypothesised relationships between energy poverty, the potential mediators and mental distress. Due to data limitations, the potential mediating roles of persistent cough and chest pain/tightness are tested in Section 5.5.

Data and variables

This research utilises longitudinal data from all five waves (2008–2017) of the National Income Dynamics Survey (NIDS), a comprehensive household panel study conducted across South Africa. The NIDS is administered by the Southern Africa Labour and Development Research Unit (SALDRU) in the University of Cape Town and captures information regarding the evolving circumstances of individuals and families over time (SALDRU, 2018). Apart from key socio-demographic characteristics covered, the NIDS offers in-depth insights into households and individual level variables such energy sources for cooking and lighting, health, assets, employment and time use, finances, and many others. For an exhaustive comprehension of the NIDS dataset and the specific modules it covers, interested parties can refer to the NIDS panel user manual [10]. Our extracted sample comprised 38,760 individuals due to low observations associated with the disposable income variable. Finally, the regression model contained 27,437 individuals due to further missing data in some of the variables.

Mental distress

Mental distress is measured using the10-item Centre for Epidemiological Studies Depression Scale (CES-D-10) which is employed to assess respondents' mental distress in the NIDS survey [8,13,29]. Respondents were asked to rate the frequency with which they experienced depressive symptoms in the past week using a four-point scale from 1 ("Rarely or none of the time") to 4 ["All of the time (5–7 days)"]. To be consistent with the CES-D-10 approach, the responses are rescaled to range from 0 to 3. These depressive feelings include: (i) I was bothered by things that usually don't bother me; (ii) I had trouble keeping my mind on what I was doing; (iii) I felt depressed; (iv) I felt that everything I did was an effort; (v) I felt hopeful about the future; (vi) I felt fearful; (vii) My sleep was restless; (viii) I was happy; (ix) I felt lonely; and (x) I could not "get going". Before summing up the responses to produce a mental

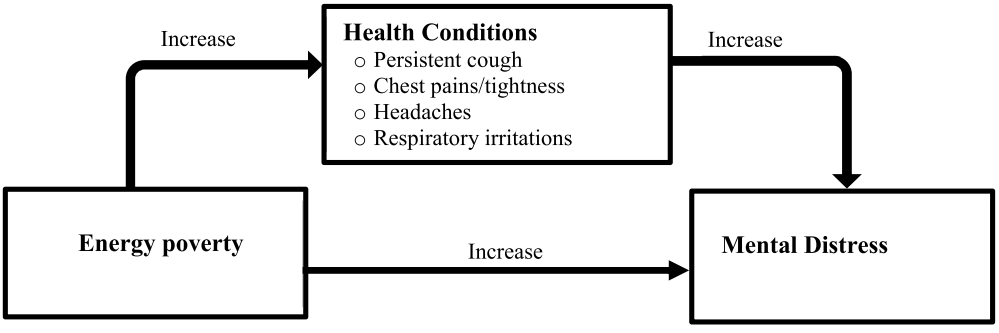

Fig. 1. Conceptual relationship between energy poverty, health conditions and mental health.
(Source: Authors' Construct).

distress/depression score, the positive mood items (v and viii) were reverse-coded to align with the other eight. Consistent with the literature [8,13,29], we obtained an additive mental distress score which ranges from 0 (least depressed) to 30 (most depressed). A unit increase in the score reflects an increase in mental distress.

Energy poverty

We measure energy poverty using the multidimensional energy poverty index (MEPI), a construct that has been commonly employed in developing country studies [2,19,20]. We derived the MEPI by considering five dimensions along with their corresponding indicators and associated weights [19,21,33]. These five dimensions encompass cooking, lighting, home appliances, entertainment/education, and communication (All indicators and weights are displayed in Table A1).

All five dimensions of the MEPI can be equally weighted (0.2) but a bigger weight is assigned to the cooking and lighting dimensions, considering their greater significance within the energy poverty context, relative to the other three [19,21,33]. The cooking dimension is given a weight of 0.41, the lighting dimension is assigned a weight of 0.20, while each of the remaining three dimensions is allocated a weight of 0.13. As shown in Table A1, all indicators of the MEPI are coded to reflect deprivations. The energy deprivation score which ranges from 0 to 1 is computed using Eq. (1):

$$MEPI_i = w_i I_i + w_2 I_2 + \ldots + w_n I_n \tag{1}$$

Where $MEPI_i$ represents the multidimensional energy deprivation score for a respondent's household. $I_i = 1$ if a household lacks indicator I, and 0 if otherwise. w_i represents the weight assigned to I. An increase in MEPI by one implies an increase in energy poverty [19,21]. We follow previous studies to obtain binary indicators of energy poverty using poverty cut-offs of 0.33 and 0.5 (see e.g., [21,22]). Using these cut-offs, a household is deemed to be energy poor if its MEPI score is equal to or greater than the cut-off. In our analyses, the MEPI score is applied as the main measure of energy poverty, while the binary versions are used for robustness testing.

Mediators

To explore some potential but intricate pathways via which energy poverty affects mental distress, we focus on persistent cough and chest pain/tightness experiences of respondents because they remain two of the main health complications that can result from indoor pollution associated with the use of traditional and dirty fuels.

With persistent cough, we use the NIDS question which asked respondents whether they have experienced persistent cough in the last 30 days. As a binary variable, an affirmative response to this question is captured as 1 while a "No" response is coded as 0. A similar cough question was also used to ensure that all cough symptoms are recorded. This question asked participants if they had experienced 'cough with blood'. Respondents who answered 'No' to the persistent cough question but answered 'Yes' to the 'cough with blood' question had the persistent cough question recoded as 1.

Chest pain/tightness is measured using a binary variable based on two questions. These questions asked whether respondents had experienced (i) chest pain; or (ii) tight chest in the last 30 days. Our variable is coded 1 if a respondent answers "Yes" to either of the two questions while a consistent "No" response to both questions is captured as 0. Table A2 provides a description and summary statistics for the variables included in the analysis.

Estimation procedure

To examine the relationship between energy poverty and mental distress, we apply ordinary least squares (OLS) and include other important covariates as indicated in our baseline model (see Eq. (2)).

$$MDstress_{iht} = \alpha MEPI_{ht} + \beta X_{iht} + \gamma H_{ht} + \delta_t + \omega_p + \varepsilon_{iht} \tag{2}$$

where $MDstress_{it}$ is the mental distress score of individual i in household h at time/wave t. $MEPI_{ht}$ is the energy poverty score of a respondent's household h. X and H respectively represent sets of individual- and household-level controls found in earlier studies as drivers of mental distress. These variables include gender, education, income, age and age-squared, household size, location, and marital status [24,26,41,48]. We also include wave (δ_t) and province (ω_p) fixed effects to capture contextual heterogeneities in time and space that can influence mental distress. ε_{iht} is a random error term.

As indicated in previous studies, the estimated effect of energy poverty on mental distress can be biased due to endogeneity [24,26,48]. The endogeneity issue associated with energy poverty has been instrumented with energy prices [26], but increases in and volatility of energy prices also have the potential to affect mental well-being [45], which can invalidate energy price as an instrument in the energy poverty–mental distress nexus. Some studies have used the energy poverty rate at the provincial level as instrument [24,48] but other contextual and missing observations can render this instrument weak or invalid. As a result, we employ the Lewbel [23] two-stage least squares (2SLS) method which does not require an external instrumental but relies on heteroskedasticity in the data to produce valid internal instruments in the 2SLS process to address endogeneity [3,17,18,23]. To apply the Lewbel [23] method, we estimate Eqs. (3) and (4).

$$Y_1 = X'\beta_1 + Y_2\gamma_1 + \xi_1 \;\; \xi_1 = \alpha_1 U + V_1 \tag{3}$$

$$Y_2 = X'\beta_2 + \xi_2 \;\; \xi_2 = \alpha_2 U + V_2 \tag{4}$$

where, Y_1 denotes mental distress and Y_2 is energy poverty. U comprises of unobserved characteristics that affect both household energy poverty and mental distress. V_1 and V_2 are idiosyncratic errors. The method is applied by taking a vector Z of observed exogenous variables and utilizing $[Z - E(Z)]\xi_2$ as an instrument, provided that:

$$E(X\ \xi_1) = 0,\ E(X\ \xi_2),\ cov(Z,\ \xi_1,\ \xi_2) = 0 \tag{5}$$

and there is some heteroskedasticity in ξ_j. The vector Z could be a subset of X or equal to X.

Results

Preliminary results

The preliminary estimates for the association between energy poverty and mental distress are shown in Table 1. Results for the full, male, and female samples are reported in Columns 1 to 3 respectively. Overall, results for the full sample suggests that an increase in energy poverty is associated with a 0.137 increase in mental distress. The outcome is consistent with our *a priori* expectation because people who live in energy poor households are more likely to experience discomfort associated with inadequate heating, and cooling which have the potential to elevate stress and anxiety levels. People residing in households without electricity experience communication and entertainment challenges which can result in social isolation and worse mental health. The health complications associated with indoor pollution due to the use of biomass cooking fuels and paraffin stove/lights can further constrain sleep and increase mental distress. In Columns 2 and 3, we observe that an increase in energy poverty is associated with 0.136 and 0.139 increases in mental distress among males and females, respectively. By inference, energy poverty has a greater deteriorating effect on mental distress among women compared to men. This notwithstanding, the preliminary results can be biased by the endogeneity problem associated with energy poverty.

Table 1
Energy poverty and mental distress (baseline results).

	(1)	(2) Gender	(3)
Variables	Full	Male	Female
Energy poverty score	0.137***	0.136***	0.139***
	(0.011)	(0.015)	(0.016)
Female	0.005	—	—
	(0.005)	—	—
Educated	−0.018*	−0.020	−0.016
	(0.010)	(0.014)	(0.013)
log(net income)	−0.034***	−0.033***	−0.035***
	(0.002)	(0.004)	(0.003)
Age	0.027*	0.036*	0.019
	(0.014)	(0.021)	(0.020)
Age squared	−0.005**	−0.007*	−0.004
	(0.003)	(0.004)	(0.004)
Household size	−0.002**	−0.002	−0.003**
	(0.001)	(0.001)	(0.001)
Rural	0.067***	0.056***	0.078***
	(0.006)	(0.009)	(0.009)
Marital status (Base=Never married)			
Married	−0.027***	−0.021***	−0.034***
	(0.005)	(0.008)	(0.007)
Widowed/Divorced/Separated	0.105***	0.118***	0.095***
	(0.011)	(0.017)	(0.015)
Wave fixed effects	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes
Observations	27,437	13,385	14,052
R-squared	0.052	0.049	0.056

Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Endogeneity-corrected results

In this section, we employ the Lewbel 2SLS method to address the endogeneity problem and report the results in Table 2. Compared with the baseline results, we see that the 2SLS estimates are bigger in magnitude. This suggests that the preliminary results were biased downwards. In Column 1, results from the full sample shows that an increase in energy poverty results in a 0.239 increase in mental distress. This implies that the high energy poverty rate in South Africa [19,35] partly accounts for the relatively high rates of depression and anxiety compared to other countries [14]. Our finding is supported by previous studies that have shown that energy poverty worsens mental distress [24,26,41,48].

Considering the gender-specific results in Columns 2 and 3, an increase in energy poverty worsens mental distress by 0.219 and 0.246 among men and women, respectively. This confirms that energy poverty worsens mental distress among women more than men. With 57 % of energy poor victims being women, while mental distress is higher among South African women, we can deduce that energy poverty can widen the gender gap in mental distress in South Africa. This gender effect is largely expected because in developing countries, women are mainly responsible for gathering firewood and traditional 'dirty' cooking fuels. Even in situations where men gather firewood, women are responsible for cooking and end up experiencing more of the health complications of indoor pollution associated with use of biomass and other dirty fuels for cooking and lighting.

Location-specific outcomes

Table 3 presents results that are specific to each location. In Column 1, we observe that an increase in energy poverty is associated with a 0.326 increase in mental distress among rural residents. Considering Column 2, an increase in energy poverty deteriorates mental distress by 0.290 among those located in urban areas. This implies that energy poverty has a greater deteriorating effect on mental distress among rural residents compared to their urban folks. Similar to the gender outcome, rural residents suffer greater deprivations in access to clean energy and are more likely to experience its negative consequence on mental distress. Rural residents are more likely to experience the prolonged cooking time and inconvenience associated with biomass fuels, hence the greater consequence of energy poverty on their mental health.

Robustness/sensitivity checks

In this section, we test for robustness using alternative energy poverty measures, different weights for dimensions and varied cut-offs (see Table 4). First, we alter the conventional weighting system, which gives the cooking dimension a weight of 0.41. Instead, we give electricity more weight (0.41), cooking gets 0.2, and the other three MEPI dimensions get 0.13 each. The results are shown in Column 1. Second, we assign each MEPI dimension an equal weight of 0.2 and generate the results shown in Column 2. Third, we use the binary energy poverty measure, which is employed to identify energy-poor households based on a union (traditional) cut-off of 0.33 and report the estimates in Column 3. Finally, we utilise a dual cut-off of 0.5 to determine if a household is experiencing energy poverty and display the findings in Column 4. All approaches consistently show that energy poverty contributes to an increase in mental distress. From Columns 1 to 4, we see that an increase in energy poverty is associated with increases in mental distress ranging from 0.225 to 0.394. We can infer that the effect of energy poverty in worsening mental distress is consistently established when alternative weights and cut-offs are employed to measure multidimensional energy poverty.

Potential pathways

In this section, we explore respondents' persistent cough and chest pain/tightness experiences as two possible pathways via which energy

Table 2
Energy poverty and mental distress (IV results).

	(1)	(2) Gender	(3)
Variables	Full	Male	Female
Energy poverty score	0.239***	0.219***	0.246***
	(0.020)	(0.029)	(0.027)
All other controls	Yes	Yes	Yes
Wave fixed effects	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes
First stage			
F-statistic	253.82	121.80	153.64
J p-value	0.1374	0.114	0.174
Observations	27,437	13,385	14,052
R-squared	0.049	0.047	0.053

Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 3
Energy poverty and mental distress (IV results: location).

	(2)	(3)
Variables	Rural	Urban
Energy poverty score	0.326***	0.290***
	(0.035)	(0.038)
All other controls	Yes	Yes
Wave fixed effects	Yes	Yes
Province fixed effects	Yes	Yes
First stage		
F-statistic	49.96	55.62
J p-value	0.136	0.124
Observations	9580	17,857
R-squared	0.030	0.043

Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4
Energy poverty and mental distress (IV results: alternative measures).

Variables	(1) Energy poverty score Bigger weight (0.41) to electricity	(2) Equal weights	(3) Energy poverty cut-offs Cut-off=0.33	(4) Cut-off=0.5
Energy poverty	0.359***	0.394***	0.225***	0.232***
	(0.025)	(0.027)	(0.016)	(0.016)
All other controls	Yes	Yes	Yes	Yes
Wave fixed effects	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
First stage				
F-statistic	141.52	156.52	178.56	175.48
J p-value	0.126	0.141	0.128	0.101
Observations	27,502	27,502	27,502	27,502
R-squared	0.033	0.041	0.031	0.037

Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5
Effect of energy poverty on persistent cough and chest pains or tightness.

Variables	(1) Persistent cough	(2) *Chest pain/tightness*
Energy poverty score [EM]	0.034***	0.051***
	(0.003)	(0.003)
All controls	Yes	Yes
Observations	27,437	27,437

Standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.
EM: Effect on mediator.

poverty can affect mental distress. To do this, we use path analysis or structural equation modelling (SEM) to estimate the total, direct, and indirect effects [1,32]. As an initial step (see Table 5), we statistically test whether energy poverty is significantly associated with coughing and chest pain/tightness experiences. The results in Columns 1 and 2 show that energy poverty is respectively associated with 3.4 and 5.1 percent increases in the probability of experiencing persistent cough and chest pain/tightness symptoms, which is consistent with the literature [12,39,43].

Next, we evaluate the mediating roles of persistent cough and chest pain/tightness in Columns 1 and 2, respectively using the estimated total, direct, and indirect effects presented in Table 6. In Column 1, we observe that experiencing a persistent cough symptom is associated with a 0.098 increase in mental distress. We also see that the total effect of energy poverty in increasing mental distress is 0.153. Of this total effect, the mediating/indirect effect of persistent cough experience is 0.003 which is statistically significant. Put differently, experiencing a cough symptom contributes about 2.2 % to the total effect of energy poverty on mental distress in South Africa. This implies that experiencing persistent cough symptom plays a significant mediating role in the energy poverty–mental distress nexus. In Column 2, suffering a chest pain/tightness is associated with a 0.163 increase in mental distress. While the total effect of energy poverty in increasing mental distress is 0.151 the mediating effect of chest pain/tightness is 0.008 (5.3 %) which is also significant at the 1 % alpha level. By inference, chest pain/tightness also plays a significant mediating role in the effect of energy poverty on mental distress.

Table 6
Path (SEM) analysis with total, direct, and indirect effects.

Variables	(1) *Mediator: Persistent cough*	(2) *Mediator: Chest pain/ tightness*
Energy poverty score [DE]	0.150***	0.143***
	(0.004)	(0.004)
Persistent cough [ME]	0.098***	
	(0.003)	
Chest pain/tightness [ME]		0.163***
		(0.004)
Mediation indicators		
Total effect [TE]	0.153***	0.151***
	(0.004)	(0.004)
Direct effect [DE]	0.150***	0.143***
	(0.004)	(0.004)
Indirect effect [IE=EM*ME]	0.003***	0.008***
	(0.001)	(0.001)
Observations	27,437	27,437

Standard errors in parentheses.
*** $p<0.01$.
DE: Direct effect; ME: Mediator effect; TE: Total effect; IE: Indirect effect.

Concluding remarks

The impact of energy poverty on mental health has gained traction in the literature but remains an underexplored phenomenon globally. While studies on this topic have been carried out in some African countries, the South African version of the story remains untold. We filled this gap in the current study by analysing the impact of energy poverty on mental distress in South Africa using the NIDS panel data. Gender and locational heterogeneities were examined while potential pathways of effect were explored. We obtained consistent estimates by employing the Lewbel 2SLS strategy to address endogeneity.

Our overall finding showed that energy poverty worsens mental distress. An increase in energy poverty increases mental distress more among women. The bigger effect on women can be attributed to women's gender roles within households, which make them more responsible for cooking and thus more susceptible to the adverse health effects of indoor pollution caused by the use of harmful fuels for cooking and lighting. Similarly, the worsening effect of energy poverty on mental distress is more pronounced among rural residents which can be linked to their greater reliance on traditional fuels for cooking and lighting.

Government and policymakers are urged to design policies that support and accelerate households' energy transition process which has the potential to eliminate the physical health impacts of energy poverty and reduce its mental health consequences. The South African government can achieve this by increasing budgetary allocations to the free basic electricity policy and providing connection subsidies to poor households which have the potential to alleviate energy poverty. Other energy poverty reducing programs that have been rolled out (e.g., INEP, FBAE, IBT etc.) must be pursued to achieve the 2025 target of attaining universal access to electricity for households. Such policies will have direct and indirect effects on the attainment of sustainable development objectives (SDGs). Accelerating households' energy transition and decreasing energy poverty are consistent with SDG 7, which seeks to guarantee that all individuals have access to cheap, reliable, sustainable, and modern energy sources for cooking and lighting. Reducing mental health consequently is also directly linked to attainment of good health and well-being (SDG 3). Indirectly, reductions in energy poverty reduce inequality (SDG 10), alleviate poverty (SDG 1), improve children's educational outcomes (SDG 4), and enhance food security (SGD 2).

Our study is limited by the data availability, which only permitted us to explore the mediating roles of persistent cough and chest pains/ tightness, despite the potential roles of headaches and respiratory irritations as indicated in the literature. Our data also limited us to the use of the MEPI construct, while the availability of a subjective measure relating to room heating inability would have provided us with an alternative energy poverty construct for a robustness check.

Declaration of Competing Interest

The authors report no conflict of interest.

Appendices

Table A1
Dimensions, indicators and weights for multidimensional energy poverty.

Dimension	Indicator (weight)	Variables	Deprivation cut-off (energy poor if…)
Cooking	Modern cooking fuel *(0.41)*	Type of cooking fuel	Any fuel use besides electricity, LPG, kerosene, natural gas, or biogas.
Lighting	Electricity access *(0.20)*	Has access to electricity	False
Services provided by means of household appliances	Household appliance ownership *(0.13)*	Has a fridge	False
Entertainment/education	Entertainment/education appliance ownership *(0.13)*	Has a radio OR television	False
Communication	Telecommunication means *(0.13)*	Has a phone land line OR mobile phone	False

Table A2
Summary statistics.

Variable	Description	Mean	Std. dev.
Mental distress	CES-D 10-item depression score	0.646	0.425
Energy poverty score	Multidimensional energy poverty score	0.145	0.252
Energy poverty score (41)	Multidimensional energy poverty score with wight of 0.41 assigned to electricity	0.143	0.250
Energy poverty score (EQ)	Multidimensional energy poverty score with equal weigh assigned to all dimensions	0.143	0.230
Energy poverty status	=1 if multidimensional energy poverty score is greater or equal to 0.33	0.160	0.367
Energy poverty status(5)	=1 if multidimensional energy poverty score is greater or equal to 0.5	0.119	0.324
Female	=1 if respondent is female	0.512	0.500
Educated	=1 if respondent is educated	0.858	0.349
log(disposable income)	log of respondent's disposable income	7.746	1.317
Age	Age of the respondent	3.009	0.925
Age squared	Age of the respondent squared	9.907	4.700
Household size	Number of persons in respondent's household	4.777	3.185
Rural	Binary variable equals 1 if respondent is located in a rural area	0.349	0.477
Married	Binary variable equals 1 if respondent is married	0.431	0.495
Widowed/Divorced/Separated	Binary variable equals 1 if respondent is widowed/divorced/separated	0.065	0.247
Persistent Cough	=1 if respondent experienced persistent cough in the last 30 days	0.133	0.339
chest pain/tightness	=1 if respondent experienced chest pain/tightness in the last 30 days	0.097	0.295

References

[1] K. Abbas, D. Xu, S. Li, K. Baz, Health implications of household multidimensional energy poverty for women: a structural equation modeling technique, Energy Build. 234 (2021), 110661.

[2] F. Adusah-Poku, K. Takeuchi, Energy poverty in Ghana: any progress so far? Renewable Sustainable Energy Rev. 112 (2019) 853–864.

[3] D. Ansong, I. Koomson, M. Okumu, M. Alhassan, T. Makubuya, M.K. Abreh, Private supplementary tutoring expenditures and children's learning outcomes: gender and locational evidence from Ghana, Stud. Educ. Eval. 76 (2023), 101232, https://doi.org/10.1016/j.stueduc.2022.101232.

[4] B.I. Awokola, G.A. Amusa, C.P. Jewell, G. Okello, M. Stobrink, L.J. Finney, N. Mohammed, A. Erhart, K.J. Mortimer, Chronic obstructive pulmonary disease in sub-Saharan Africa, Int. J. Tuberc. Lung Dis. 26 (3) (2022) 232–242.

[5] R. Banerjee, V. Mishra, A.A. Maruta, Energy poverty, health and education outcomes: evidence from the developing world, Energy Econ. 101 (2021), 105447.

[6] A.S. Belay, M.M. Guangul, W.N. Asmare, G. Mesafint, Prevalence and associated factors of psychological distress among nurses in public hospitals, Southwest, Ethiopia: a cross-sectional study, Ethiop. J. Health Sci. 31 (6) (2021). https://www.ajol.info/index.php/ejhs/article/view/219291.

[7] R. Bentley, L. Daniel, Y. Li, E. Baker, A. Li, The effect of energy poverty on mental health, cardiovascular disease and respiratory health: a longitudinal analysis, Lancet Regional Health–Western Pacific (2023).

[8] T. Björgvinsson, S.J. Kertz, J.S. Bigda-Peyton, K.L. McCoy, I.M. Aderka, Psychometric properties of the CES-D-10 in a psychiatric sample, Assessment 20 (4) (2013) 429–436.

[9] S. Bouzarovski, S. Petrova, A global perspective on domestic energy deprivation: overcoming the energy poverty–fuel poverty binary, Energy Res. Soc. Sci. 10 (2015) 31–40.

[10] T. Brophy, N. Branson, R.C. Daniels, M. Leibbrandt, C. Mlatsheni, I. Woolard, *National Income Dynamics Study Panel User Manual* (Technical Note Release 2018. Version 1), Southern Africa Labour and Development Research Unit, Cape Town, 2018. http://www.nids.uct.ac.za/images/documents/20180831-NIDS-W5PanelUserManual-V1.0.pdf.

[11] O.L. Campbell, D. Bann, P. Patalay, The gender gap in adolescent mental health: a cross-national investigation of 566,829 adolescents across 73 countries, SSM-Population Health 13 (2021), 100742.

[12] D. Chakraborty, N.K. Mondal, J.K. Datta, Indoor pollution from solid biomass fuel and rural health damage: a micro-environmental study in rural area of Burdwan, West Bengal, Int. J. Sustain. Built Environ. 3 (2) (2014) 262–271.

[13] W. Chen, Y. Huang, A. Riad, Gender differences in depressive traits among rural and urban Chinese adolescent students: secondary data analysis of nationwide survey CFPS, Int. J. Environ. Res. Public Health 18 (17) (2021) 9124.

[14] A. Craig, T. Rochat, S.N. Naicker, W. Mapanga, A. Mtintsilana, S.N. Dlamini, L. J. Ware, J. Du Toit, C.E. Draper, L. Richter, The prevalence of probable depression and probable anxiety, and associations with adverse childhood experiences and socio-demographics: a national survey in South Africa, Front. Public Health 10 (2022), 986531.

[15] R. Day, G. Walker, N. Simcock, Conceptualising energy use and energy poverty using a capabilities framework, Energy Policy 93 (2016) 255–264.

[16] N.W. Harriman, D.R. Williams, J.W. Morgan, R. Sewpaul, T. Manyaapelo, S. Sifunda, M. Mabaso, A.D. Mbewu, S.P. Reddy, Racial disparities in psychological distress in post-apartheid South Africa: results from the SANHANES-1 survey, Soc. Psychiatry Psychiatr. Epidemiol. (2021) 1–15.

[17] R.E. Kofinti, I. Koomson, J.A. Peprah, Borrower discouragement and multidimensional child deprivation in Ghana, J. Econ. Inequality (2023) 1–19.

[18] I. Koomson, C. Afoakwah, Can financial inclusion improve children's learning outcomes and late school enrolment in a developing country? Appl. Econ. (2022) 1–18, https://doi.org/10.1080/00036846.2022.2086683.

[19] I. Koomson, C. Afoakwah, A. Ampofo, How does ethnic diversity affect energy poverty? Insights from South Africa, Energy Econ. (2022), 106079, https://doi.org/10.1016/j.eneco.2022.106079.

[20] I. Koomson, S. Awaworyi Churchill, Employment precarity and energy poverty in post-apartheid South Africa: exploring the racial and ethnic dimensions, Energy Econ. (2022), 106026, https://doi.org/10.1016/j.eneco.2022.106026.

[21] I. Koomson, M. Danquah, Financial inclusion and energy poverty: empirical evidence from Ghana, Energy Econ. 94 (2021), https://doi.org/10.1016/j.eneco.2020.105085.

[22] I. Koomson, E. Orkoh, S. Ahmad, Non-farm entrepreneurship, caste, and energy poverty in rural India, Energy Econ. 127 (2023), 107118.
[23] A. Lewbel, Using heteroscedasticity to identify and estimate mismeasured and endogenous regressor models, J. Bus. Econom. Statist. 30 (1) (2012) 67–80.
[24] X. Li, H. Yang, J. Jia, Impact of energy poverty on cognitive and mental health among middle-aged and older adults in China, Human. Soc. Sci. Commun. 9 (1) (2022) 1–13.
[25] C. Liddell, C. Morris, Fuel poverty and human health: a review of recent evidence, Energy Policy 38 (6) (2010) 2987–2997.
[26] B. Lin, M.A. Okyere, Multidimensional energy poverty and mental health: micro-level evidence from Ghana, Int. J. Environ. Res. Public Health 17 (18) (2020) 6726.
[27] O.M. Longe, A review of energy and gender poverty nexus in south africa, in: 2020 IEEE PES/IAS PowerAfrica, 2020, pp. 1–5.
[28] I.B. Mboya, B. John, E.S. Kibopile, L. Mhando, J. George, J.S. Ngocho, Factors associated with mental distress among undergraduate students in northern Tanzania, BMC Psychiatry 20 (1) (2020) 28, https://doi.org/10.1186/s12888-020-2448-1.
[29] W.C. Miller, H.A. Anton, A.F. Townson, Measurement properties of the CESD scale among individuals with spinal cord injury, Spinal Cord 46 (4) (2008) 287–292.
[30] N.W. Minja, D. Nakagaayi, T. Aliku, W. Zhang, I. Ssinabulya, J. Nabaale, W. Amutuhaire, S.R. de Loizaga, E. Ndagire, J. Rwebembera, Cardiovascular diseases in Africa in the twenty-first century: gaps and priorities going forward, Front. Cardiovasc. Med. 9 (2022), 1008335.
[31] G. Mohan, The impact of household energy poverty on the mental health of parents of young children, J. Public Health 44 (1) (2022) 121–128.
[32] P. Nie, Q. Li, A. Sousa-Poza, Energy poverty and subjective well-being in China: new evidence from the China Family Panel Studies, Energy Econ. 103 (2021), 105548.
[33] P. Nussbaumer, F.F. Nerini, I. Onyeji, M. Howells, Global insights based on the multidimensional energy poverty index (MEPI), Sustainability 5 (5) (2013) 2060–2076.
[34] N.P. Nzimande, M. El Tantawi, R.A.A. Zuñiga, R. Opoku-Sarkodie, B. Brown, O. C. Ezechi, B.S. Uzochukwu, P. Ellakany, N.M. Aly, A.L. Nguyen, Sex differences in the experience of COVID-19 post-traumatic stress symptoms by adults in South Africa, BMC Psychiatry 22 (1) (2022) 238.
[35] S. Olawumi Israel-Akinbo, J. Snowball, G Fraser, An investigation of multidimensional energy poverty among South African low-income households, South African Journal of Economics 86 (4) (2018) 468–487.
[36] K. Prakash, M.E. Munyanyi, Energy poverty and obesity, Energy Econ. 101 (2021), 105428.
[37] Presidential Climate Commission, A Presidential Climate Commission Energy Poverty Dialogue Report, Presidential Climate Commission, 2023. https://pccommissionflo.imgix.net/uploads/images/Energy-Poverty-Dialogue-Report.pdf.
[38] Y. Ruan, Y. Guo, Y. Zheng, Z. Huang, S. Sun, P. Kowal, Y. Shi, F. Wu, Cardiovascular disease (CVD) and associated risk factors among older adults in six low-and middle-income countries: results from SAGE Wave 1, BMC Public Health 18 (1) (2018) 778, https://doi.org/10.1186/s12889-018-5653-9.
[39] N.P. Saravanan, Indoor air pollution: danger at home, Resonance 9 (1) (2004) 6–11.
[40] I. Satia, A.J. Mayhew, N. Sohel, O. Kurmi, K.J. Killian, P.M. O'Byrne, P. Raina, Impact of productive and dry chronic cough on mortality in the Canadian Longitudinal Study on Aging (CLSA), J. Thorac. Dis. 14 (12) (2022) 5087.
[41] M. Shupler, M. Baame, E. Nix, T. Tawiah, F. Lorenzetti, J. Saah, R.A. de Cuevas, E. Sang, E. Puzzolo, J. Mangeni, Multiple aspects of energy poverty are associated with lower mental health-related quality of life: a modelling study in three peri-urban African communities, SSM-Mental Health 2 (2022), 100103.
[42] B.K. Sovacool, I.M. Drupady, Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy in Developing Asia, Routledge, 2016.
[43] UNICEF, Clear the Air for children: The Impact of Air Pollution on Children, UNICEF, New York, 2016. https://www.unicef.org/media/60106/file.
[44] W.J.J. van Rensburg, Post-mortem evidence of a diverse distribution pattern of atherosclerosis in the South African population, Sci. Rep. 12 (1) (2022) 11366.
[45] H. Welsch, P. Biermann, Energy affordability and subjective well-being: evidence for European countries, Energy J. 38 (3) (2017).
[46] World Health Organization. (2007). *Housing, energy and thermal comfort: a review of 10 countries within the WHO European Region*. https://apps.who.int/iris/handle/10665/107815.
[47] Y. Ye, S.F. Koch, Measuring energy poverty in South Africa based on household required energy consumption, Energy Econ. 103 (2021), 105553.
[48] Z. Zhang, H. Shu, H. Yi, X. Wang, Household multidimensional energy poverty and its impacts on physical and mental health, Energy Policy 156 (2021), 112381.