Empirical evidence on the incidence and persistence of energy poverty in Australia

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Abstract

Reducing energy poverty will help improve the nation's health and help achieve sustainability. Using sixteen years of the Household, Income and Labour Dynamics in Australia (HILDA) Survey, we study the dynamics, persistence and determinants of energy poverty. Results indicate that energy poverty in Australia is generally a temporary condition, yet a non-negligible share of the Australian population (ranging from 0.41% to 8.1% depending on the energy poverty indicator used) is exposed to persistent energy disadvantage. Thus, examining the dynamics of energy poverty is essential to make sure that policy targets are effective and reach those in need. Single individuals (whether elderly or not), single-parent households and those with a disabled household member are at high risk of persistently experiencing energy poverty in Australia. This is also true for non-working individuals and immigrants from non-English speaking countries. In contrast, highly educated individuals, those living in metropolitan areas and homeowners face lower likelihoods of persistently experiencing energy poverty. Government investment in energy efficiency for houses and apartments is crucial to generate savings in electricity bills, healthier homes and evident reductions in carbon emissions.

1. Introduction

Household Energy prices have climbed substantially in Australia since 2007 (the cost of electricity has increased by 76% in real terms and gas prices by 53%). Between 2005-2011 evidence from the HILDA Survey suggests that even though costs for energy rose, the proportion of income people spent on fuel remained fairly constant. However, it is worth bearing in mind that households on low incomes spend a high proportion of their income on energy than those on high incomes (Azpitarte et al., 2015). On average, low-income households spend 6.4% of their income on energy, while high-income ones spend far less relative to their incomes – an average of 1.5%. The situation for many low-income households has gone from bad to worse, and one in four of these households are now paying over 8.8% of their income in energy, a figure that goes up to over 9.7% for those households relying on income support payments such as Newstart/JobSeeker[1] (ACOSS and Brotherhood of St. Laurence, 2018; Bryan et al., 2022).

Australia is a vast country with a variety of climatic regions, from tropical areas to deserts and cool and rainy regions. Both federal and state governments are responsible for putting in place policies that maintain the energy supply, improve energy efficiency and provide the necessary support programs for those most in need.

An individual is considered energy poor if they cannot sufficiently heat/cool their home because of a lack of resources or the inefficiency of the housing insulation and heating/cooling (Boardman, 1991, 2012; Bouzarovski et al., 2012; Liddell et al.,2012). Hence, energy poverty is a multi-dimensional concept

[1] In March 2020, the JobSeeker Payment replaced Newstart Allowance.

which depends on household income, energy cost, and the energy efficiency of an individual's home. Moreover, while understanding the level of energy poverty at any point in time is critical, the dynamics of energy poverty are equally important because the welfare implications and, thus, policy measures will differ depending on how such poverty is experienced. For example, suppose many households experience energy poverty for a short period of time. In that case, the required policy response will differ from that required if a small number of households experience energy poverty persistently.

The government's recognition of the adverse welfare impacts of energy poverty is growing. These include negative impacts on physical and mental health (Liddell and Morris, 2010; Public Health England, 2014; Brown and Vera-Toscano, 2021); on educational attainments (Barnes et al., 2008); and for future generations, on global climate change. In turn, this requires a better understanding of the nature of energy poverty.

Conceptually the need to understand the dynamic processes underlying energy poverty has been recognised. Bouzarovski et al. (2014) argue that energy poverty should be embedded within a wider energy poverty framework focusing on the notion of 'energy vulnerability' as it allows a better focus on the pathways through which households are prevented from achieving their energy needs. However, while previous studies have considered the importance of targeting energy poverty policies either spatially or by housing type (Sefton, 2002; Walker et al. 2012), there has been comparatively little attention to the dynamics of energy poverty of individuals. Phimister et al. (2015) use Spanish longitudinal data, while Chaton and Lacroix (2018) provide evidence from France, Karpinska and Śmiech (2020) rely on Polish longitudinal data, and Drescher and Janzen (2021) examine the dynamics of energy poverty for Germany.

This paper uses data from the last sixteen years of the Household, Income and Labour Dynamics in Australia (HILDA) Survey to provide further evidence on the level and the dynamics of energy poverty in Australia over the last sixteen years. Using various indicators of energy poverty to account for the multi-dimensional nature of the concept, we study energy poverty dynamics at a descriptive level. We find that most of Australia's energy poor households are only temporarily energy poor. Yet, a non-negligible share of the Australian population, ranging from 0.41% to 8.1% depending on the energy poverty indicator used, is exposed to persistent energy disadvantage.[2] Next, we explore differences between temporarily and persistently energy poor households using multinomial logistic regression analysis. We find that single individuals, single parent households, and those with a disabled household member are particularly vulnerable to persistent energy poverty. The results further show a higher probability of being trapped in persistent energy poverty among those living in detached house, in rental/social housing accommodation, and remote rural areas. Interestingly, the results suggest monitoring changes in the rates of energy poverty and how energy poverty is experienced at the individual level regarding persistence and duration of energy poverty to ensure that policy targets are effective and reach those most in need.

2.Data and Methods

This analysis uses 16 years of data from the Household, Income and Labour Dynamics of Australia (HILDA) Survey, a household panel survey that started in 2001 and provided a nationally representative sample of Australian households (Watson and Wooden, 2021). The HILDA Survey is conducted annually

[2] Interestingly, if we gather all those individuals in our sample defined as persistently poor across any of the 5 measures used, the percentage goes up to 14.5%.

to all members of participating households aged 15 years or older, along with any individuals who subsequently join a household in which an original household member resides. The first wave comprised 13 969 participants from 7682 households. The HILDA survey contains a wealth of individuals' data on income, consumption expenditure and household socio-economic characteristics relevant to our aims. More specifically, the HILDA Survey includes questions related to self-reported energy poverty indicators since respondents are asked about the household's ability to keep the home adequately warm. Moreover, since Wave 5 (2005), respondents have also been asked about household expenditure on electricity, gas and other heating fuel (e.g., firewood and heating oil), which allows analysing expenditure-based energy poverty indicators. Given its longitudinal nature, it will enable us to effectively explore the dynamics of energy poverty.

From this data, a balanced panel of 8 842 individuals who have remained in the sample since wave 5 (2005) was constructed, excluding those participants recruited in later years. Rates of sample loss and attrition are low, with the re-interview rate rising from 87% in wave 2 to over 95% by wave 8 (2008) and remaining above that level in subsequent waves (Summerfield et al., 2021). All analyses are weighted, adjusting for both complex survey design and non-response.

2.1. Measuring energy poverty

Energy poverty involves a "complex interaction of low income and energy efficiency" (Healy and Clinch, 2002), with energy prices, individual energy needs and climatic conditions being important components (Boardman, 2012; Bouzarovski et al., 2012; Liddell et al., 2012). As expected, there is no single accepted definition for identifying individuals in energy poverty (Moore, 2012; Li et al., 2014; Herrero, 2017).

In this paper, we adopt five different indicators of energy poverty generally used in the literature to ensure we cover a wide range of people affected by this phenomenon. We utilise three expenditure-based energy poverty indicators (Hills, 2012; Thema et al., 2020). First, as suggested by the Energy Poverty Observatory (EPOV) and Moore (2012), we identify households as energy poor if their expenditure on energy is larger than twice the national mean [RELEPOOR]. Next, following Boardman (1992), we identify energy poor households if their share of income spent on energy bills exceeds 10% [ABSPOOR]. Last, we rely on the objective energy poverty measure proposed by Hills (2012), by which households are defined as energy poor if their actual energy expenditures are above the median and if their residual income (equivalised income after equivalised energy expenditure) is below the income poverty line of 50% of the median income after housing costs [LINCHCOST].

To equivalise income, we use the 'modified OECD' scale (Hagenaars et al. 1994), which divides household income by 1 for the first household member plus 0.5 for each other household member aged 15 or over, plus 0.3 for each child under 15. A family comprising two adults and two children under 15 years of age would, therefore, have an equivalence scale of 2.1 (1 + 0.5 + 0.3 + 0.3), meaning that the family would need to have an income 2.1 times that of a single-person household to achieve the same standard of living. This scale recognises that larger households require more income. It also accounts for economies of scale in consumption (for example, the rent on a two-bedroom flat is typically less than twice the rent on an otherwise comparable one-bedroom apartment) and that children require fewer resources than adults. The equivalised income calculated for a household is then assigned to each household member. The implicit assumption is that all household members experience the same standard of living (which will, of course, not always be the case—particularly in households containing unrelated people).

We also include self-reported energy poverty indicators. Following Thomson and Snell's (2013), we consider: (1) the inability to keep the home adequately warm [NOHEAT] but also (2) the inability to pay utility bills on time [NOPAYBILLS]. These are modelled as dummy variables that take the value 1 when the household reports that they cannot keep their home warm and cannot pay the bills on time, respectively. These measures control for a self-reported inadequacy to keep one's home at a comfortable temperature or difficulty in paying one's energy bills which can be perceived as being under financial stress (Breunig and Cobb-Clark 2005). Some households restrict their energy consumption to the detriment of their health or well-being but pay their energy bills. They do not feel like they have difficulty paying this bill because of lower costs from reduced consumption. Thus, they may not self-report as being behind with their bills. This hardship is often hidden, and there is relatively little empirical data on households such as these facing material deprivation, either directly due to reducing their energy consumption or indirectly through doing without other goods or services. For households in arrears with their energy bills, some of these may report no energy expenditure and not be recorded in our expenditure-based measures. Most Australian jurisdictions have increased disconnection because of failure to pay for energy.[3]

2.2. Modelling persistent energy poverty

After providing a descriptive analysis of energy poverty dynamics in the data, we employ a discrete choice model to explore the differences between never being energy poor and temporary and persistent energy poverty. Exploring the factors that affect the moves between energy poverty statuses entails estimating logistic regression models of energy poverty transitions.

Borrowing from the income poverty dynamics literature (Jenkins, 2000; Biewen, 2006), we distinguish between never energy poor, temporarily and persistently energy poor based on the amount of time that individuals spend in energy poverty as follows:[4]

(1) Never energy poor: The individual (and their household) has spent no time in energy poverty in our sample period.
(2) Temporarily poor: The individual has been energy poor for up to half of the sample years.
(3) Persistently poor: The individual has been energy poor for more than 50% of the years observed in our sample.

It is important to point out that we use relatively simple methods that do not address the spell-censoring problem.[5] To analyse the differences between temporarily and persistently energy poor households, we estimate the following multinomial logit model:

$$\lambda_{ijk}(x_i) = \frac{\exp(\beta'_{jk}x_i)}{\sum_{m=0,1,2}\exp(\beta'_{jm}x_i)} \quad (1)$$

[3] See for example: Households in the dark. Mapping electricity disconnections in South Australia, Victoria, New South Wales and South East Queensland (https://www.vinnies.org.au/content/Document/VIC/2016-June-Households-in-the-dark2.pdf)

[4] Descher and Janzen (2021) use a similar approach with the German Socio-Economic Panel (GSOEP). However, they define *chronic energy poor*, those households which have spent more than 70% of the observed periods in energy poverty. We opted for the 50% cut off since our panel included 16 years of observations (they used 7 years of data only). Yet, using additional cut off points (i.e., 70% cut off) bring in similar conclusions.

[5] Energy poverty-spell start or end dates are not observed in longitudinal sets (the problem of 'censoring'). Thus, completed spell lengths cannot always be determined directly. It is out of the scope of this paper to handle this 'censoring' problem.

where m = 0 (never energy poor), 1 (temporarily energy poor), and 2 (persistently energy poor); λ_{ijk} is the conditional probability of a transition into energy poverty state, given that individual i is in employment state j. Then, x_i is a vector of covariates for individual i that are considered to affect the transitions rates, and β_{jk} is a vector of parameters to be estimated.

We follow Bhatta and Sharma (2011) 's view and argue that we cannot suppose that persistent energy poverty denotes a higher poverty level than temporary energy poverty. Thus, the specification implies independence of the three possible energy poverty states, and never energy poor is taken as the base category.

We select our covariates based on the current literature and data available in the HILDA Survey. Thus, we add socio-demographic and socio-economic characteristics such as household type and place of birth (immigrant status) as households with migration backgrounds may be more vulnerable to energy poverty (Belaïd, 2016; Churchill and Smyth, 2020). We further distinguish between elderly[6] and non-elderly households when controlling for household type. Older people in Australia prefer to live in their own home (Judd et al., 2014) which tend to be not energy efficient particularly if in low-income households (Romanach et al., 2017). Similarly, we expect that the presence of a disabled person in the household influences household income and domestic energy demands. Educational attainment and labour force status are included as a proxy of socio-economic status and a reference for energy education and energy saving behaviour (Chato and Lacroix, 2018). Following Boardman (2010), we further control for home ownership since renters may be negatively affected by their landlords' underinvestment in energy efficiency (Melvin, 2018) and place of residence. Unfortunately, we don't have any information on housing conditions (e.g., construction year of the building, main energy source, etc.) which could provide crucial evidence on the different energy poverty predictors. However, we control for household type as it has been found that households living in detached and semi-detached dwellings which may be associated with higher levels of heat loss are more likely to be at risk for energy poverty (Karpinska, and Śmiech, 2020; Riva, et al., 2021), than those living in apartment buildings (Leahy and Lyons, 2010). Last, place of residence may also affect energy poverty (Thomson and Snell, 2013; Roberts et al., 2015; Dalla Longa, et al., 2021). Last, we include state and year-fixed effects to control for differences in energy policies across states, and unobserved year-specific characteristics, respectively. Descriptive statistics for the explanatory variables used are presented in Table 1.

[6] Elderly couples are those couples (married or de facto) with both members 65 years old or older. Elderly single are those individuals aged 65 years old or older and living alone.

Table 1. Descriptive statistics (pooled sample 2005-2020)

VARIABLES	Mean (*100)	Standard Errors
Household type		
Couple no children	0.180	(0.00120)
Couple with children	0.463	(0.00169)
Single parent	0.104	(0.00110)
Single person	0.089	(0.000842)
Elderly couple	0.087	(0.000871)
Elderly single person	0.036	(0.000503)
Others	0.040	(0.000745)
Place of birth		
Indigenous	0.019	(0.000440)
Other native-born	0.763	(0.00154)
ESB Immigrant	0.088	(0.000932)
NESB Immigrant	0.130	(0.00133)
Disability in the household	0.232	(0.00142)
Place of residence		
Major city	0.658	(0.00153)
Inner regional	0.242	(0.00136)
Remote	0.100	(0.000943)
Educational attainment		
Degree + (University)	0.241	(0.00141)
Diploma/Certificate 3 or 4	0.299	(0.00153)
Year 12	0.168	(0.00130)
Less than Year 12	0.293	(0.00153)
Labour force status		
Employed FT	0.427	(0.00167)
Employed PT	0.223	(0.00136)
Unemployed	0.028	(0.000571)
Not in labour force	0.323	(0.00157)
Homeowner	0.759	(0.00142)
Type of dwelling		
Detached house	0.854	(0.00116)
Semi-detached house	0.055	(0.000732)
Flat	0.086	(0.000926)
Other	0.006	(0.000228)
State		
NSW	0.306	(0.00161)
VIC	0.266	(0.00148)
QLD	0.196	(0.00127)
SA	0.078	(0.000837)
WA	0.103	(0.00105)
TAS	0.026	(0.000458)
NT	0.008	(0.000303)
ACT	0.018	(0.000391)
Energy poverty indicators		
NOHEAT	0.024	(0.000540)
NOPAYBILLS	0.101	(0.001059)
ABSEPOOR	0.087	(0.000889)
RELEPOOR	0.183	(0.001207)
LINCHCOST	0.043	(0.000638)
Observations	121,903	

Note: Household income is not included as an explanatory variable since it is used to construct the expenditure-based energy poverty indicators. Educational attainment and employment variables are used as a proxy of socio-economic status.

3. Results

3.1. Descriptive analysis on energy poverty.

Table 2 shows energy poverty rates by household income deciles (ranked from lowest to highest) related to the five indicators we use in this paper. The first clear observation that emerges from Table 2 is that while there is a higher share of energy poor households in the lowest (poorest) income deciles, we still capture some energy poor individuals in the higher (richer) income groups. These results reflect the fact that energy poverty contains higher income individuals dealing with high fuel prices and/or living in energy inefficient homes.

Then, depending on the indicator used, the incidence of energy poverty in our pooled sample varies from 2.38% (NOHEAT) to 18.30% (RELEPOOR).

Table 2. Energy poverty rates using different indicators by household income deciles (pooled sample 2005-2020)

	Household income deciles										
	Lowest									**Highest**	
Energy poverty measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**All**
NOHEAT	8.03	6.11	3.23	2.72	2.19	1.80	1.15	0.66	0.61	0.30	2.38
NOPAYBILLS	17.29	16.82	15.04	14.20	13.24	10.55	8.16	6.11	3.86	2.18	10.03
LINCHCOST	29.59	22.07	0.83	0.05	0.01	0.01	0.03	0.00	0.11	0.00	4.33
ABSEPOOR	33.06	16.90	12.46	11.32	8.93	5.58	4.68	2.89	1.24	0.43	8.72
RELEPOOR	46.77	32.61	29.61	24.56	21.24	15.30	12.67	9.01	4.77	1.81	18.30

Table 3 reports the correlation between the different indicators of energy poverty. More specifically, it reports the overlap between the different measures for the overall population (Panel A) and those in the two poorest income deciles (Panel B). Results in Panel A show that 3.8% of those individuals who were energy poor under the RELEPOOR indicator (their expenditure on energy is larger than twice the national mean) reported the incapacity to keep their home adequately warm. On the contrary, 26.4% that reported difficulties in heating their home spent more than twice the median share of their income on energy bills. Thus, not all expenditure-based energy poor households self-report an inability to keep their homes adequately warm or pay electricity bills.

In addition, Panel B of Table 3, we observe how those experiencing the inability to heat their home adequately are almost twice more likely to report energy poverty under any of the expenditure-based energy poor indicators (20.8% for ABSEPOOR, 38.4 % for RELEPOOR and 22.5% for LINCHCOST compared to 13.1%, 26.4% and 11.0%, respectively). While energy poverty seems more strongly felt among those in the lowest income groups (since there is a stronger correlation between expenditure-based and self-reported energy poverty indicators among those in the two poorest income deciles), there are still individuals self-reporting energy poverty (using NOHEAT and NOPAYBILLS) who are not energy poor using any of the expenditure-base indicators both in Panels A and B. This highlights the difficulty of targeting energy poverty policies to assist those most in need.

Table 3. Overlapping between the different energy poverty indicators (pooled sample 2005-2020)

	All sample (Panel A)					Individuals in the two poorest household income deciles (Panel B)				
	Also in									
Given in:	No heat	No pay bills	absepoor	relepoor	linchcost	No heat	No pay bills	absepoor	relepoor	linchcost
No heat	-	59.4	13.1	26.4	11.0	-	59.6	20.8	38.4	22.5
No pay bills	14.2	-	14.0	26.9	7.9	24.8	-	25.8	40.6	27.4
absepoor	4.1	18.3	-	1.0	37.3	6.5	19.7	-	1.0	77.9
relepoor	3.8	16.1	47.6	-	23.5	7.4	18.7	62.3	-	64.7
linchcost	6.7	20.1	75.0	99.3	-	6.8	20.0	74.4	99.3	-

3.2. Energy poverty dynamics

Table 4 shows that for the 16 years studied, most individuals never experienced energy poverty. Results vary from 28.8% of the individuals never being energy poor under the ABSEPOOR indicator to 88.89% never declaring to be unable to adequately warm their home (NOHEAT). On the contrary, a smaller percentage of the sample report being in energy poverty for more than 8 years of the 16 years observed[7]. For the ABSEPOOR indicator, 8.09% report this measure for at least 8 years of the survey, but only 0.41% of the individuals report being unable to heat the warm for more than 8 years. Therefore, most of the individuals in our sample, if ever energy poor, are temporarily energy poor (that is, energy poor for less than 8 years of the 16 years followed).

Interestingly, last column in Table 4 reports the share of individuals who declare to be energy poor using any of the 5 energy poverty indicators used. That is, we identify an individual as energy poor if she declares to be energy poor under any of the 5 indicators used. Interestingly, the share of individuals who are never energy poor drops to 21.2%, confirming that different indicators cover different features of energy poverty.

An energy poverty duration of 8 years or more is the threshold we have used in this paper to distinguish between those identified as being temporarily poor (<=50% of the time observed as being energy poor) from those defined as persistently poor (spent more than 50% of the time observed during the 16 years as being energy poor). Next, we explore differences between never, temporarily, and persistently energy poor.

[7] Notice that the number of years in energy poverty does not necessarily mean consecutive years.

Table 4. Share of household by time spent in energy poverty (%), 2005-2020.

		Poverty measure					
Subgroups by time spent in energy poverty	Number of years in energy poverty	No heat	No pay bills	linchcost	absepoor	relepoor	Energy poor under at least one of the 5 energy poverty indicators
Never energy poor	Never	88.89	66.95	50.27	28.8	72.13	21.2
Temporarily energy poor	1	5.41	11.99	19.81	18.51	13.12	15.75
	2	2.06	5.63	9.79	11.34	5.58	11.05
	3	1.08	3.32	6.21	9.48	3.34	9.48
	4	0.85	2.76	4.62	7.38	1.96	7.89
	5	0.56	1.92	3.03	4.87	1.15	5.88
	6	0.33	1.75	2.31	4.13	0.89	5.51
	7	0.26	1.24	1.53	3.91	0.61	4.56
	8	0.15	1.26	0.91	3.49	0.3	4.14
Persistently energy poor	More than 8	0.41	3.18	1.53	8.08	0.92	14.54
N	121,903						

3.3. Results from the multinomial logit.

We present the regression results in Tables 5a (for self-reported indicators) and 5b (for expenditure-based indicators). The estimates for temporarily and persistent energy poor must be understood in comparison to being never energy poor (our base category). Standard errors are shown in parentheses, and we provide the p-values that show if the coefficients for temporarily and persistently energy poor are equal.

Table 5a. Multinomial logistic relative risk ratio coefficients of the probability of being in one energy poverty status compared to another: Self-reported energy poverty indicators

	No heat			No pay bills		
Variables[a]	Temporary	Persistent	p-value[b]	Temporary	Persistent	p-value
Household type						
Couple with children	1.125***	1.085	0.849	1.435***	2.475***	0
	(0.0376)	(0.202)		(0.0296)	(0.135)	
Single parent	2.508***	4.197***	0.005	2.053***	4.014***	0
	(0.101)	(0.762)		(0.0617)	(0.255)	
Single person	1.890***	6.557***	0	1.360***	1.840***	0
	(0.0743)	(1.117)		(0.0380)	(0.120)	
Elderly couple	0.632***	0.248***	0.003	0.800***	0.180***	0
	(0.0324)	(0.0772)		(0.0264)	(0.0280)	
Elderly single person	1.034	3.179***	0	1.133***	0.629***	0
	(0.0554)	(0.556)		(0.0433)	(0.0715)	
Others	1.394***	1.600	0.666	2.196***	1.757***	0.032
	(0.0883)	(0.507)		(0.0951)	(0.183)	
Place of birth						
Indigenous	1.680***	1.877***	0.597	1.372***	1.353***	0.876
	(0.105)	(0.398)		(0.0727)	(0.127)	
ESB Immigrant	0.997	1.089	0.557	0.952*	0.628***	0
	(0.0410)	(0.160)		(0.0258)	(0.0483)	
NESB Immigrant	1.467***	2.273***	0.001	1.168***	0.813***	0
	(0.0542)	(0.304)		(0.0317)	(0.0590)	
Disability in the household	1.818***	3.148***	0	1.499***	2.093***	0
	(0.0446)	(0.329)		(0.0285)	(0.0853)	
Place of residence						
Inner regional	1.268***	2.039***	0	1.176***	1.594***	0
	(0.0331)	(0.224)		(0.0214)	(0.0653)	
Remote	1.105***	2.630***	0	1.312***	1.568***	0.001
	(0.0407)	(0.319)		(0.0334)	(0.0877)	
Educational attainment						
Diploma/Certificate 3 or 4	1.923***	2.971***	0.013	1.799***	2.465***	0
	(0.0641)	(0.513)		(0.0381)	(0.134)	
Year 12	1.374***	2.501***	0.002	1.289***	1.399***	0.205
	(0.0546)	(0.475)		(0.0328)	(0.0894)	
Less than Year 12	1.931***	1.694***	0.453	1.795***	1.619***	0.09
	(0.0688)	(0.292)		(0.0404)	(0.0965)	
Labour force status						
Employed PT	1.022	1.993***	0	0.869***	1.088*	0
	(0.0320)	(0.297)		(0.0172)	(0.0493)	
Unemployed	1.653***	2.715***	0.033	1.195***	1.343***	0.189
	(0.0905)	(0.628)		(0.0545)	(0.123)	
Not in labour force	1.426***	4.323***	0	0.783***	1.251***	0
	(0.0424)	(0.600)		(0.0170)	(0.0590)	
Homeowner	0.415***	0.395***	0.651	0.358***	0.179***	0
	(0.0105)	(0.0422)		(0.00677)	(0.00726)	
Type of dwelling						
Semi-detached house	0.961	1.068	0.527	0.932**	0.738***	0.003
	(0.0445)	(0.175)		(0.0309)	(0.0575)	
Flat	1.044	0.929	0.402	0.917***	0.903	0.817
	(0.0415)	(0.127)		(0.0267)	(0.0627)	
Observations	121,081	121,081		121,081	121,081	
Pseudo R2	0.1051			0.0781		

Relative risk ratios: e^{β}. "Never energy poor" is the base category. Relative risk ratios are interpreted in comparison to never being energy poor.

[a] Omitted categories: Couple no children, non-Indigenous Australian born, Metropolitan area, University Degree, Employed FT, Detached house.

[b] *P-values* for the likelihood ratio test of the difference of coefficients between temporarily and persistently energy poor.

Table 5b. Multinomial logistic relative risk ratio coefficients of the probability of being in one energy poverty status compared to another: Expenditure-based indicators

	ABSEPOOR			RELEPOOR			LINCHCOST		
	Temporary	Persistent	*p-value*	Temporary	Persistent	*p-value*	Temporary	Persistent	*p-value*
Household type									
Couple with children	1.809***	5.227***	0	1.956***	6.948***	0	1.003	1.331*	0.056
	(0.0347)	(0.531)		(0.0393)	(0.349)		(0.0227)	(0.200)	
Single parent	1.448***	3.774***	0	1.742***	2.922***	0	1.345***	2.013***	0.038
	(0.0416)	(0.508)		(0.0545)	(0.201)		(0.0425)	(0.392)	
Single person	0.928***	0.249***	0	0.813***	0.604***	0	0.794***	0.462***	0.034
	(0.0249)	(0.0763)		(0.0217)	(0.0524)		(0.0249)	(0.118)	
Elderly couple	1.038	1.622***	0	1.081**	1.216***	0	1.227***	2.307***	0
	(0.0302)	(0.201)		(0.0333)	(0.0836)		(0.0376)	(0.310)	
Elderly single person	0.800***	0.0523***	0	0.693***	0.493***	0	0.779***	0.00837***	0
	(0.0288)	(0.0268)		(0.0263)	(0.0468)		(0.0306)	(0.00843)	
Others	1.325***	0.743	0.054	1.680***	3.289***	0	1.102*	2.692***	0
	(0.0564)	(0.224)		(0.0801)	(0.324)		(0.0562)	(0.611)	
Place of birth									
Indigenous	1.218***	8.46e-11***	0	1.440***	0.382***	0	1.210***	0***	0
	(0.0604)	(0)		(0.0840)	(0.0760)		(0.0656)	(0)	
ESB Immigrant	1.101***	1.480***	0.005	0.980	0.981	0.986	1.037	0.916	0.439
	(0.0279)	(0.157)		(0.0248)	(0.0571)		(0.0308)	(0.148)	
NESB Immigrant	1.210***	2.892***	0	1.232***	1.973***	0	1.832***	4.751***	0
	(0.0317)	(0.236)		(0.0343)	(0.0924)		(0.0524)	(0.504)	
Disability in the household	1.189***	1.626***	0	1.123***	1.599***	0	1.305***	3.163***	0
	(0.0216)	(0.114)		(0.0223)	(0.0587)		(0.0254)	(0.306)	
Place of residence									
Inner regional	1.227***	2.902***	0	1.160***	2.010***	0	1.331***	3.169***	0
	(0.0208)	(0.201)		(0.0213)	(0.0680)		(0.0260)	(0.294)	
Remote	1.371***	4.567***	0	1.398***	3.407***	0	1.454***	2.439***	0.002
	(0.0338)	(0.445)		(0.0375)	(0.164)		(0.0393)	(0.421)	
Educational attainment									
Diploma/Certificate 3 or 4	1.598***	2.615***	0	1.520***	1.968***	0	1.640***	3.086***	0.002
	(0.0311)	(0.291)		(0.0306)	(0.0855)		(0.0404)	(0.643)	
Year 12	1.539***	3.352***	0	1.562***	2.090***	0	1.473***	6.932***	0
	(0.0357)	(0.392)		(0.0392)	(0.106)		(0.0435)	(1.506)	
Less than Year 12	1.677***	3.177***	0	1.730***	2.100***	0	2.058***	6.702***	0
	(0.0346)	(0.330)		(0.0376)	(0.0968)		(0.0516)	(1.334)	
Labour force status									
Employed PT	1.200***	0.985	0.023	1.194***	1.377***	0	1.458***	4.072***	0
	(0.0221)	(0.0860)		(0.0236)	(0.0540)		(0.0332)	(0.922)	
Unemployed	1.749***	1.056	0.015	1.894***	2.065***	0.281	2.548***	2.782***	0.824
	(0.0784)	(0.220)		(0.101)	(0.186)		(0.123)	(1.094)	
Not in labour force	1.727***	2.808***	0	1.739***	2.801***	0	2.691***	15.67***	0
	(0.0355)	(0.220)		(0.0393)	(0.114)		(0.0621)	(3.014)	
Homeowner	0.670***	1.094	0	0.683***	0.586***	0	0.602***	0.619***	0.835
	(0.0124)	(0.1000)		(0.0135)	(0.0228)		(0.0124)	(0.0812)	
Type of dwelling									
Semi-detached house	0.800***	0.198***	0	0.690***	0.321***	0	0.768***	0.208***	0
	(0.0250)	(0.0573)		(0.0216)	(0.0283)		(0.0287)	(0.0626)	
Flat	0.687***	0.115***	0	0.676***	0.310***	0	0.709***	0.135***	0
	(0.0192)	(0.0562)		(0.0187)	(0.0281)		(0.0231)	(0.0355)	
Observations	121,081	121,081		121,081	121,081		121,081	121,081	
Pseudo R2	0.0648			0.0828			0.1056		

Relative risk ratios: e^{β}. "Never energy poor" is the base category. Relative risk ratios are interpreted in comparison to never being energy poor.
[a] Omitted categories: Couple no children, non-Indigenous Australian born, Metropolitan area, University Degree, Employed FT, Detached house.
[b] *P-values* for the likelihood ratio test of the difference of coefficients between temporarily and persistently energy poor.

Results show how household characteristics show that compared to couples with no children households, single-parent households face a higher risk of being temporarily poor in both self-reported indicators and the LINCHCOST expenditure-based one than other household types. They are also significantly more likely to be persistently energy poor. Notice that in most single-parent households, the household head is a woman (90.31%). Moreover, elderly couples are at lower risk of being energy poor using the self-reported indicators (compared to couples with no children). Still, they are at a higher risk of energy poverty by any expenditure-based indicators. This divergence may result from differences between the perception and actual struggle managing energy bills. On the contrary, one-person households (whether elderly or not) face a higher risk of being persistently energy poor than being never or temporarily energy poor using self-reported indicators. However, they are at a lower risk of being temporarily (even less persistently) energy poor using expenditure-based indicators. One potential explanation could be that they have restricted their energy consumption, which is why they show this lower risk under the expenditure-based indicators. Last, as expected, compared to couples with no children, couples with children are at a higher risk of temporarily and persistent energy poverty by most of the indicators used.

Likewise, being an immigrant from a non-English speaking country or having a disabled household member increases the likelihood of facing temporary and persistent energy poverty.

Concentrating on the place of residence variable, people living in remote areas are at a higher risk of facing energy poverty temporarily but also persistently. Households in remote areas may lack the necessary infrastructure for adequate heating/cooling systems, limiting their chances of exiting energy poverty (Roberts et al. 2015).

Having a university degree significantly reduces the likelihood of facing persistent energy poverty, but we do not observe a clear pattern for lower levels of education.

Regarding labour-market characteristics, not being in the labour force significantly increases the probability of suffering from persistent energy poverty.

Living in a flat or semi-detached home and homeownership decreases the chances of persistent energy poverty compared to a detached dwelling.

4. Conclusions and policy implications

There is increasing political interest in the harmful impacts of energy poverty on individuals' well-being. These include impacts on physical and mental health, socio-economic outcomes and, more broadly, impact on global climate change.

This paper contributes further evidence on household energy poverty drivers and dynamics. We use up to five indicators of energy poverty (both expenditure-based and self-reported ones) to cover all those affected by this issue. Our results suggest that while most individuals never experienced energy poverty in Australia and the majority of households ever experiencing energy poverty do so only temporarily, a small group of individuals report being in energy poverty for more than 8 years of the 16 years observed in our sample. Evidence of this poverty persistence shows the importance of policy actions to break the vicious cycle of disadvantage (Karpinska and Śmiech, 2020). Our multivariate analysis shows that socio-economic, socio-demographic, and housing characteristics are associated with the energy poverty experience differently. Thus, single individuals (whether elderly or not), single-parent households and those with a disabled household member are at high risk of persistently experiencing energy poverty. This is also true for non-working individuals and immigrants from non-English speaking countries. In contrast, highly educated individuals, those living in metropolitan areas and homeowners face lower likelihoods of persistently experiencing energy poverty.

From a policy perspective, there are four key messages from this analysis. First, the results confirm that when implementing policies to address the energy poverty problem, it is critical to examine both expenditure-based and self-reported indicators. Focussing only on expenditure-based measures may omit households that restrict their energy consumption and are likely to be more vulnerable. Thus, it is essential to comprehensively consider all aspects of energy poverty. Second, results show that energy poverty is very much linked to lower income and those who are more disadvantaged. Meaningful reform of retail energy markets is needed to promote energy affordability, particularly, these low-income and vulnerable consumers. They include subsidies for energy efficiency measures such as insulation and double-glazed windows and renewable energy such as solar panels or heat pumps. Any policy measures to improve housing stock conditions will significantly decrease energy poverty. Moreover, if there are sudden shocks and substantial prices rises, the government should consider subsiding energy bills for those most in need as is currently happening in many European countries because of the war in Ukraine. Third, results further show that individuals renting, living in detached houses and/or remote areas are at higher risk of energy poverty. A potential explanation for this finding may be reduced access to certain fuel types (Office of Fair Trading, 2011) and inefficient housing stock (Healy, J.D. et al., 2004). Government investment in energy efficiency for houses and apartments (whether owned, in social housing or rented privately) is crucial to generate savings in electricity bills, along with healthier homes and evident reductions in carbon emissions. Last but not least, results reveal the need to monitor not only the levels (rates) of energy poverty but also its dynamics. This is essential to helping those most in need and reducing the negative health burden associated with energy poverty.

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