



The impact of energy poverty on physical violence

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ABSTRACT

Despite the fact that energy poverty and violence are emerging as a priority in many countries' policy agendas, little is known regarding the interplay between energy poverty and violence. This paper is the first to investigate the impact of energy poverty on physical violence. Using longitudinal data from the HILDA survey and employing a variety of methods, including an instrumental variable approach, we find strong evidence that energy poverty increases the likelihood of experiencing physical violence. We find that psychological distress, substance use and social capital are important mechanisms through which the effect of energy poverty is transmitted to physical violence. Our results are robust to alternative specifications and various measures of energy poverty.

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1. Introduction

Energy is essential in our lives and economic activities. Thus, access to and the use of energy are emerging as a priority in policy agendas worldwide, and have continued to be a vital determinant of household's well-being and living standards. Although there are many definitions of energy poverty there is a consensus in the literature that energy poverty refers to a situation where the need for energy consumption is not sufficiently satisfied (e.g., Lewis, 1982; Gonzalez-Eguino, 2015; Papada and Kaliampakos, 2016; Llorca et al., 2020). For example, according to Papada and Kaliampakos (2016), the definition of energy poverty can be summarized as "the difficulty or the inability of a household to afford an adequate coverage of its energy needs (heating comfort and other essential energy services)"; and agreeing with Reddy (2000), Gonzalez-Eguino (2015) adopt Reddy's definition of energy poverty which is defined as "the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development". Hence, following the above notions, energy poverty remains a major problem for many parts of the world (OECD, 2007). For example, there were around 1.3 billion people with no access to electricity, and the majority live in developing countries (Gonzalez-Eguino, 2015). It is also well documented that many individuals in developed countries encounter the problem of energy affordability (e.g., McInnes, 2017). Rising energy costs, inadequate income and energy inefficiency of housing

(e.g., Boardman, 2010; Hills, 2011; Heindl and Schuessler, 2015; OECD/IEA and International Energy Agency, 2011; Papada and Kaliampakos, 2016; Okushima, 2017), among others, are important factors that increase energy expenditure and, thus, intensify energy poverty among vulnerable households in both developing and developed countries.

When looking at the effects of energy poverty, empirical research in this literature has examined various effects of energy poverty. For example, many existing studies have analysed how energy and social well-being are connected or the impacts of energy poverty on social well-being, including health (e.g., Bridge et al., 2016; Krauss, 2016; Thomson et al., 2017; Phoumin and Kimura, 2019; Rodríguez-Álvarez et al., 2019; Awaworyi Churchill et al., 2020; Llorca et al., 2020; Awaworyi Churchill and Smyth, 2021). According to Bridge et al. (2016) and Krauss (2016), poverty and welfare of households are related to energy and gas tariffs. Compared with households without energy poverty, energy poor households tend to suffer from health problems, spend more on medical care, drop out from schools, and have lower earning opportunities (Phoumin and Kimura, 2019). Despite the growing interest in understanding the impacts of energy poverty, no existing studies have, thus far, explored the impact of energy poverty on physical violence, another pressing welfare issue besides energy poverty.

The purpose of this study is to empirically examine the impact of energy poverty on physical violence in Australia and to explore important mechanisms of influence. We use longitudinal data from the Household, Income and Labour Dynamics in Australia (HILDA) survey for the period from 2002 to 2018. To measure physical violence, we use information reported by the participants on whether they were victims of physical violence in the past year (e.g., Johnston et al., 2018; Smith and Weatherburn, 2013). As stated by Johnston et al. (2018), the HILDA

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based definition of physical violence is expected to cover the general forms of violence that encompasses physical and sexual assault, robbery with violence, and all other types of common violence emanating from all sources, including people known and strangers to the victims. We use the ratio of energy (and related) expenses to household income (e.g., Awaworyi Churchill and Smyth, 2019; Awaworyi Churchill et al., 2020; Robinson et al., 2018) as our primary measure of energy poverty, and incorporate alternative measures of energy poverty for robustness exercises. Employing a variety of methods, including an instrumental variable approach, our results suggest that energy poverty increases the likelihood of experiencing physical violence.

Specifically, when we use our primary measure of energy poverty, we find that energy poverty increases the likelihood of experiencing physical violence by 1.9 to 3.2 percentage points across various specifications that include specific control variables and the full set of control variables. Relative to the mean of physical violence at 0.015, these increases are substantial.¹ We also find that the estimated coefficients on various measures of energy poverty are positive and statistically significant at conventional significance levels. Our findings are in line with empirical evidence that violent crime is associated with resource deprivation (e.g., McIlwaine and Moser, 2003; Cunradi et al., 2000; De Olarte and Llosa, 1999). In addition, we find that psychological distress, substance use (given by consumption of cigarettes and tobacco) and social capital are important mechanisms through which the effect of energy poverty is transmitted to physical violence. These findings are consistent with the well-established evidence in the related literature. Conceptually, poverty-related stress that contributes to the development of stress-related disorders such as conduct problems and distress emotions (e.g., Wadsworth and Achenbach, 2005) can lead to physical violence (Gibbs et al., 2018); and decreased social capital that leads to higher levels of social mistrust can also produce economic disadvantages such as physical violence (Kennedy et al., 1998; Lederman et al., 2002). To further understand how energy poverty may influence physical violence, Section 2 provides an extended discussion about the relationship between energy poverty and physical violence, and several potential channels of influence.

We focus on Australia due to the following reasons. First, energy affordability is a key concern for many Australians. The cost of electricity faced by Australian households ranks among the highest globally (Awaworyi Churchill et al., 2020). According to Australian Competition and Consumer Commission (ACCC), in real terms, there is a 35% increase in households' bills and a 56% increase in the price of electricity for the period from 2007 to 08 to 2017–18. More importantly, ACCC reports that, compared to higher income households, the ratio of electricity expenses to disposable income is much higher for low income households. Second, violence is common in Australia. According to a personal safety survey in 2016 by Australian Bureau of Statistics (ABS), 2 in 5 people have experienced one or more incidents of violence since the age of 15, and 1 in 6 women experienced partner violence. ABS also reported that during the 2018–19 period around 5% of Australians aged 15 or older experienced at least one personal crime in the last 12 months, where 2.4% experienced physical assault. In a separate research for Western Australia in the period from 1990 to 2009, Orr et al. (2019) document that hospitalizations for mothers assaulted 12 months before their child's birth month and 36 months after the birth month have increased from 2.7 to 7.7 per 1000 births and from 8.9 to 19.4 per 1000 births, respectively. This indicates that physical violence is a growing problem in Australia. Third, existing studies that examine the impacts of energy poverty mainly focus on countries other than Australia (e.g., Thomson et al., 2017; Phoumin and Kimura, 2019; Rodríguez-

¹ Studies that examine the impacts of other factors such as divorce laws or combat services on physical violence also find similar effect size (e.g., Cesur and Sabia, 2016; García-Ramos, 2021). For example, Cesur and Sabia (2016) find that combat services increase the probability of experiencing physical violence by 3.2 to 4.8 percentage points in the U.S.

Álvarez et al., 2019; Llorca et al., 2020). Hence, Australia makes for an important and interesting case study based on these facts.

Our study fills an important gap in the following two strands of literature that relate violent crime to resource deprivation or climate change. First, there is a vast literature linking resource deprivation with violent crime (e.g., McIlwaine and Moser, 2003; Cunradi et al., 2000; De Olarte and Llosa, 1999). For example, Cunradi et al. (2000) suggest that households living in poor neighbourhood have a higher chance of experiencing violence in the United States. Some other studies find that poverty and inequality are important determinants of violent crime (e.g., Land et al., 1990; Arthur, 1991; Kelly, 2000; Fajnzylber et al., 2002a, 2002b; Gibbs et al., 2018). Second, it has been documented that violent crime is correlated with climate. A recent climate economics literature has found evidence on the effects of extreme temperatures on aggressive behavior or violence (e.g., Anderson, 1989; Ranson, 2014; Baylis, 2020; Bruederle et al., 2017). This is possible when environmental conditions affect people's decision making that may lead them to lose control or behave aggressively (e.g., Card and Dahl, 2011; Baumeister and Heatherton, 1996). Since energy poverty is a distinct form of resource deprivation (Moore, 2012) and climate change tends to aggravate energy poverty (Jessel et al., 2019), both resource deprivation and climate change are closely related to energy poverty. Our study builds on these strands of literature by specifically focusing on the effect of energy poverty on physical violence. Crutchfield and Wadsworth (2003) support the argument of identifying different types of resource deprivation before linking them to violence (e.g., Stark, 1987; Sampson and Groves, 1989; Krivo and Peterson, 1996). Dissecting different types of resource deprivation will aid in granular analysis of the actual effect of each type of resource deprivation on violence and the magnitude of violence.

Our study also contributes to the literature that links negative emotion or social capital with violence. Some recent studies (e.g., Card and Dahl, 2011; Hammack et al., 2004; Wadsworth et al., 2008; Gibbs et al., 2018) find empirical evidence that negative emotional cues such as stress of poverty and occupational-related stress are associated with physical violence. These findings are consistent with the frustration-aggression hypothesis (Dollard et al., 1939; Berkowitz, 1962), i.e., the notion that negative emotion can lead to aggression. For example, Gibbs et al. (2018) find that resource deprivation such as food insecurity drives substance abuse and suboptimal mental health outcomes, which then lead to intimate partner violence in South Africa. Regarding social capital, research has demonstrated a close link between social capital such as social network support and social trust and criminal activities (e.g., De Olarte and Llosa, 1999; Kennedy et al., 1998; Lederman et al., 2002). For example, De Olarte and Llosa (1999) find evidence that physical violence is associated with social support networks in Lima, Peru. Hence, our results, which suggest that psychological distress, substance use and social capital triggered by energy poverty are associated with physical violence, contribute to and extend the literature that links negative emotional cues and social capital with violence by highlighting the role of energy poverty.

The remainder of the paper is organized as follows. The next section discusses how energy poverty may affect physical violence. Section 3 describes the data and provides descriptions of the key variables. Section 4 describes the methodology. Section 5 presents the empirical results and discussions. Section 6 concludes.

2. The relationship between energy poverty and physical violence: channels of influence

In this section, we explore several potential channels given by psychological distress, substance use, social capital and dissatisfaction with partner through which energy poverty may influence physical violence.

Inspired by the literature that examines poverty-related stress and behavior, households living in energy poverty are at higher risk for

developing a range of stress-related disorders such as psychological distress than those who do not suffer from energy poverty (e.g., Wadsworth and Compas, 2002; Wadsworth and Achenbach, 2005). Since households living in energy poverty lack the ability to change their situation and cope with stress, they likely experience uncontrollable and overwhelming stress, which may give rise to psychological distress. Evidence shows that there are significant levels of physically violent victimization among people affected by psychological distress or other mental health problems (e.g., Bhavsar and Bhugra, 2018; Maniglio, 2009). For example, based on a review study by Maniglio (2009), rates of victimization among persons with mental health problems are 2.3–140.4 times higher than rates of victimization in the general population. Using data from police reports on the Danish population from 2001 to 2013, Dean et al. (2018) also find that onset of mental health problems is associated with increased risk of exposure to violent crime. Persons with mental health problems are high-risk group because of their poor judgment, social skills, planning and problem solving, among others (Fuji et al., 2004; Gearon and Bellack, 1999).

In addition, criminal victimization is most frequently associated with substance use disorders (Gearon and Bellack, 1999; Maniglio, 2009; Dean et al., 2018). Hence, substance use such as cigarette smoking and alcohol use is another potential channel of influence. Intuitively, the stress of energy poverty could also contribute to substance abuse, which may influence physical violence. Studies that examine the relationship between intimate partner violence victimization and smoking or alcohol use have generally found positive relationships (Foran and O'Leary, 2008; Vest et al., 2002; Feingold et al., 2008). Substance abusers not only are more likely to perpetrate physical violence but also are more likely to experience physical violence. For example, studies by White and Chen (2002) and Anderson (2002) have found a positive association between women's substance abuse and their experiences of intimate partner violence. Cesur and Sabia (2016) find that psychological distress as well as the use of substances are potential channels through which war service increases domestic violence.

The third potential channel is related to social capital. Social capital could broadly be understood as an array of shared values that enable society members to cooperate towards achieving a common purpose or a goal. The literature has several granular definitions of social capital ranging from Fukuyama (1995) who defined social capital as 'the ability of people to work together for common purposes in groups and organizations' to OECD that defined social capital as a set of shared values and social norms that adds to the well-being of the society (OECD, 2013). According to Scrivens and Smith (2013), there are four ways in which social capital could be contextualized: i) personal relationships; ii) social network support; iii) civic engagement; and iv) trust and cooperative norms. Social capital plays an important role on the number and significance of criminal activities including physical violence. According to Lederman et al. (2002), social capital enables peaceful resolution of conflicts and promotes social cohesion which can help communities to overcome problems arising from market failures. Robison et al. (2002) argue that the influence of social capital on societal outcomes via sympathetic relationships depends on networks. These relationships produce economic benefits, for example, socio-emotional goods, however, if neglected, the outcome will produce economic disadvantages such as physical and emotional violence. Indeed, the empirical findings show that decreased social capital given by higher levels of social mistrust was associated with higher levels of violent crime (Kennedy et al., 1998; Lederman et al., 2002).

The fourth potential channel of influence is dissatisfaction or satisfaction with partner. Family studies have highlighted that economic hardship can lead to conflict and relationship dissatisfaction (e.g., Conger et al., 2010), which have been considered as risk factors to intimate partner violence. Evidence shows that intimate partners are at higher risk for physical violence if there are more frequent violent arguments or lower levels of agreement in their relationships (e.g., Aldarondo and Sugarman, 1996; DeMaris et al., 2003). Hence,

dissatisfaction or satisfaction with partner may be a potential channel through which energy poverty can affect physical violence.

3. Data and variables

To examine the effect of energy poverty on physical violence, we utilize household and individual levels longitudinal data from the HILDA survey. As a nationally representative longitudinal survey, HILDA provides rich data on the socio-economic aspects of the lives of Australian residents, including income, expenditure, education, work, social support, life events and experiences of physical violence. The survey provides an extensive coverage in socio-economic variables across the Australian states and territories since 2001. This study utilizes the rich dataset from Release 18 of HILDA. As the first four waves of HILDA do not have information concerning household energy expenditure, we use data from waves 5 to 18 over the periods from 2005 to 2018. The HILDA survey maintains highest standards with low attrition rates comparable to other international popular surveys, including German Socio-Economic Panel and the British Household Panel Survey (Watson and Wooden, 2011). HILDA adjusts any selective attrition using cross-sectional and longitudinal weights at individual and household levels (Watson and Wooden, 2012).

3.1. Outcome variable

In line with the literature (see e.g., Johnston et al., 2018; Smith and Weatherburn, 2013), our outcome variable is a binary indicator for experiencing physical violence in the last 12 months of the given wave. HILDA asks respondents regarding the key events that have occurred in their life in the past year including physical violence such as assault. Responses are coded as 1 if they answer "Yes" and 0 if their response is "No". As pointed out by Johnston et al. (2018), the general wordings used in the HILDA survey concerning victimization are expected to incorporate the common forms of violence from all sources, such as physical and sexual assault by spouses, intimate partners, friends, relatives and strangers, among others. Although the HILDA survey does not ask the relationship between offenders and victims, national statistics in 2019 report that around 30% of violent crime are related to family and domestic violence (Australian Bureau of Statistics, 2019).

3.2. Energy poverty (EPOV)

In the literature, several measures of energy poverty have been used to help researchers and policymakers understand energy poverty. These measures include (1) an expenditure-based measure with an objective indicator such as the ratio of energy-related expenditure to household income (e.g., Awaworyi Churchill and Smyth, 2019; Awaworyi Churchill et al., 2020; Robinson et al., 2018) or the ratio of energy related expenses to disposable household income that exceeds 10% (e.g., Awaworyi Churchill and Smyth, 2020; Boardman, 2010; Hills, 2011, 2012; Thomson et al., 2017, 2) a subjective indicator such as self-assessed ability to heat their homes (e.g., Awaworyi Churchill and Smyth, 2020; Price et al., 2012; Thomson and Snell, 2013); and (3) measures that combine multiple indicators (e.g., Lawson et al., 2015). Each of these indicators has its own strength and shortcomings in measuring energy poverty. An expenditure-based measure is easy to measure and interpret but it does not capture an intentional reduction in energy consumption especially by low income households due to the problem of affordability (Papada and Kaliampakos, 2016); a subjective indicator may capture aspects of energy poverty that an expenditure-based measure fails to capture but such indicator may suffer from inconsistency among respondents (Thomson et al., 2017); and measures that combined multiple indicators present broader pictures of the issue but they are not easy to measure, interpret and obtain meaningful insights (Nussbaumer et al., 2012). Since there is no absolute reference for

what satisfies adequate and affordable energy needs, there is no single universally accepted measure for energy poverty. Hence, different indicators may complement each other to capture different dimensions of the concept of energy poverty.

A popular measure of energy poverty widely adopted in the literature is the ratio of energy (and related) expenses to household income (see, e.g., Awaworyi Churchill et al., 2020; Awaworyi Churchill and Smyth, 2019; Robinson et al., 2018). A higher ratio indicates more serious energy deprivation since poorer households tend to spend a larger percentage of their income on energy compared to richer households (Healy and Clinch, 2004; Gleeson and Randolph, 2002). Beginning with the fifth round of the HILDA survey, persons responding to HILDA questionnaire have been asked about their household energy spending including electricity, gas, and other sources of energy. Our main measure of energy poverty is the ratio of energy (and related) expenses to household income (EPOV1).

We also use alternative measures of energy poverty for robustness exercises. Research shows that households can be considered as fuel poor if the ratio of energy expenditure to disposable income is beyond a certain threshold level. Specifically, Boardman (1991) suggests that this threshold level is estimated at 10%. This means households are under energy poverty if the fraction of their disposable income spent on energy related bills exceeds 10%. Based on this threshold, this measure of energy poverty (EPOV2) is defined as a binary indicator that takes value of 1 if the energy expenditure share is above 10%, and zero otherwise.

One issue with the threshold method of determining the level of energy poverty is that it may potentially understate or overstate the threshold for certain reasons such as access to energy rationing and energy efficient technologies. For example, as pointed out by Hills (2012), households with access to energy efficient technologies require relatively low spending on energy services. As a result, these households may be classified as fuel poor if their reported income in the survey is very low. Although the objective nature of this measure is appealing, some studies suggest the use of subjective measure of energy poverty such as the feeling to be unable to heat their homes as a measure of energy deprivation (Thomson et al., 2017). Therefore, as a further robustness check we use this subjective measure of energy poverty (EPOV3) which captures the respondents' self-assessed ability to heat their homes based on their responses in the HILDA survey. The responses are coded as a binary indicator taking value of 1 if households respond 'Yes' to the question on the ability to heat their homes, and zero if the response is "No". EPOV3 as a measure of energy poverty has been used in previous studies in other contexts (see e.g., Price et al., 2012; Thomson and Snell, 2013). Although data for EPOV3 is available for all waves except for wave 10, we use data from waves 5 to 18 to maintain consistency in our sample size with the other measures of energy poverty. Lastly, following Awaworyi Churchill et al. (2020), we use data on state-level gas price indices from the Australian Bureau of Statistics to instrument energy poverty as energy prices are strong predictor of energy poverty.²

3.3. Control variables

Following the related literature on physical violence, we control a range of covariates that can affect the relationship between physical violence and energy poverty. We control for indicators of life events derived from the responses to HILDA's questions on life events in the past year, such as "the death of spouse or child", "the death of close relative", and "the death of close friend". Consistent with the literature that emphasizes the socio-economic factors, we include education levels, marital status, age, employment status, household disposable income

(normalized by its standard deviation), home ownership status and the number of dependents, among others.

3.4. Mediating variables

Following on from the discussion in Section 2, we provide descriptions for these four potential mediating variables- psychological distress, substance use (focusing on consumption of cigarettes and tobacco), social capital and life satisfaction with partner- through which the effect of energy poverty may be transmitted to physical violence.

3.4.1. Psychological distress

Consistent with the literature (e.g., Perales et al., 2014; Awaworyi Churchill et al., 2020b), we use psychological distress (Kessler1) and psychological distress risk categories (Kessler2) to measure the level of psychological distress. In HILDA, the measure of psychological distress (Kessler1) is constructed based on respondents' responses to a 10-item questionnaire. The value of the K10 measure ranges from a minimum of 10 (the lowest level of psychological distress) to a maximum of 50 (the highest level of psychological distress). Kessler psychological distress risk categories (Kessler2), another measure of psychological distress, is constructed from four psychological risk categories based on the responses to the K10 scale. Scores from "10 to 15" represent the "low risk" category; scores from "16 to 21" represent the "moderate risk" category; scores from "22 to 29" represent the "high risk" category; and scores from "30-50" represent the "very high risk" category. These risk categories are reported in an ordinal scale ranging from 1 to 4 in ascending order of psychological distress. Data on Kessler1 and Kessler2 are available in waves 7, 9, 11, 13, 15 and 17 of the HILDA survey.

3.4.2. Consumption of cigarettes and tobacco

Consumption of cigarettes and tobacco products is measured as weekly household expenditures on cigarettes and tobacco based on the responses to the HILDA question: "In a typical week, does this household spend money on ... c) cigarettes and other tobacco products?". HILDA reports information on this variable from wave 5 onwards. This measure has been used in the literature that examines issues related to tobacco consumption (see e.g., Bentley et al., 2021).

3.4.3. Social capital

We use social support as a proxy for social capital. Social support is constructed from the responses to a 10-item questionnaire in HILDA about how much support respondents were able to get from other people (see e.g., Milner et al., 2016). Respondents rate the sentiments they perceive about the level of support they are likely to receive from other people including their friends and families in a scale of 1 to 7 where 1 indicates 'strongly disagree' and 7 indicates 'strongly agree'. Following the literature (e.g., Awaworyi Churchill and Farrell, 2020; Milner et al., 2016), we use the average of responses from the 10 items in the scale as a measure of social capital. This variable is available in all waves of HILDA.

3.4.4. Life satisfaction with partner

In all waves of HILDA, respondents were asked to respond how satisfied or dissatisfied they are in their relationship with their partners. The responses are coded on a scale of 0 to 10 where higher numbers indicate more satisfaction with partner. Thus, 0 represents completely dissatisfied and 10 represents completely satisfied. This variable has been used in the literature to examine issues related to satisfaction or dissatisfaction with partner (e.g., Lee and McKinnish, 2018; Lee and McKinnish, 2019).

Table A1 in the Appendix presents an overview of the summary statistics and the descriptions of the key variables. Specifically, Table A1 shows that there are significant variations in the key variables as can

² While Awaworyi Churchill et al. (2020) use electricity and gas prices as their instrument variable, we use only gas prices because only gas prices satisfy the criteria for a good instrument for our case.

be observed from the standard deviations of the data relative to the mean values.

4. Methodology

To investigate whether energy poverty increases the probability of experiencing physical violence, we estimate a linear probability model of the form:

$$VIO_{iht} = \beta_1 EPOV_{ht} + \sum_j \beta_j X_{j,it} + \mu_t + \varepsilon_{iht} \tag{1}$$

where VIO_{iht} is a binary dependent variable of physical violence indicator which is equal to 1 if an individual i in household h experiences physical violence at time t , and 0 otherwise. $EPOV_{ht}$ is a measure of energy poverty for household h at time t , X denotes a vector of covariates that are described in Section 3.3. μ_t denotes time fixed effect and ε is the error term. Our parameter of interest is β_1 which captures the response of VIO to changes in $EPOV$.

An important issue in estimating Eq. (1) is a potential bias arising from endogeneity of $EPOV$ due to reverse causality, omission of relevant variables, or measurement errors. To address this potential issue of endogeneity, we employ an instrumental variable approach where energy poverty is instrumented with fuel prices. The use of fuel prices to instrument energy poverty is adopted in the recent literature (see e.g., Awaworyi Churchill et al., 2020). Our first stage regression is specified as:

$$EPOV_{ht} = \theta_1 EPRICE_{st} + \sum_j \theta_j X_{j,it} + \gamma_t + v_{iht} \tag{2}$$

where $EPRICE_{st}$ denotes energy prices (fuel prices) in state s at time t , γ_t is the wave fixed effect, v is the error term, and other variables are as defined in Eq. (1). θ_1 captures the effect of energy prices on energy poverty.

Concerning the quality of our instrumental variable, the first criteria for a good instrument is the existence of a canonical correlation between the instrument and the endogenous variable, which is energy poverty in our case. It is a stylized fact that the demand for energy (measured as energy spending) is correlated with energy prices (see e.g., Awaworyi Churchill et al., 2020; Narayan and Smyth, 2005). Thus, the relevance of energy prices as an instrument is plausible given that energy prices contain predictive information on energy poverty. With regard to the validity of the instrument, the key exclusion assumption is that energy prices will affect physical violence only via energy poverty. This assumption is reasonable because higher energy prices imply higher energy spending as a fraction of household income, which may then lead to financial stress and frustration, and, thus, physical violence. Therefore, we argue that the exclusion restriction is plausible as without energy poverty, one cannot establish a direct link from energy prices to physical violence. Hence, exogeneous variations in energy prices can be used to empirically isolate the causal effect of energy poverty on physical violence.

5. Results and discussions

5.1. Baseline results

Table 1 presents the estimates from the linear probability model. Column 1 presents the estimates where we regress the physical violence indicator only on energy poverty measured by the ratio of energy (and related) expenses to household income ($EPOV1$). In Column 2 we control for socio-economic status, and in Column 3 we include life events such as deaths of family members, close friends or relatives in addition to the socio-economic control variables. Column 4 presents the unrestricted model that includes the full set of control variables including educational status of respondents. Table 1 shows that the estimated coefficient on $EPOV1$ is positive and statistically significant at conventional significance

Table 1
Estimates of linear probability model- Full results.

Variables	Unconditional (1)	Socio-economic (2)	Life events (3)	Education level (4)
EPOV1	0.0317*** (0.0093)	0.0256*** (0.0097)	0.0191** (0.0091)	0.0190** (0.0091)
Income		-0.0014*** (0.0003)	-0.0012*** (0.0003)	-0.0009*** (0.0003)
Female		-0.0005 (0.0006)	-0.0007 (0.0006)	-0.0003 (0.0006)
Age		0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)
Age squared		-0.0004*** (0.0001)	-0.0005*** (0.0001)	-0.0005*** (0.0001)
Married		-0.0069*** (0.0007)	-0.0059*** (0.0007)	-0.0058*** (0.0007)
Divorced		0.0043*** (0.0015)	0.0051*** (0.0015)	0.0051*** (0.0015)
Single		0.0084*** (0.0012)	0.0088*** (0.0012)	0.0090*** (0.0012)
Separated		0.0207*** (0.0029)	0.0208*** (0.0029)	0.0208*** (0.0029)
Dependents		0.0011*** (0.0003)	0.0011*** (0.0003)	0.0011*** (0.0003)
Unemployed		0.0075*** (0.0025)	0.0071*** (0.0025)	0.0070*** (0.0025)
Employed		-0.0091*** (0.0009)	-0.0085*** (0.0009)	-0.0081*** (0.0009)
Home		-0.0105*** (0.0008)	-0.0101*** (0.0008)	-0.0101*** (0.0008)
Death of spouse or child			0.0327***	0.0327***
Death of close relative			0.0058	0.0058
Death of close friend			0.0092***	0.0090***
Postgrad			0.0011	0.0011
Bachelor			0.0177***	0.0175***
Graduate diploma			0.0012	0.0012
Diploma				-0.0025** (0.0011)
Certificate				-0.0052*** (0.0008)
Year 12				-0.0027*** (0.0010)
Observations	179,415	179,405	178,527	178,441

The dependent variable is a dummy indicator for victim of physical violence. All regressions include wave fixed effects. Robust standard errors in parentheses.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

levels in all regressions, suggesting that energy poverty is positively associated with the likelihood of experiencing physical violence. The interpretation of the coefficient of 0.032 in Column 1 is that energy poverty has led to an increase in the probability of experiencing physical violence of 3.2 percentage points, holding other things constant. Notice that this positive relationship between energy poverty and physical violence remains strongly consistent across alternative specifications given in Columns 2–4. In summary, we find that energy poverty increases the likelihood of experiencing physical violence by 1.9 to 3.2 percentage points across these specifications, and these increases are substantial relative to the mean of physical violence at 0.015. Hence, our baseline results are in line with the literature that has demonstrated a positive link between resource deprivation and violence (e.g., McIlwaine and Moser, 2003; Cunradi et al., 2000; De Olarte and Llosa, 1999).

Coming to the control variables, our results show that access to better education significantly reduces the likelihood of experiencing physical violence. Household disposable income and home ownership have

negative and statistically significant effects on the probability of experiencing physical violence. Life events such as the death of a close family member have a positive and statistically significant association with the likelihood of experiencing physical violence. With regard to socio-economic variables, being employed and being married are found to be negatively associated with the likelihood of experiencing physical violence. On the other hand, the probability of experiencing physical violence increases with being unemployed, being single, being separated, and divorced.³

We also re-estimate Eq. (1) using a probit model. Table 2 shows the estimated marginal effects of energy poverty on physical violence following the probit estimations. The results are consistent with our estimates from the linear probability model presented in Table 1. The estimated coefficient on EPOV1 remains robust, confirming that energy poverty leads to a higher probability of experiencing physical violence.

5.2. Instrumental variable (IV) estimates

As mentioned in Section 3.2, we use data on state-level gas price indices from the Australian Bureau of Statistics to instrument energy poverty as energy prices are strong predictor of energy poverty (Awaworyi Churchill et al., 2020). Thus, this section considers our main two stage least square (2SLS) estimates. Table 3 presents the estimates from the 2SLS along with the associated first-stage diagnostic test results where energy poverty is instrumented with gas prices. The instrumental variable (IV) estimates reveal that energy poverty causes an increase in the probability of experiencing physical violence. The results from the 2SLS estimation are quantitatively larger compared to the baseline results, suggesting a downward bias in the baseline results that may be driven by endogeneity. Specifically, it is likely that energy poverty may have a feedback effect and that the data could be measured with errors. For example, earlier studies suggest that respondents underreport their annual spending on energy bills of up to 20% in their responses to the HILDA survey (Wilkins and Sun, 2010). This kind of classical measurement errors could attenuate the basic estimates of the impact of energy poverty on physical violence. Similarly, omitted variable bias could lead to an upward or downward bias on the coefficient estimate of energy poverty. As pointed out by Forbes (2000), one cannot precisely identify the direction of the bias as there could be several unobserved factors that may lead to either overestimation or underestimation of the parameter of interest. However, in our case, it is evident that the direction of the bias is downward.

With regard to the instrument quality, the Kleibergen-Paap F-statistic is way above 10 in all regressions, indicating the rejection of the null of weak instrument. Moreover, the first stage F-statistics far exceeded the rule of thumb of 10. The coefficient on fuel prices from the first stage regression shows that there is a significant positive correlation between the instrument and the endogenous variable in all regressions. These results confirm the relevance of the instrument. Since our model is exactly identified with one endogenous variable and one instrument, the Sargan test of overidentification cannot be computed. However, the fact that our estimates are consistent across alternative specifications suggest that the assumption of the exclusion restriction is unlikely to be violated.

5.3. Robustness check

To check the sensitivity of our main results, we estimate our model using alternative measures of energy poverty, namely EPOV2 and

³ Since energy poverty may be correlated with state-level macroeconomic conditions, we have used monthly labour force data from the Australian Bureau of Statistics, including the employment rate, unemployment rate and participation rate, to re-estimate our model. The results show that the coefficient of energy poverty is still significant and robust, while the coefficients of these macro variables are statistically indistinguishable from zero. Thus, we do not report these results to conserve space. Results are available upon request.

Table 2
Marginal effects from probit estimates.

	Unconditional (1)	Socio-economic (2)	Life events (3)	Education level (4)
EPOV1	0.024*** (0.005)	0.013*** (0.004)	0.009*** (0.004)	0.009*** (0.004)
Socio-economic	No	Yes	Yes	Yes
Life events	No	No	Yes	Yes
Educational level	No	No	No	Yes
Full controls	No	No	No	Yes
Observations	179,415	179,405	178,527	178,441

The dependent variable is a dummy indicator for victim of physical violence. All regressions include wave fixed effects. Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 3
IV estimates of the effect of energy poverty on physical violence.

	Unconditional (1)	Socio-economic (2)	Education level (3)	Life events (4)
<i>Two-stage least square</i>				
EPOV1	0.870** (0.397)	0.786** (0.384)	0.815** (0.381)	0.754** (0.373)
Socio-economic	No	Yes	Yes	Yes
Education level	No	No	Yes	Yes
Life events	No	No	No	Yes
Full controls	No	No	No	Yes
Observations	179,415	179,405	179,319	178,441
Kleibergen-Paap F statistic	73.754	84.544	86.581	90.047
<i>First stage</i>				
Gas prices	0.011*** (0.001)	0.011*** (0.001)	0.012*** (0.001)	0.012*** (0.001)
F statistic	73.75	84.54	86.58	90.05

The dependent variable is a dummy indicator for victim of physical violence. All regressions include wave fixed effects. Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 4
Sensitivity of estimates to alternative measures of energy poverty.

	Panel A: Linear probability model		Panel B: Probit model	
	(1)	(2)	(3)	(4)
EPOV2	0.005** (0.002)		0.002*** (0.001)	
EPOV3		0.048*** (0.004)		0.012*** (0.001)
Controls	Yes	Yes	Yes	Yes
Observations	178,441	173,946	178,441	173,946

The dependent variable is a dummy indicator for victim of physical violence. All regressions include wave fixed effects. Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05.

EPOV3, as described in Section 3. Panel A of Table 4 shows the results from the linear probability model, while Panel B presents that estimates from the probit model. The coefficient estimates are positive and statistically significant in all regressions. This suggests that our main finding that energy poverty is associated with higher probability of experiencing physical violence is robust.

We perform additional robustness checks by including the lagged dependent variable in our specification. The results reported in Table A2 of the Appendix show that our main conclusion is robust. The coefficient of energy poverty remains positive and statistically significant. The coefficient of the lagged dependent variable is

Table 5
Heterogeneous effects by age group.

	Age group				
	15–24	25–34	35–44	45–54	≥55
EPOV1	0.077 (0.048)	0.008 (0.035)	0.120** (0.054)	0.055*** (0.021)	0.003 (0.007)
Observations	29,977	26,618	27,428	28,266	54,064
Controls	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. All regressions include wave fixed effects.

*** $p < 0.01$, ** $p < 0.05$.

also positive and statistically significant suggesting the persistent nature of physical violence. We further investigate the sensitivity of our results by including the lagged value of energy poverty. As shown in Table A3 in the Appendix, our main results on the effect of energy poverty on physical violence remain robust, while the coefficient on the lagged value of energy poverty is statistically indistinguishable from zero.

5.4. Heterogeneous effects

In this section, we examine the impact of energy poverty on physical violence based on age groups, gender and income levels to further understand the link between energy poverty and physical violence.

Regarding age, we split our sample into five categories capturing age groups of 15 to 24, 25 to 34, 35 to 44, 45 to 54, and 55 years and above. As depicted in Table 5, the relationship between energy poverty and physical violence is statistically insignificant for relatively young people who are below the age of 35 years. However, the effect of energy poverty on the likelihood of experiencing physical violence is statistically significant to those in the age group 35 to 54 years. The effect is much stronger in the 45 to 54 years cohort. We find no evidence of the link between energy poverty and the probability of experiencing physical violence in the age group of 55 years and above.

Additionally, the impact of energy poverty on the probability of experiencing physical violence might differ by gender and income levels. As presented in Table 6, even though energy poverty is a statistically significant predictor of the probability of experiencing physical violence for both males and females, males are more likely to experience physical violence than females. The last two columns of Table 6 show that income levels tend to influence the relationship between energy poverty and physical violence. For households with income below the median, energy poverty increases the likelihood of experiencing physical violence. For households with income above the median, the relationship between energy poverty and the probability of experiencing physical violence is negative but is statistically insignificant. By comparing our results with the related empirical evidence, our findings lend support to the findings of some recent studies, including Cunradi et al. (2002) and Smith and Weatherburn (2013). Since low-income households typically live in energy poverty, our empirical evidence supports Cunradi et al.'s finding that intimate partner violence is more likely to take place in low-income households. Using longitudinal data from HILDA, Smith and Weatherburn (2013) also find that there is a

Table 6
Heterogeneous effects by gender and income.

	Male	Female	Below median income	Above median income
EPOV1	0.029** (0.013)	0.021* (0.012)	0.019** (0.010)	−0.003 (0.022)
Observations	83,797	94,644	78,089	100,352
Controls	Yes	Yes	Yes	Yes

Standard errors in parentheses. All regressions include wave fixed effects.

** $p < 0.05$, * $p < 0.1$.

Table 7
Estimates of the effect of energy poverty on the proposed mediating variables.

	(1)	(2)	(3)	(4)	(5)
	Kessler1	Kessler2	Cigarette	Social capital	Satisfaction with partner
EPOV1	5.398*** (0.759)	0.711*** (0.096)	0.157*** (0.031)	−0.568*** (0.072)	−0.277 (0.192)
Observations	78,174	78,174	124,018	178,183	128,950
Controls	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. All regressions include wave fixed effects.

*** $p < 0.01$.

higher probability of experiencing physical violence by those who reported financial stress, including the inability to pay electricity and gas bills, which tends to be experienced by households with lower income levels.

5.5. Mechanisms

As implied by the discussions given in Section 2, this section examines if the four potential mediating variables given by: (i) psychological distress (Kessler1 and Kessler2), (ii) substance use (consumption of cigarettes and tobacco), (iii) social capital, and (iv) life satisfaction with partner, are primary mechanisms linking energy poverty with the likelihood of experiencing physical violence.

To be qualified as mechanisms through which energy poverty influences physical violence, the potential mediating variables need to be correlated with energy poverty and the indicator of physical violence. Furthermore, the coefficient on energy poverty is expected to become smaller in magnitude or statistically insignificant when the potential mediating variables are included in the regression of physical violence on energy poverty as additional covariates.

Table 7 shows the effect of energy poverty on these four potential mediating variables: psychological distress (Kessler1 and Kessler2), consumption of cigarettes and tobacco, social capital, and life satisfaction with partner. Column (1) reports the effect of energy poverty on Kessler1; Column (2) presents the effect on Kessler2; Column (3) reports the effect on consumption of cigarettes and tobacco; Column (4) and Column (5) report the effects on social capital and life satisfaction with partner, respectively. The results support the existence of a statistically significant correlation between energy poverty and each of the proposed mechanisms except for life satisfaction with partner. Specifically, energy poverty is positively associated with both measures of psychological distress as well as with consumption of cigarettes and tobacco but it is negatively associated with social capital. Although the relationship between energy poverty and life satisfaction with partner is statistically insignificant, they are negatively correlated. Hence, all these results are consistent with the discussions given in Section 2.

Table 8 presents the results that include the measures of the potential mediating variables as additional covariates in the regression of physical violence on energy poverty. In Column 1, we include Kessler1 as an additional covariate, and Column (2) reports the results where we exclude the distress variable, i.e., Kessler1, with the same sample size so that we can compare the coefficient on energy poverty. We repeat such pairs of regressions in the subsequent columns for the remaining mechanism variables. Our results reveal that both measures of psychological distress and substance use (consumption of cigarettes and tobacco) lead to a higher likelihood of experiencing physical violence. As shown in Table 8, the inclusion of these additional covariates leads to a decrease in the magnitude of the coefficient on energy poverty. For example, in Column (2) the coefficient on EPOV1 is 0.027. When Kessler1 is included in Column (1), the coefficient on EPOV1 becomes statistically indistinguishable from zero. Similarly, the coefficient

Table 8
Transmission mechanism.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EPOV1	0.017 (0.012)	0.027** (0.012)	0.019 (0.012)	0.027** (0.012)	0.024** (0.010)	0.026** (0.010)	0.021** (0.009)	0.024*** (0.009)	0.024** (0.012)	0.025*** (0.012)
Kessler1	0.002*** (0.000)									
Kessler2			0.012*** (0.001)							
Cigarette					0.009*** (0.001)					
Social capital							-0.007*** (0.000)			
Satisfaction with partner									-0.003** (0.0002)	
Observations	78,004	78,004	78,004	78,004	123,746	123,746	177,800	177,800	128,702	128,702
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is a dummy indicator for victim of physical violence. All regressions include wave fixed effects.

Robust standard errors in parentheses.

*** p < 0.01, ** p < 0.05.

Table 9
Estimates of the structural equation model.

	Mediating variable				
	(1) Kessler1	(2) Kessler2	(3) Cigarette	(4) Social capital	(5) Satisfaction with partner
Direct effect	0.017 (0.011)	0.018* (0.011)	0.024*** (0.011)	0.020*** (0.008)	0.025*** (0.009)
Indirect effect	0.010*** (0.001)	0.008*** (0.001)	0.002*** (0.000)	0.004*** (0.023)	0.001 (0.001)
Total effect	0.027** (0.030)	0.026** (0.011)	0.026*** (0.009)	0.024*** (0.008)	0.025*** (0.009)

Robust standard errors in parentheses.

*** p < 0.01, ** p < 0.05, * p < 0.1.

on EPOV1 is 0.026 in Column (6) and the coefficient on EPOV1 is reduced to 0.024 in Column (5) when we add consumption of cigarettes and tobacco as an additional explanatory variable to the regression. Similar results are observed for social capital (Column 7 and Column 8).

In Table 9, we employ a structural equation model to pin down the magnitude of the direct effect of energy poverty and its indirect effect through each of the potential mediating variables. The economic interpretation of the results is as follows. For example, the results in Column (3) of Table 9 show that the effect of energy poverty on the probability of experiencing physical violence is significantly mediated by consumption of cigarettes and tobacco. As shown by Column (3) of Table 9, energy poverty has a total effect of increasing the probability of experiencing physical violence by 2.6 percentage points, of which 2.4 percentage points are the direct effect and 0.2 percentage points are the indirect effect through higher level of substance use (cigarettes and tobacco). A similar interpretation applies to other potential mediating variables except for life satisfaction with partner. Notice that life satisfaction with partner has no role in mediating the link between energy poverty and the likelihood of experiencing physical violence. Hence, we find no evidence that life satisfaction with partner can mediate the relationship between energy poverty and physical violence, and instead we find that psychological distress, substance use and social capital are important channels through which energy poverty influences the probability of experiencing physical violence. Our results are consistent with some recent studies which also find psychological distress, substance

use and social capital as important variables that can affect violence (Cesur and Sabia, 2016; Gibbs et al., 2018; Kennedy et al., 1998; Lederman et al., 2002).

6. Conclusions

Energy poverty and physical violence generate substantial socio-economic costs to society at individual, community, and national levels. At national levels, energy poverty thwarts economic development and sustainability (OECD, 2007); and at individual and community levels, energy poverty reduces the quality of life of energy poor households (e.g., Thomson et al., 2017; Phoumin and Kimura, 2019). Physical violence is another major socio-economic problem due to the fact that there has been an outstanding increase in violent crime (e.g., Fajnzylber et al., 2002b). Physical violence not only reduces the well-being of victims and people close to them but also threatens social stability (e.g., Dolan et al., 2005; Cohen, 2005; Mervin and Frijters, 2014).

Although the issues related to energy poverty and violence have received separate attention in the literature, the interplay between energy poverty and violence has not yet been examined. In this paper we examine the effect of energy poverty on the probability of experiencing physical violence using Release 18 of the HILDA survey. Interestingly, our results reveal that energy poverty increases the likelihood of experiencing physical violence. We identified potential channels that link energy poverty with physical violence. Specifically, we find that psychological distress, substance use and social capital are important channels through which the effect of energy poverty is transmitted to the likelihood of experiencing physical violence.

Our results have important policy implications for policymakers and advocates. Specifically, policy approaches that promote access to affordable energy to low income households could be effective in combating the adverse effects of energy poverty on physical violence. Moreover, our analysis of the mechanisms suggests that mental health service, counselling on substance abuse and policies that reinforce and promote social capital could help in dampening the effect of energy poverty on physical violence.

Declaration of Competing Interest

None

Appendix

Table A1
Description of variables and summary statistics.

Variable	Descriptions	Mean	SD
VIO	Life events in past year: Victim of physical violence	0.015	0.123
EPOV1	Energy expenditure share of household income	0.025	0.034
EPOV2	Dummy variable equals 1 if EPOV1 exceeds 10%	0.019	0.137
EPOV3	Dummy variable equals 1 if unable to heat home	0.030	0.172
Death of spouse or child	Life events in past year: Death of spouse or child	0.009	0.093
Death of close relative	Life events in past year: Death of close relative/family member	0.118	0.322
Death of close friend	Life events in past year: Death of a close friend	0.113	0.316
Postgrad	Highest level of education is masters or doctorate	0.042	0.200
Bachelor	Highest level of education is Bachelor or honours	0.132	0.338
Graduate diploma	Highest level of education is graduate diploma or certificate	0.051	0.220
Diploma	Highest level of education is diploma	0.088	0.283
Certificate	Highest level of education is certificate III or IV	0.207	0.405
Year12	Highest level of education is Year 12	0.153	0.360
Female	Gender indicator if the respondent is female	0.513	0.500
Age	Age of respondent	36.283	22.667
Age squared	Age squared divided by 100	18.303	18.528
Married	Respondent is legally married	0.479	0.500
Divorced	Respondent is divorced	0.060	0.237
Single	Respondent is never married and not de facto	0.241	0.428
Separated	Respondent is legally separated	0.027	0.163
Dependents	Number of dependents	0.477	0.955
Unemployed	Labor force status is unemployed	0.039	0.193
Employed	Labor force status is employed	0.633	0.482
Income	Annual household disposable income ('000)	82.609	59.657
Home	Home ownership status	0.640	0.480
Kessler1	Kessler Psychological Distress Scale (K10) score	15.955	6.532
Kessler2	Kessler Psychological Distress Scale (K10) risk categories	1.592	0.889
Cigarette	Weekly household expenditures on cigarettes and tobacco (\$)	14.933	39.093
Social capital	Social support	5.417	1.020
Satisfaction with partner	Life satisfaction with partner	8.266	2.035
Gas prices	State-level gas prices (\$)	96.696	30.348

Table A2
Sensitivity of estimates to the inclusion of lagged dependent variable.

	Unconditional (1)	Life events (2)	Education level (3)	Socio-economic (4)	Unrestricted model (5)
EPOV1	0.031*** (0.009)	0.019** (0.009)	0.026*** (0.009)	0.031*** (0.009)	0.021** (0.009)
Lag violence	0.224*** (0.010)	0.223*** (0.010)	0.224*** (0.010)	0.216*** (0.010)	0.214*** (0.010)
Life events	No	Yes	No	No	Yes
Education level	No	No	Yes	No	Yes
Socio-economic	No	No	No	Yes	Yes
Full controls	No	No	No	No	Yes
Observations	155,647	154,929	155,580	155,643	154,858

Standard errors in parentheses. All regressions include wave fixed effects. *** $p < 0.01$, ** $p < 0.05$.

Table A3
Sensitivity of estimates to the inclusion of lagged energy poverty.

	Unconditional (1)	Life events (2)	Education level (3)	Socio-economic (4)	Unrestricted model (5)
EPOV1	0.034*** (0.010)	0.024** (0.010)	0.028*** (0.010)	0.034*** (0.010)	0.026*** (0.010)
Lag EPOV1	0.001 (0.008)	-0.003 (0.008)	-0.005 (0.008)	0.001 (0.008)	-0.002 (0.008)
Life events	No	Yes	No	No	Yes
Education level	No	No	Yes	No	Yes
Socio-economic	No	No	No	Yes	Yes
Full controls	No	No	No	No	Yes
Life events	No	Yes	No	No	Yes
Observations	146,588	145,916	146,518	146,583	145,841

Standard errors in parentheses. All regressions include wave fixed effects. *** $p < 0.01$, ** $p < 0.05$.

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