Effects of renting on household energy expenditure: Evidence from Australia

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Abstract

This paper uses household survey data from Australia to investigate whether renters face larger energy bills than otherwise similar households. We find that a negative unconditional effect of renting on residential electricity expenditure becomes positive when controlling for log net wealth, with renters on average spending about 8% more than otherwise similar households. This is a larger effect than in most prior studies. The effect operates via higher usage quantities rather than higher average prices, and a similar effect is found for overall residential energy expenditure including natural gas. Central to the story is that renters tend to have lower net wealth, and net wealth is associated with higher energy use due to reasons including additional appliance ownership. This makes net wealth an important control. The findings cast light on the potential for more ambitious policy responses to reduce energy-related disadvantages faced by renters in Australia. There is also scope for further research into whether similarly large effects are evident in other countries.

Keywords: energy expenditure; electricity consumption; wealth; rent; split incentive

1. Introduction

Renters typically do not have full information on the energy characteristics of a property that they may be considering, making them often unwilling to pay commensurately higher rent for more energy-efficient dwellings. As a result, landlords often have an inadequate incentive to invest in energy efficiency. There is a "split-incentive" or "principal-agent" problem. The result is that renters may face higher energy bills and/or difficulty controlling home temperatures, introducing a source of disadvantage for what is a relatively large share of the population in countries such as Australia (about 30%; ABS, 2017). Empirical analysis of split-incentive effects for renters has been identified as a promising area for research (Gerarden *et al.*, 2017).

This paper uses household survey data for Australia to explore whether renting households spend more on residential energy relative to otherwise similar households. We find that the additional residential energy expenditures of renters is larger than often realised. Our approach of including net wealth as a control could be utilized in follow-up studies to examine if a similarly sized effect exists in other countries.

Initial evidence, shown in Figure 1, indicates that as of 2012 renting households in Australia spent 11% *less* on grid-supplied electricity than non-renters (ABS, 2013). It can also be seen that this is similar for overall spending on electricity and domestic fuels including natural gas in 2015–16 (ABS, 2017). However, it is important to remember that renters differ from non-renters across various socio-economic dimensions, including average incomes and net wealth levels. This paper explores whether the negative unconditional effect of renting on household energy bills changes when key other factors are considered.

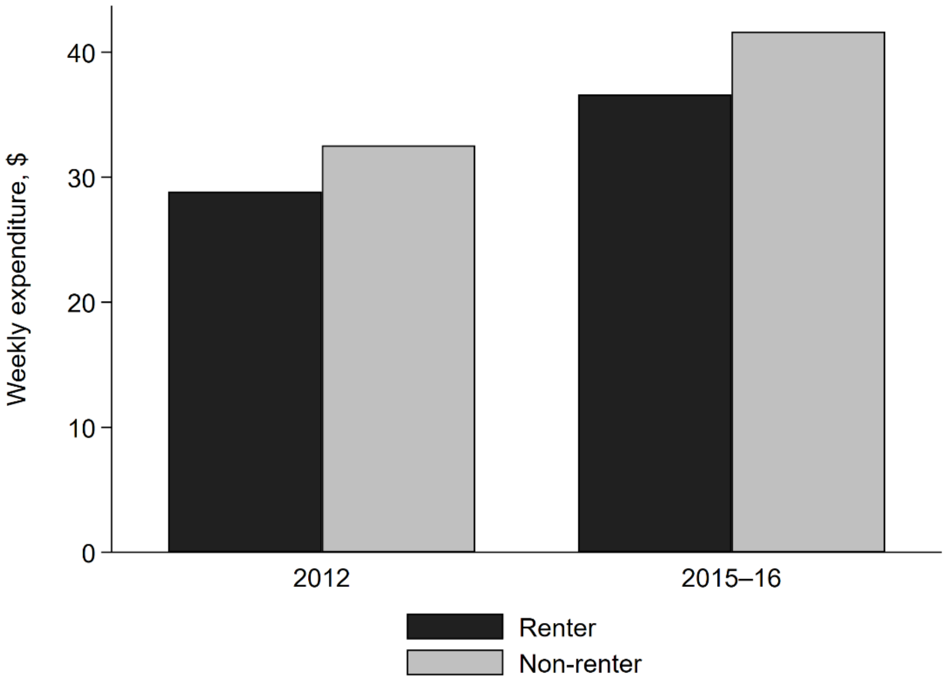

Fig. 1. Average weekly household expenditure on electricity in 2012 and electricity and domestic fuel in 2015–16 for renters and non-renters. The units are Australian dollars (A$). Zeroes were excluded. The ABS calculates averages by dividing expenditure by the number of weeks in the recall period, which is generally quarterly based on this common billing frequency. Surveys were conducted throughout the year. Data: Australian Bureau of Statistics (ABS, 2013; 2017).

In prior research, some studies have found positive and significant effects of renting on energy use when including control variables, consistent with the existence of a split-incentive problem (Gerarden *et al.*, 2017). For example, Melvin (2018) found that renters' energy bills are approximately 2% higher due to split incentives in the United States (US). Best *et al.* (2021) found that renters in the US use approximately 9% more electricity than non-renters based on a model with many controls. Rehdanz (2007) found evidence of significantly higher expenditures on space heating and hot water supply for non-owner-occupiers in Germany, all else equal. Bernard *et al.* (1996) found that renters use more electricity in Quebec than homeowners, all else equal.

There is some contrasting evidence also. Meier and Rehdanz (2010) found a positive and significant coefficient for homeowners in the UK in explaining the log of annual heating expenditure per room, with some controls included. Studies for Australia have also found a negative effect of rental status on energy consumption (Wood *et al*., 2012; Cao *et al.*, 2015; Poruschi and Ambrey, 2016) after conditioning on controls. Wood *et al*. (2012) concluded that the split-incentive problem may be less relevant in Australia due to landlords being adequately able to capture rent premia for energy-efficient properties. Australia maintains tax advantages (such as negative gearing allowances) for property investors, relatively unregulated rental markets without broad price controls, and a relatively high property turnover rate between owner-occupier and renter status (Wood *et al*., 2012). Whether this context is sufficient to avoid split incentives is an open question.

Of the many other factors that may affect household consumption and expenditure on energy, net wealth may be particularly important. Higher net wealth means that households have a more relaxed budget constraint and the collateral to more easily borrow (Cooper and Dynan, 2016), and might lead to more energy consumption via three channels. First, wealthier households may acquire a higher number of energy-using appliances. Second, the appliances they acquire may potentially use more energy, for example their televisions may be larger. Third, wealthier households may tend to use some appliances more intensively, for example their air conditioning system may be used more often or to cool a larger space.

There is a long history of studies that have documented wealth effects on various forms of consumption (Cooper and Dynan, 2016; Veirman and Dunstan, 2012), including in Australia (Windsor *et al*., 2015; Atalay *et al*., 2016). Both financial and nonfinancial wealth have been found to be positively associated with household consumption levels (Tan and Voss, 2003; Dvornak and Kohler, 2007). There is also a positive association between housing wealth and purchases of new passenger vehicles (Gillitzer and Wang, 2016), and wealth variables have been found to be relevant for investment in new energy generation capacity at various scales (Kim and Park, 2016; Best, 2017; Best *et al*., 2019a). Yet to date there has been a lack of evidence on the effect of household wealth levels on household energy consumption. Prior studies on the effect of renting have yet to comprehensively control for household wealth effects.

A strong correlation between net wealth and tenure type is evident in Figure 2. In 2015–16, average net wealth was about A$1.2 million for non-renting households and only about A$0.25 million for renters. The correlation between net wealth and renting status was –0.2. Interestingly, the correlation between income and renting was weaker, at only –0.1.

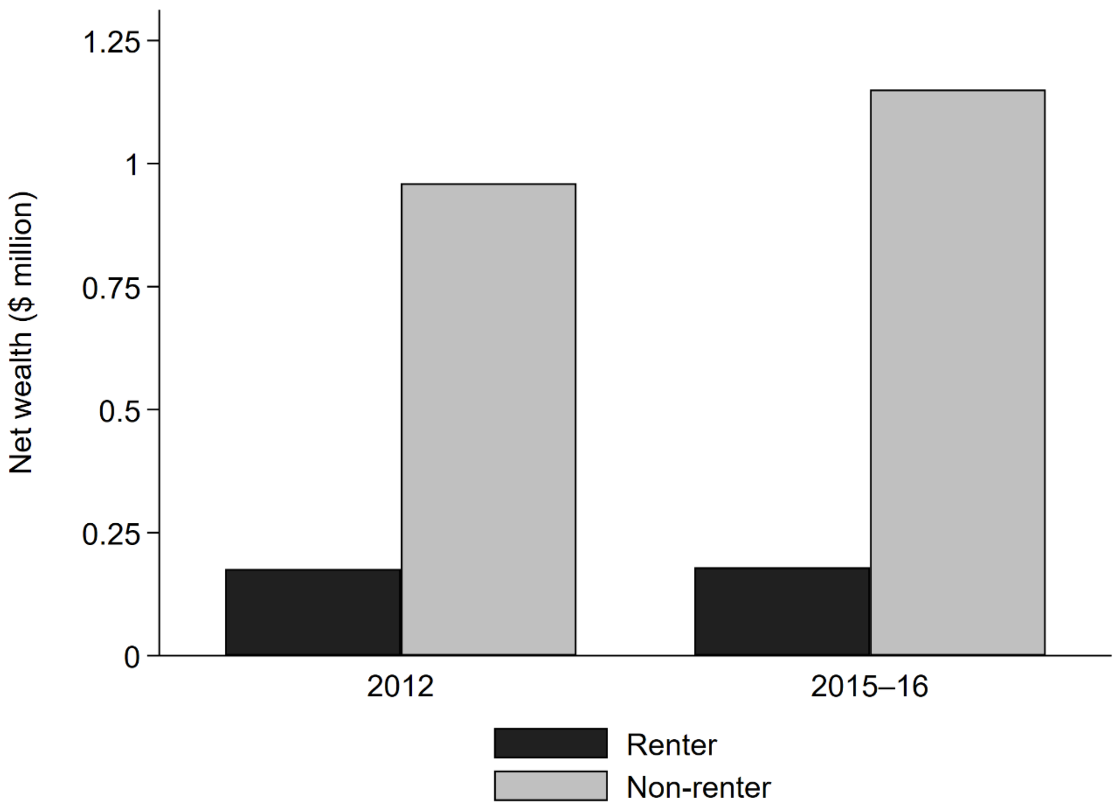

Fig. 2. Household net wealth (A$ million) for renters and non-renters. Data: ABS (2013; 2017).

Figure 3 shows that the energy burden (energy expenditure divided by income) is on average slightly higher for renters than non-renters. This is despite renters on average consuming less energy; according to the ABS (2013), renters on average consumed 15% less residential electricity than other households in 2012, for example. This points to a relative disadvantage: renters both consume less energy and have higher energy burdens than non-renters. Our econometric analysis controls for income, net wealth, and other factors to seek to identify whether renting places upward pressure on energy bills once potentially key variables are taken into account.

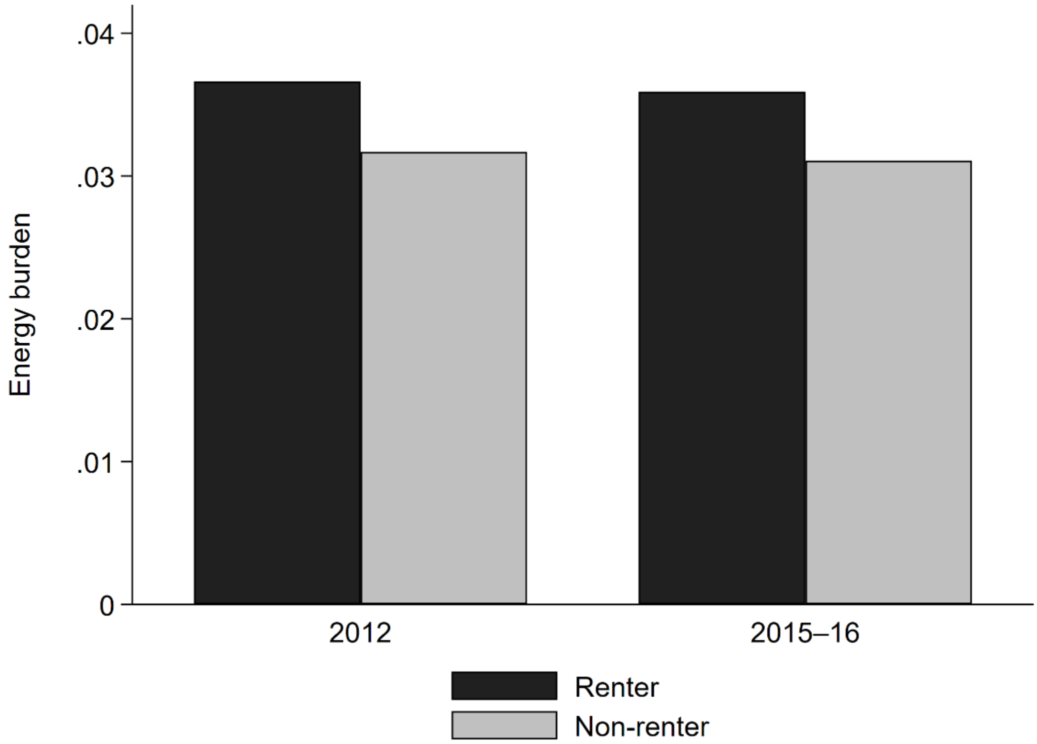

Fig. 3. Energy burden (energy expenditure divided by income). Data: ABS (2013; 2017).

The conceptual framework for the paper is concise: while renters spend less on energy in an unconditional sense, this may be due to their lower average net wealth and incomes, among other factors. When accounting for these differences, renters may in fact spend more on energy relative to otherwise similar households, potentially reflecting the inferior energy efficiency characteristics of rental properties and also perhaps other reasons. We investigate this issue using data from two separate household surveys.

The analysis also explores the effects of many variables other than net wealth and income. Ownership of household appliances and equipment, which can be a positive function of net wealth, are likely to be relevant. For example, having rooftop solar photovoltaic panels helps households to reduce their use of grid-supplied electricity – and renters have been found to be substantially less likely to have solar panels, all else equal (Best *et al*., 2019a, 2019b; Zander, 2020). In addition, there can be differences in behavioural measures between renters and non-renters (Nie *et al*., 2020), so we include variables such as participation in a green power scheme. We also control for variables including whether a household is a single-parent household, the main source of household welfare such as age pensions, and whether there is a household member requiring energy-consuming medical equipment.

Our focus is partly motivated by the fact that renters are known to be more likely to experience energy-related financial stress in Australia (Best and Burke, 2019). Some already disadvantaged groups such as ethnic minorities and female-headed households are more likely to rent (ABS, 2017; Flage, 2018), heightening the importance of the issue. If there are potentials for improving energy efficiency in rental accommodation, this would deliver both socio-economic and environmental benefits. Evidence relating to a market failure in the rental market could thus carry policy relevance.

2. Method and data

2.1 Model and variables

The model in equation (1) considers household energy expenditure (E_h) as a function of renting, net wealth, and other variables:

$$\ln E_h = \alpha + \beta R_h + \gamma \ln W_h + \boldsymbol{X'}_h \boldsymbol{\delta} + \varepsilon_h \qquad (1)$$

Separate regressions are run for residential electricity expenditure and for expenditure on residential energy including both electricity and natural gas.[1] Electricity bills include a supply charge that is independent of the quantity consumed plus a variable charge related to usage. In Australia, renters typically pay their own energy bills other than in a relatively small share of cases such as when a property is not separately metered. Indeed, about 94% of renters had non-zero electricity expenditure in the 2012 Household Energy Consumption survey that we

[1] Spending on energy for transport is not included.

use (ABS, 2013). Analysis in Section 3 uses the log of expenditure variables, so focuses on households with non-zero expenditures.

The 2012 Household Energy Consumption survey (ABS, 2013) provides data on electricity expenditure for all households and electricity usage for households who had their latest electricity bill readily available. As an additional dependent variable, we use the average electricity price paid by each household. We calculate this as the usage charge for grid-supplied electricity (excluding the fixed charge component) divided by the on-grid electricity usage quantity. We exclude the top 2% of responses (those above $0.59 per kWh), as these appear to be inaccurate. An average price of $0.59 per kWh is about three times the average and may in some cases reflect reporting errors. Electricity prices paid at the household level are partly affected by regional variation in average price levels, so we include location controls as described below.

We consider that net wealth and income are fundamental variables that may influence residential energy expenditure. There are two types of other variables. First are other household and housing characteristics that may be directly relevant for residential energy use, such as the number of people in the household. Second are variables that are potential direct channels via which net wealth and income may influence energy expenditure, including the types of hot-water systems used and the average hours of use of air conditioning. Like this study, the US study by Gillingham et al. (2012) controlled for characteristics of occupants, dwellings, and energy variables such as measures of heating system characteristics.

In equation (1), R_h is a binary variable equal to one for renters (defined at the household level) and zero otherwise. W_h is net wealth, equal to total assets minus total liabilities for each household. Assets include all financial, property, business assets, and other assets. Liabilities include loans for property, education, and credit card debt. Households with negative or zero values of net wealth are excluded when taking the log. This affects approximately 1% of households.

Other explanatory variables are in the ***X*** vector. These include a range of location, housing, socioeconomic, and energy variables. The location variables include binary variables for regions. Climate zone controls are also included in some estimations. The housing variables include the tenure type, dwelling structure, and number of bedrooms in the residence to give an indication of size. Socioeconomic variables include household income along with a range of social variables such as single-parent status of households and also the age of the respondent who completed the survey on behalf of the household. Energy variables include a binary variable for having a mains gas connection, the principal substitute for electricity for residences. Table A.1 has a full list of the explanatory variables and their definitions. ε_h is the error term in what are ordinary least squares regressions. The results tables will show heteroskedasticity-robust standard errors.

2.2 Data

We use data from two household surveys conducted by the Australian Bureau of Statistics (ABS, 2013; 2017): the 2012 Household Energy Consumption (HEC) survey and the 2015–16 Household Expenditure Survey (HES). The advantage of these surveys is their wide coverage of energy variables. More recent surveys have included fewer energy-related questions. For example, the 2017–18 Survey of Income and Housing does not provide data on energy consumption. An alternative household survey, the Household Income and Labour Dynamics in Australia (HILDA) survey, does not include many energy variables (e.g. solar-panel uptake). Summary statistics for each variable are in Table A.2 and A.3.

2.3 Econometric and data issues

Sample selection bias could be an issue if the characteristics of the survey respondents are not representative of the Australian population. However, the two surveys were large and intended to be nationally representative. The HEC survey covered 11,978 households and the HES a sample of 10,046 households. We use the survey sampling weights in some regressions to assess the robustness of the main results. These weights are the inverse of the probability of a household being selected for the survey.

Variables such as net wealth and renting status tend to be relatively persistent over time, meaning that earlier data are likely to remain relevant in the current context. Similarity in the descriptive statistics for different surveys supports this expectation. For example, the proportion of renters is 30% in each of the two surveys used in this study, while the proportion of apartment dwellers is 9% in the earlier survey and 10% in the later survey. Dwellings on average had 3.09 bedrooms in the earlier survey and 3.07 bedrooms in the later survey. Both surveys use similar sampling approaches and were conducted by the same statistical agency. The 2017–18 Survey of Income and Housing also has generally similar statistics.

Measurement error is a relevant consideration. For instance, net wealth could be subject to measurement error if respondents do not have accurate estimates of the values of their assets and liabilities. Taking the log of net wealth helps to remove a small number of outliers, such as households who report mortgages that are many times their home's value. As will be seen, similar coefficients are obtained using either survey.

Reverse causation is a potential problem for some variables. For example, electricity expenditure could influence appliance purchase decisions. This is unlikely to be a major issue though, as most energy-using or energy-generating appliances would have been installed in years prior to the survey year. We also conduct a number of robustness tests to reduce reverse causation concerns, including replacing a binary explanatory variable for households who have solar photovoltaic panels with a variable restricted to only panels installed at least two years prior to the survey. Causation or correlation between explanatory variables, such as renting and net wealth, is not a concern unless it is extremely high. Variance inflation factors will be examined to check for excessive multicollinearity.

The potential for omitted variable bias is another consideration. We attempt to reduce this by including many controls. These include measures of tenure, household financial resources and tendencies, household occupant characteristics, and building structure characteristics. Binary variables are also included for 14 regions: the Australian Capital Territory, the Northern Territory, and two for each of the six states using a capital city versus non-capital city split. We also control for the six climate zones available in the HEC data.

3. Results and discussion

3.1 2012 HEC survey

3.1.1 Main results

Column (1) of Table 1 uses the 2012 survey data, finding a negative coefficient for renting in explaining electricity expenditure.[2] This result is obtained while controlling for only location, climate, the survey timing over four quarters, and some socioeconomic and housing variables, including the number of people in the household. Column (2) adds a variable for the number of bedrooms, which tends to be higher for wealthier households. The coefficient for renting becomes less negative, moving from –0.116 to –0.068. Additional robustness tests in Appendix Table A.4 control for the number of electric appliances such as fridges. This also leads to the renter coefficient becoming less negative. However without the net wealth variable included as a control, the regressions still show a negative renter coefficient.

[2] Each column is for a constant sample to allow a focus on only the effects of including additional explanatory variables. This is achieved by excluding a small number of households with missing data for some variables from the estimation sample. Results available through the online code in the supplementary material are similar if this is not done.

Columns (3)–(4) of Table 1 include additional energy controls. The renter coefficient becomes more negative in column (3) when having solar panels is included as a control, since renters are less likely to benefit from self-generation of solar electricity. Controlling for some other energy measures, such as the hours of use of air conditioning, leads to the renter coefficient becoming slightly less negative in column (4). Controlling for the number of TV set top boxes used at least once a week has minimal impacts, as evident via the Stata code.

Column (5) of Table 1 adds the log net wealth variable to the regression. Doing so results in the renter binary variable switching to being positive and significant. We refer to the coefficient here as the conditional direct effect of renting (Imai *et al*., 2010). The result suggests that omitting net wealth in the earlier regressions led to the renter coefficient being biased downward because the renting variable was partly picking up the effect of lower net wealth among renters. The renter coefficient now has a magnitude of 0.075, suggesting that renters spend approximately 8% more on electricity than otherwise similar households who own their homes.

A positive coefficient is obtained for the net wealth variable in Table 1, suggesting that net wealth is relevant for residential electricity use in ways that have not been controlled for in the model. For example, wealthier households may tend to have larger residences that require greater electricity use for heating and cooling, and this is not fully controlled for by the variable measuring the number of bedrooms. Residence area in square meters has not been controlled for due to an absence of data for this variable.

Table 1. Results for household electricity expenditure, HEC survey, 2012.

	Dependent variable: Log household weekly electricity expenditure				
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Tenure type: renter ^	-0.116***	-0.068***	-0.103***	-0.085***	0.075***
	(0.024)	(0.024)	(0.023)	(0.023)	(0.027)
Household income, log	0.062***	0.056***	0.058***	0.057***	0.042***
	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
Save: just break even ^	-0.058***	-0.052***	-0.056***	-0.054***	-0.057***
	(0.018)	(0.018)	(0.017)	(0.017)	(0.017)
Save most weeks ^	-0.125***	-0.116***	-0.117***	-0.115***	-0.133***
	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)
Weekly housing costs, log	0.071***	0.063***	0.059***	0.064***	0.062***
	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)
Green power scheme ^	0.062**	0.064**	0.081***	0.081***	0.075***
	(0.028)	(0.028)	(0.027)	(0.027)	(0.027)
Number of persons #	0.178***	0.153***	0.160***	0.157***	0.160***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Number of employed persons #	0.037***	0.031***	0.031***	0.034***	0.019**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Number of children under 15 #	-0.076***	-0.067***	-0.070***	-0.068***	-0.069***
	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
Single parent ^	0.049**	0.035	0.019	0.032	0.057***
	(0.022)	(0.022)	(0.022)	(0.021)	(0.021)
Survey respondent 60+ years ^	-0.055***	-0.063***	-0.058***	-0.063***	-0.089***
	(0.018)	(0.018)	(0.017)	(0.017)	(0.017)
Mortgage ^	-0.088***	-0.065***	-0.064***	-0.072***	-0.019
	(0.024)	(0.024)	(0.023)	(0.022)	(0.022)
Dwelling age: 20+ years ^	0.015	0.036***	0.022*	0.018	0.021*
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Flat/unit/apartment ^	-0.061**	-0.016	-0.013	-0.028	-0.024
	(0.026)	(0.026)	(0.026)	(0.025)	(0.025)
Separate house ^	0.156***	0.083***	0.096***	0.092***	0.084***
	(0.020)	(0.020)	(0.020)	(0.019)	(0.019)
Number of bedrooms #		0.109***	0.113***	0.117***	0.101***
		(0.008)	(0.008)	(0.008)	(0.008)
Solar electricity ^			-0.520***	-0.528***	-0.531***
			(0.032)	(0.032)	(0.032)
Medical equipment ^				0.141***	0.137***
				(0.033)	(0.033)
Mains gas ^				-0.162***	-0.170***
				(0.022)	(0.022)
Net wealth of household, log					0.072***
					(0.006)
Additional controls	Yes	Yes	Yes	Yes	Yes
Other energy characteristics	No	No	No	Yes	Yes
Observations	10,861	10,861	10,861	10,861	10,861
R^2	0.272	0.283	0.322	0.364	0.372

Notes. ***, **, * show statistical significance at 1, 5 and 10 per cent level respectively. Robust standard errors are in brackets below the coefficients. Coefficients for constants are not shown. "Additional controls" include categorical variables for calendar quarter of survey, state-capital city regions, and climate zones. "Other energy characteristics" includes the list of variables, as described in Table A.1. We also control for Tenure type = "Other". A detailed education variable with 11 levels for the household respondent is also used. The coefficients for this are nearly all insignificant, especially when controlling for log net wealth. ^ denotes binary variables, # denotes integer variables.

The log net wealth coefficient in Table 1 is 0.07. This is an elasticity, as net wealth and electricity expenditure are both logged. The point estimate for the income elasticity of electricity expenditure is lower, at 0.04. Households who currently are more successful savers spend less on electricity, as indicated by negative and significant coefficients for those who just break even or usually save, relative to the excluded category of households who spend more than they receive. Robustness tests in the online code show similar coefficients for log net wealth and the binary renter variable when the saving variables are excluded. Households with higher log housing costs also spend more on electricity.

There are many significant effects of occupant characteristics on electricity expenditure in Table 1. Households with more people spend more on electricity, as expected. The coefficient of 0.16 indicates that an additional person adds about 17% to average household electricity expenditure, all else equal.[3] In column (5) there is a positive coefficient for single-parent households and a negative coefficient for households with a survey respondent aged 60 years or over.

The coefficients for the dwelling characteristics in Table 1 also match expectations. There is a positive effect of building age, as measured by a binary variable for houses aged 20 years or over, although statistical significance is mixed. Households in stand-alone houses spend more on electricity, while the effect for apartments is insignificantly different from that for the excluded category of medium-density townhouses in most columns. Having more bedrooms leads to higher electricity expenditure, as expected.

Column (5) of Table 1 indicates that having rooftop solar photovoltaic panels has a substantial impact on grid electricity expenditure net of feed-in tariffs, with a coefficient of –0.53. This implies that households with solar panels on average spend approximately 41% less on their electricity purchases from the grid than households without solar panels, all else

[3] $100 * (e^{0.16} - 1)$.

equal.[4] We explored a number of robustness tests for this result, such as splitting the solar variable into two: a binary variable for solar panels in New South Wales (NSW) and the Australian Capital Territory (ACT) where gross rather than net feed-in tariffs were initially offered, and one for solar panels in other states. These give similar results. We also found similar results when the solar binary variable is restricted to solar installations from more than two years prior to the survey (to reduce possible reverse causation issues).

Energy-related explanatory variables in column (5) of Table 1 also have significant coefficients. Households with an occupant who uses energy-consuming medical equipment on average spend more on electricity, all else equal. This is as expected. There is a negative coefficient for households with mains gas connections, since this provides a substitute for electricity for space heating, water heating, and cooking. Multicollinearity does not appear to be a major concern in Table 1, as the average variance inflation factor, along with the values of the variance inflation factor for the renting and net wealth variables, are well below 10.

Extra robustness tests in Appendix A.4 include a model with additional explanatory variables for fridges/freezers, the number of hot water systems, having a pool or spa, and the taking of energy-saving actions. The coefficient for renting remains similar when including these. A number of further robustness tests are available through the online code in the Supplementary section, producing similar effects. Specifically, adding log net wealth without any other controls makes the renting coefficient positive and significant. A substantial change in the renting coefficient is also observed when net wealth is adjusted to exclude the value of the family home, although the renting coefficient does not become significant.

[4] $100 * (e^{-0.53} - 1)$.

3.1.2 Decomposing the effect

Table 2 examines effects on three separate dependent variables: the log of electricity expenditure, the log average electricity price (excluding fixed charges), and the log electricity usage quantity. The coefficients in the log expenditure regression can be decomposed into the sum of the coefficients in the log price and log quantity regressions. For example, the renter coefficient of 0.098 in column (1) equals 0.005 plus 0.093. The small and insignificant coefficient for renters in explaining the average electricity price in column (2) and the large positive coefficient in explaining electricity use in column (3) suggest that renters have (conditionally) higher electricity expenditure primarily because of greater usage quantities. The magnitude of the impact on electricity use is similar to a finding for the US (Best *et al.*, 2021).

Electricity consumers in Australia can generally choose their preferred retail pricing arrangement based on a range of market options. For this and other reasons, there can be variation in the average electricity prices paid by individual households.[5] However, many of the other variables in column (2) of Table 2 are insignificant. Location is an exception, with each of 13 location variables having positive and significant coefficients at the 1% level relative to the excluded zone of the ACT (see the online code in the Supplementary material section). This reflects the fact that the ACT has relatively low electricity prices. The largest coefficients are for the two South Australian regions (capital city and other), consistent with South Australia's relatively high retail electricity prices as of the year of the survey.[6]

[5] The mean for the electricity consumption price in Table A.2 is $0.21/kWh, with a standard deviation of $0.05/kWh.

[6] The average electricity consumption price in the 2012 HEC survey was highest for South Australia at $0.24/kWh and lowest for the ACT at $0.15/kWh.

Table 2. Results for electricity spending, price, and consumption, HEC survey, 2012.

	Ln spend (1)	*Ln price* (2)	*Ln use* (3)	*Ln use* (4)
Tenure type: renter ^	0.098***	0.005	0.093***	0.096***
	(0.032)	(0.014)	(0.032)	(0.037)
University education ^	-0.049***	0.001	-0.050***	-0.027*
	(0.014)	(0.006)	(0.015)	(0.016)
Household income, log	0.043***	-0.005	0.048***	0.041***
	(0.009)	(0.004)	(0.009)	(0.009)
Save: just break even ^	-0.057***	-0.015	-0.042**	-0.057**
	(0.021)	(0.009)	(0.022)	(0.024)
Save most weeks ^	-0.155***	-0.010	-0.146***	-0.143***
	(0.022)	(0.009)	(0.022)	(0.024)
Weekly housing costs, log	0.051***	0.003	0.048***	0.054***
	(0.010)	(0.005)	(0.010)	(0.011)
Green power scheme ^	0.024	0.003	0.020	0.027
	(0.032)	(0.012)	(0.034)	(0.038)
Number of persons #	0.199***	0.005	0.195***	0.188***
	(0.011)	(0.005)	(0.011)	(0.013)
Number of employed persons #	-0.000	0.001	-0.001	0.003
	(0.011)	(0.005)	(0.011)	(0.012)
Number of children under 15 #	-0.083***	-0.007	-0.076***	-0.069***
	(0.013)	(0.006)	(0.014)	(0.015)
Single parent ^	0.077**	0.007	0.071**	0.075**
	(0.030)	(0.012)	(0.032)	(0.035)
Survey respondent 60+ years ^	-0.027	-0.031***	0.004	-0.014
	(0.019)	(0.008)	(0.020)	(0.022)
Mortgage ^	0.010	0.011	-0.001	-0.005
	(0.025)	(0.012)	(0.026)	(0.030)
Dwelling age: 20+ years ^	0.040***	-0.007	0.047***	0.010
	(0.014)	(0.006)	(0.014)	(0.016)
Flat/unit/apartment ^	0.024	0.015	0.009	0.023
	(0.033)	(0.014)	(0.035)	(0.035)
Separate house ^	0.079***	-0.000	0.080***	0.107***
	(0.025)	(0.011)	(0.026)	(0.027)
Number of bedrooms #	0.114***	0.001	0.113***	0.115***
	(0.010)	(0.004)	(0.010)	(0.012)
Net wealth of household, log	0.090***	0.004	0.086***	0.095***
	(0.008)	(0.003)	(0.008)	(0.010)
Electricity price, log				-0.595***
				(0.053)
Additional controls	Yes	Yes	Yes	Yes
Other energy characteristics	No	No	No	Yes
Probability weights	No	No	No	Yes
Observations	7,409	7,409	7,409	7,409
R^2	0.348	0.171	0.328	0.451

Notes. ***, **, * show statistical significance at 1, 5 and 10 per cent level respectively. Robust standard errors are in brackets below the coefficients. Coefficients for constants are not shown. "Additional controls" include categorical variables for calendar quarter of survey, state-capital city regions, and climate zones. "Other energy characteristics" includes the list of energy variables, as described in Table A.1. We also control for Tenure type = "Other". ^ denotes binary variables, # denotes integer variables.

Column (2) of Table 2 also finds a negative and significant effect on the log electricity price for households with a survey respondent who was aged 60 years or more. These households tend to pay approximately 3% less in terms of their average electricity consumption price than other households, all else equal. This likely largely reflects access to seniors' discounts (Victorian State Government, 2019; Australian Government, 2021). A negative and significant coefficient is also evident in Table A.5 when households with an average electricity consumption price in the top 5% (rather than the top 2%) are excluded from the sample.

Table 2 controls for a more concise education variable than was used in Table 1, equal to one for university-educated respondents and zero otherwise. The coefficient is negative and significant in explaining electricity spending and use but not price. That university-educated respondents have lower electricity use when controlling for other differences was also found for the US (Best *et al*., 2021). Scale effects are also evident in the positive and significant coefficients for the number of people and the number of bedrooms. The estimate for the net-wealth elasticity of electricity use, of about 0.09, is similar to the corresponding elasticity for electricity expenditure.

Appendix Table A.6 presents evidence on one channel for the influence of net wealth on energy consumption. Specifically, we find a positive relationship between log net wealth and the number of fridges/freezers owned by households. On average, a standard deviation increase in log net wealth is associated with a 0.1 unit increase in the number of fridges/freezers that a household has. There is also a positive net wealth effect on having a pool or spa, as expected. These are energy-using appliances.

Column (4) of Table 2 includes the log electricity price as an explanatory variable. The negative and significant coefficient of about –0.6 is a cross-sectional estimate of the price elasticity of electricity demand. This is within the range of estimates for Australia and other countries (Narayan and Smyth, 2005; Cao *et al*., 2015; Poruschi and Ambrey, 2016; Burke and Abayasekara, 2018; Burke and Kurniawati, 2018). Most of the other coefficients remain similar with the inclusion of this electricity price variable.

Reverse causation from electricity usage to the average electricity price (excluding the fixed charge) is possible. However it may not be a major concern because most electricity customers retain their provider and electricity contract for multiple years (Australian Competition and Consumer Commission [ACCC], 2018). While block-tariff pricing exists in South Australia, which means that average price would be a function of quantity, the block increments are typically not large.[7] Block pricing has been uncommon in much of the rest of Australia.

3.2 2015–16 HES

Table 3 uses 2015–16 data from the HES, with the dependent variable now being log expenditure on electricity plus other domestic fuels, principally natural gas. A similar pattern is evident, with a negative and significant effect for renters in column (1) changing to a positive and significant effect when log net wealth is included in column (4). Renters are again found to spend approximately 8% more on residential energy, all else equal, when the log net wealth variable is added to the regression. This is similar to the finding in Table 1 for electricity expenditure.

Key explanatory variables in Table 3 also produce reasonable results. The net wealth elasticity of expenditure of 0.07 is similar to the corresponding finding in Table 1. The point estimate for the net wealth coefficient is again higher than for the income coefficient. The average effect of having solar panels in Table 3 is lower than in Table 1. This is expected, as

[7] Based on energy deal comparisons on https://www.energymadeeasy.gov.au.

the dependent variable now includes expenditure on natural gas and other fuels. There is still a substantial negative association between having solar panels and energy bills, with significance at the 1% level.

Table 3. Results for expenditure on electricity and domestic fuel, HES, 2015–16.

	Dependent variable: Log expenditure on electricity and domestic fuel			
	(1)	*(2)*	*(3)*	*(4)*
Tenure type: renter ^	-0.135***	-0.085***	-0.084**	0.076**
	(0.026)	(0.027)	(0.035)	(0.038)
University education ^	-0.048***	-0.054***	-0.032**	-0.046***
	(0.013)	(0.013)	(0.016)	(0.016)
Household income, log	0.055***	0.050***	0.070***	0.050***
	(0.009)	(0.009)	(0.012)	(0.011)
Save: just break even ^	-0.026	-0.021	-0.015	-0.010
	(0.020)	(0.019)	(0.024)	(0.024)
Save most weeks ^	-0.111***	-0.105***	-0.110***	-0.119***
	(0.021)	(0.020)	(0.026)	(0.026)
Weekly housing costs, log	0.075***	0.066***	0.038***	0.041***
	(0.010)	(0.010)	(0.013)	(0.013)
Age pension ^	-0.199***	-0.195***	-0.150***	-0.137***
	(0.023)	(0.023)	(0.028)	(0.027)
Unemployment and student	-0.123***	-0.116***	-0.111***	-0.082**
allowances ^	(0.031)	(0.030)	(0.034)	(0.035)
Number of persons #	0.199***	0.174***	0.167***	0.163***
	(0.011)	(0.011)	(0.013)	(0.013)
Number of employed persons #	0.001	0.000	-0.001	-0.005
	(0.011)	(0.011)	(0.014)	(0.013)
Number of children under 15 #	-0.093***	-0.080***	-0.069***	-0.062***
	(0.013)	(0.013)	(0.015)	(0.015)
Single parent ^	0.044*	0.031	0.016	0.036
	(0.026)	(0.026)	(0.029)	(0.029)
Mortgage ^	-0.088***	-0.069***	-0.006	0.042
	(0.026)	(0.026)	(0.034)	(0.034)
Flat/unit/apartment ^	-0.103***	-0.061**	-0.079**	-0.069**
	(0.026)	(0.026)	(0.032)	(0.032)
Separate house ^	0.131***	0.065***	0.069***	0.062***
	(0.019)	(0.019)	(0.022)	(0.022)
Number of bedrooms #		0.098***	0.092***	0.078***
		(0.010)	(0.013)	(0.013)
Solar electricity ^			-0.437***	-0.439***
			(0.028)	(0.028)
Net wealth of household, log				0.069***
				(0.009)
Additional controls	Yes	Yes	Yes	Yes
Probability weights	No	No	Yes	Yes
Observations	9,495	9,495	9,495	9,495
R^2	0.263	0.273	0.312	0.320

Notes. ***, **, * show statistical significance at 1, 5 and 10 per cent level respectively. Robust standard errors are in brackets below the coefficients. Coefficients for constants are not shown. Other social assistance categories are controlled for, with coefficients available through the Supplementary section; the reference category is “no social assistance”. “Additional controls” include categorical variables for calendar quarter of survey and state-capital city regions. We also control for Tenure type = “Other”. ^ denotes binary variables, # denotes integer variables.

The coefficients for the other control variables in Table 3 are also reasonable. There are positive and significant coefficients for household income, with statistical significance at the 1% level in each case. Energy expenditure is lower for households who have a general tendency to save, as indicated by the negative and significant coefficients for the "save most weeks" variable relative to the reference category of spending more than received. Households with higher housing costs also tend to spend more on energy. A scale effect is also evident, as there are positive and significant coefficients for the number of people in the household. Dwelling structure also matters, as there is a positive impact on energy expenditure for separate houses and negative coefficients for apartments. Larger dwellings are also associated with higher expenditure, all else equal, as suggested by the positive coefficients for the number of bedrooms.

Variables for the main source of social assistance also have significant associations with energy expenditure in Table 3. There are negative and significant coefficients for binary variables identifying age pensions and unemployment or student allowances as the main source of social assistance. These are in relation to a base category of households receiving no social assistance. This suggests that age pension and unemployment or student allowance recipients spend less on energy on average, all else equal. In contrast, other major welfare categories tend to have energy expenditure that is not statistically different to the base category, as identified by insignificant coefficients that are available through the code in the Supplementary section.

3.3 Discussion

The positive net wealth effects found in this paper are consistent with the fundamental notion that consumption and investment will be greater when households have greater accumulated net wealth to finance their purchases. This is particularly relevant in the residential energy context given the large up-front costs of some energy-using appliances. Our results suggest that it can be difficult to accurately estimate the renter effect on residential energy expenditure without accounting for such net wealth effects.

Our main practical contribution is quantifying the renter effect in Australia. The estimated 8% higher energy bills for renters relative to otherwise similar households is large in magnitude – in dollar terms, it works out to be about A$150 per year. This represents a specific additional burden for renters, some of whom are already under financial pressure. The paper feeds in to the understanding of factors contributing to residential energy insecurity, which is also a pressing concern in other countries like the US (Graff and Carley, 2020).

4. Conclusion and policy implications

While the residential energy expenditure of Australian renters is on average lower than for non-renters, this paper finds that a primary reason for this is that renters on average have lower net wealth. After controlling for log net wealth, we found positive effects of renting on residential energy expenditures. Specifically, renters spend approximately 8% more on electricity than otherwise similar households. The effect on overall residential energy expenditure (including natural gas) is similar. The effect on electricity bills is primarily due to higher electricity usage rather than higher average prices.

The apparent renter effect is likely to be at least in part due to a split incentive between renters and landlords resulting from information asymmetries. If this leads to rental properties being less energy efficient, it places upward pressure on the energy use of renters. There may also be other explanations, such as differences in socio-demographic factors and attitudes between renters and non-renters. However we have controlled for a range of socio-economic characteristics, a behavioural variable for air conditioning use in some estimations, and for the taking of energy-saving actions (see Appendix).

The apparently inferior energy efficiency of rental properties is a problem that can be difficult to address. Underinvestment by landlords is not only related to the famous principal-agent problem but also reflects broader issues such as a lack of landlord knowledge about energy efficiency (Ambrose, 2015). There is also often a lack of engagement from tenants, especially when the size of potential energy savings is not well understood or when tenant tenure is not long (Palm, 2013). Government policy related to residential energy efficiency has also often not focused on landlords (Hope and Booth, 2014). Policymakers face the challenge of designing policies with sufficient scale and endurance, that allow for a fair distribution of incentives between tenants and landlords, and that have low transactions costs and sufficient political feasibility (Bird and Hernández, 2012).

One option is for incentives to invest in insulation, efficient energy-use equipment, or solar panels to be targeted at rental properties. For rooftop solar panels, the state of Victoria has indeed recently begun to specifically target subsidies to rental properties (Solar Victoria, 2021). Tax credits are another option (Charlier, 2015). There is also the potential for policymakers to better facilitate market solutions, such as third-party ownership approaches. For example, solar panel leasing could be increasingly suitable for budget-constrained renters (Rai and Sigrin, 2013).

Some of our other findings also carry policy relevance. Higher electricity expenditure and use among households with a household member who needs energy-consuming medical equipment highlights the case for this group to receive ongoing financial support.[8] Single-parent households also tend to have higher electricity expenditure and usage, all else equal, pointing to a need for ongoing policy attention.

[8] At the federal level in Australia, support is currently available via the Essential Medical Equipment Payment.

Future research could potentially use a similar approach of controlling for net wealth in exploring whether the large conditional effect of renting on residential energy expenditure estimated here for Australia exists in other countries. Future research could also potentially incorporate additional attitudinal variables or do more to break down the net wealth effect into its components. Additional research directly examining the energy efficiency performance of rental properties would also be of interest. Work into the efficacy of approaches to reduce the principal-agent problem also has the potential to be highly beneficial.

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