The Mortality Effects of Winter Heating Prices

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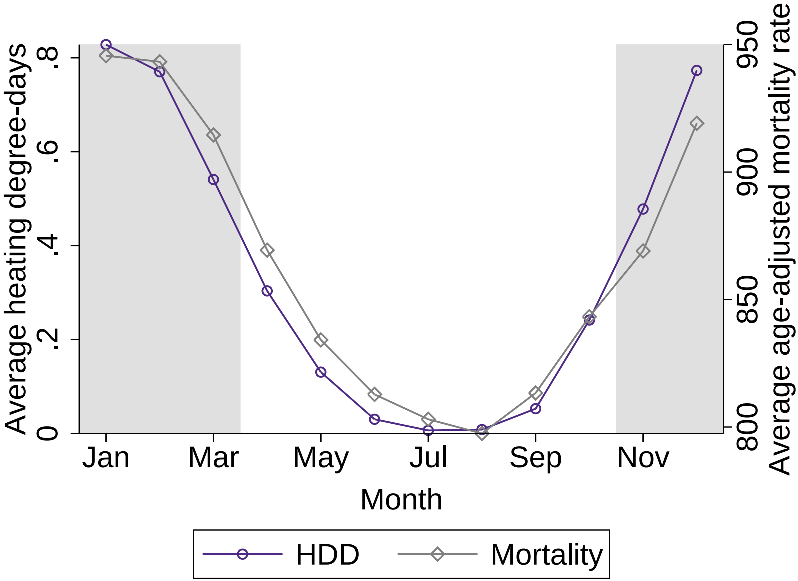
Introduction

- 17% of US households spend >10% of income on home energy bills
- Heating is the largest category of home energy consumption (42% of annual use)
  - Additional 18% of use is water heating

- Hypothesis: High price of heating → worse health
- Heating consumption channel: Cut back heating use; being cold causes physical and mental health problems
- Non-heating consumption channel: High spending on heating crowds out other spending (e.g., food, health care) and induces stress

Mortality rate peaks in winter



Preview of results

- Higher price of heating leads to lower energy consumption in winter months
- Cutback in usage not one-for-one, so higher price also leads to higher energy bills
- Higher price of heating $\rightarrow$ higher mortality rate in winter
  - Mainly driven by cardiovascular and respiratory causes of death
  - Larger effect in winter/colder months than rest of year

Related literature

- **Health effects of cold weather**
  - Large literature on excess winter mortality and on link between cold temperature and mortality
- **Health effects of policies to mitigate heating costs**
  - Home weatherization (mostly small studies with self-reported health)
  - Heating-bill subsidy programs (mostly correlational studies)
- **Contribution**
- First causal estimate of role of heating price, policy-relevant mediator
- National scope, statistical precision to measure impacts on mortality

Related literature

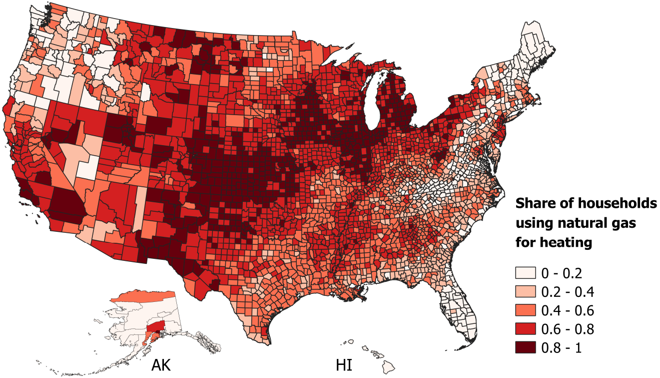
- **Effects of shale gas production**
  - Health effects: Harm from chemicals used, but also reduced air pollution as natural gas displaces coal in electricity generation
- **Contribution:** Fracking boom also has health effects via lower energy (heating) prices

Outline

Overview of research design

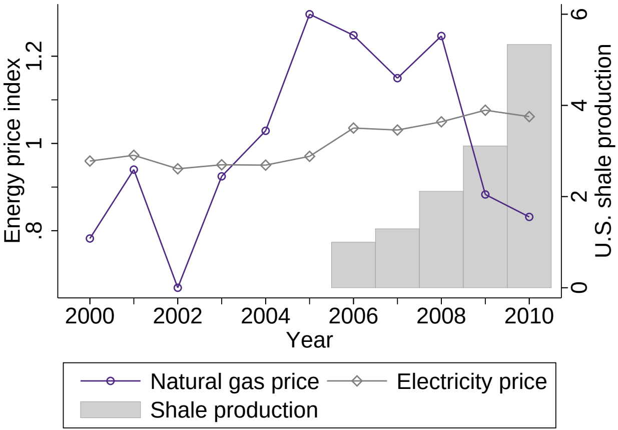
- Large geographic variation in the US in type of energy source used for home heating — natural gas vs. electricity (and also fuel oil)
- Prices of natural gas and electricity do not move in lockstep
  - Boom in shale production of natural gas caused price of natural gas, relative to other energy sources, to fall in mid-2000s
- Isolating the causal effect of heating prices: Combine cross-county variation in heating source with over-time variation in energy prices

Spatial variation: % using natural gas for heating in 2000



58% of households use natural gas & 30% of households use electricity

Temporal variation: US natural gas and electricity prices



Relative price of natural gas fell by 42% (54 log points) from 2005 to 2010

Empirical specification

- In principle, we want to estimate:

$$\log(m_{jt}) = \alpha + \beta \log(p_{jt}^{H}) + \epsilon_{jt}$$

- There are no data on heating price p_{jt}^{H} so we proxy for it using $ShareGas_{jt} \times \log(RelPrice_{jt})$
  - $ShareGas_{jt}$ = % of HHs in area j using gas for heating in year t
  - $log(RelPrice_{jt})$ = log(state price of natural gas ÷ price of electricity)
- $ShareGas_{jt} \times \log(RelPrice_{jt})$ could be endogenous to local demand, so we instrument for it with $ShareGas_{j,2000} \times \log(RelPrice_{US,t})$
  - i.e. combining pre-period local variation in energy source for heating and national variation in energy prices

Empirical specification

- Estimate the following using instrumental variables regression:

$$\log(m_{jt}) = \alpha + \beta\,\mathrm{ShareGas}_{jt} \times \log(\mathrm{RelPrice}_{jt}) + \gamma_j + \tau_t + \theta Z_j \times \log(\mathrm{RelPrice}_{\mathrm{US},t}) + \delta X_{jt} + \epsilon_{jt} \quad (1)$$

$$\mathrm{ShareGas}_{jt} \times \log(\mathrm{RelPrice}_{jt}) = \tilde{\alpha} + \tilde{\beta}\,\mathrm{ShareGas}_{j,2000} \times \log(\mathrm{RelPrice}_{\mathrm{US},t}) + \tilde{\gamma}_j + \tilde{\tau}_t + \tilde{\theta} Z_j \times \log(\mathrm{RelPrice}_{\mathrm{US},t}) + \tilde{\delta} X_{jt} + \nu_{jt} \quad (2)$$

- Controls:
  - γ_j, τ_t = Area fixed effects, time fixed effects
  - X_{jt} includes housing price index (state), unemployment rate, manufacturing share (state), air pollution, humidity, heating degree-days (HDD)
  - Z_j = Log HH income (25th, 50th, 75th percentile) in 1999, % population ≥ 70 in 2000

Empirical specification

- Sample comprises winter months (November to March) ▸ HDD by months
- Cluster standard errors by state
- Identification assumption: When natural gas prices are high relative to electricity, places with more natural gas usage for heating have higher mortality only because of the higher price of heating they face, conditional on fixed effects and control variables.

Data

- Sample: Continental US; 2000 to 2010
- Home energy price and consumption
  - Energy Information Administration (monthly, state and US level)
  - For *RelPrice* average of 3- and 4-month lags
- Home energy (gas, electric, etc.) expenditures
  - Census (2000) and American Community Survey (2005-2010)

Mortality data

- Vital Statistics data (2000-2010)
- Aggregated to county-month
- Calculate age-adjusted mortality rate
- Drop smallest 10% of counties (many months with 0 deaths)

▸ Other data used as covariates

Outline

Higher heating price → Lower energy use

	Dependent variable: Log of average electricity and gas price		Dependent variable: Log of total energy consumption	
	(1)	(2)	(3)	(4)
Heating price proxy	0.35***	0.36***	-0.13***	-0.093**
	[0.067]	[0.070]	[0.039]	[0.039]
Observations	2,695	2,695	2,695	2,695
Mean price/quantity	21.1	21.1	22.1	22.1
Basic fixed effects	Yes	Yes	Yes	Yes
All other controls	No	Yes	No	Yes
Implied elasticity			-0.36	-0.26

Households cut back usage quite a bit when price rises, but not one-for-one.

Implies a price elasticity of 0.26: If price rises 10%, cut back use by 2.6%.

Higher heating price → Higher home energy bills

	Dependent variable:			
	Log of total monthly energy bill	Log of total monthly energy bill	Total monthly energy bill	Total monthly energy bill
	(1)	(2)	(3)	(4)
Heating price proxy	0.27^{***}	0.25^{***}	57.4^{***}	50.9^{***}
	[0.037]	[0.035]	[7.33]	[6.94]
Observations	21,665	21,665	21,665	21,665
Mean bill	220.7	220.7	220.7	220.7
Basic fixed effects	Yes	Yes	Yes	Yes
All other controls	No	Yes	No	Yes

10% increase in the price of heating is associated with a $5 increase in the monthly home energy bill

Relative price of natural gas fell by 42% (54 log points) from 2005 to 2010. This led to a 12% or $330 annual decrease in energy bills for natural gas users.

Outline

Some causes of death peak in winter more than others

- We examine "excess winter mortality" (EWM) causes of death
  - More plausible that they are exacerbated by cold than others
  - Medical research posits a mechanism linking some causes to cold exposure (e.g., strokes, heart attacks)
  - Many other causes still peak in winter (e.g., influenza, Alzheimer's)
- We use a data-driven approach to choose specific causes
  - Start with the 113 Selected Causes of Death
  - Narrow down to 14 causes with biggest peak in winter
    - These account for 61% of total mortality

Causes of death exhibiting high excess winter mortality

Cause of death (ICD-10 codes)	Mean monthly mortality rate	Level Coefficient	Log Coefficient
Septicemia (A40-A41)	0.95	0.14	0.14
Parkinson's disease (G20-G21)	0.53	0.08	0.16
Alzheimer's disease (G30)	1.92	0.36	0.18
Acute myocardial infarction (I21-I22)	4.34	0.62	0.14
All other forms of chronic ischemic heart disease (I20,I25.1-I25.9)	6.32	0.80	0.12
Heart failure (I50)	1.61	0.21	0.13
Cerebrovascular diseases (I60-I69)	4.12	0.52	0.12
Atherosclerosis (I70)	0.30	0.04	0.14
Influenza (J09-J11)	0.04	0.06	2.21
Pneumonia (J12-J18)	1.63	0.58	0.34
Emphysema (J43)	0.38	0.08	0.21
Other chronic lower respiratory diseases (J44,J47)	3.11	0.63	0.20
Pneumonitis due to solids and liquids (J69)	0.47	0.09	0.18
Other diseases of respiratory system (J00-J06,J30- J39,J67,J70-J98)	0.77	0.11	0.14
All other diseases (Residual)*	6.17	0.80	0.13
Accidental exposure to smoke, fire and flames (X00-X09)*	0.09	0.05	0.56

Effect of heating price on EWM mortality rate

	Dependent variable: Log of mortality rate		Dependent variable: Mortality rate	
	(1)	(2)	(3)	(4)
Heating price proxy	0.048**	0.059***	30.0***	31.8***
	[0.021]	[0.017]	[10.5]	[9.66]
Observations	152,927	152,927	153,340	153,340
Mean mortality rate	577.6	577.6	576.0	576.0
Basic fixed effects	Yes	Yes	Yes	Yes
All other controls	No	Yes	No	Yes

- 10% increase in heating price leads to 0.6% increase in EWM mortality rate
- No effect on non-EWM causes
  - Coefficient for log specification is 0.0033, s.e. 0.021

Effect is mainly driven by circulatory and respiratory causes

Dependent variable: Log of specified disease mortality rate			
Septicemia	0.021 [0.025] {74.2}	Atherosclerosis	0.053 [0.044] {45.9}
Parkinson's disease	0.044 [0.026] {32.2}	Influenza	-0.14 [0.12] {24.4}
Alzheimer's disease	0.030 [0.031] {63.2}	Pneumonia	0.10^{***} [0.031] {104.9}
Acute myocardial infarction	0.11^{***} [0.031] {107.3}	Emphysema	0.13^{***} [0.044] {29.7}
Chronic ischemic heart disease	0.080^{***} [0.027] {158.0}	Other chronic lower respiratory diseases	0.11^{***} [0.023] {114.2}
Heart failure	0.055^{**} [0.023] {137.4}	Pneumonitis (solids and liquids)	0.053 [0.042] {44.4}
Cerebrovascular diseases	0.082^{**} [0.031] {114.4}	Other respiratory diseases	0.053^{*} [0.028] {107.4}

Interpreting the size of the effect

- We also examine all-cause mortality: 10% heating price increase leads to 0.32% increase in mortality
- Natural gas price fell by 42% from 2005 to 2010 $\rightarrow$ Averted 12,500 annual deaths across the US
- This is equivalent to 1.7% decrease in winter mortality rate for families using natural gas
- For aggregate US population, this is a 1.0% decrease in winter mortality, or 0.4% in annual mortality rate

Additional results

- Findings confirmed when non-winter months are incorporated
  - Higher energy price increases mortality in winter relative to rest of year
  - Effect of higher heating price is larger in colder months (higher heating-degree-days)
- Results do not just represent short-run hastening of mortality
  - Cumulative effect persistent in size for 6 months
- Results are robust to varying the statistical model
  - Varying definition of winter months and which energy prices are used
  - Excluding Great Recession period, fracking states
  - Weighting by population
  - Controlling for LIHEAP spending or additional pollutants
  - Using controls selected by double-selection post-Lasso method

Larger effects on mortality among the poor

	Dependent variable: Log of all-EWM-causes MR Trait is:			
	Below-median county income	Proportion below 150% of poverty line	Above-median proportion below 150% of poverty line	No high school degree
	(1)	(2)	(3)	(4)
Heating price proxy × Trait	0.021	0.36**	0.057**	0.033
	[0.032]	[0.17]	[0.026]	[0.039]
Heating price proxy	0.049***	-0.025	0.038**	0.027
	[0.016]	[0.037]	[0.016]	[0.045]
Observations	152,927	152,927	152,927	284,700
Mean mortality rate	577.6	577.6	577.6	999.4
Implied effect for Trait = 1	0.07**	0.33**	0.10***	0.06
	[0.03]	[0.14]	[0.03]	[0.05]

Mortality effects do not significantly differ by sex or race

Outline

Conclusion

- Winter mortality is lower when the price of heating is lower
  - Elasticity of mortality with respect to the heating price of 0.032
  - Drop in price of natural gas from 2005 to 2010 $\rightarrow$ 1.0% lower winter mortality, or 0.4% lower total mortality rate
- Total effect could be larger if there are also longer-term effects on health
- Policy implications: Reduced mortality is important benefit of heating subsidy policies, weatherization and increases in energy supply

Backup slides

Other data used as covariates

- Temperature: PRISM Climate Group
- Housing prices: Federal Housing Finance Agency
- Air pollution: US EPA Air Quality System
- Unemployment rate: Bureau of Labor Statistics
- Share of manufacturing: Bureau of Economic Analysis
- Locality's median income and age structure: 2000 Census

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Mortality effects by specific cause of death

Dependent variable: Log of specified disease mortality rate					
Septicemia	0.021 [0.025] {74.2}	Heart failure	0.055** [0.023] {137.4}	Emphysema	0.13*** [0.044] {29.7}
Parkinson's disease	0.044 [0.026] {32.2}	Cerebrovascular diseases	0.082** [0.031] {114.4}	Other chronic lower respiratory diseases	0.11*** [0.023] {114.2}
Alzheimer's disease	0.030 [0.031] {63.2}	Atherosclerosis	0.053 [0.044] {45.9}	Pneumonitis (solids and liquids)	0.053 [0.042] {44.4}
Acute myocardial infarction	0.11*** [0.031] {107.3}	Influenza	-0.14 [0.12] {24.4}	Other respiratory diseases	0.053* [0.028] {107.4}
Chronic ischemic heart disease	0.080*** [0.027] {158.0}	Pneumonia	0.10*** [0.031] {104.9}		

Cumulative net effect: Not just short-run "harvesting"

	Dependent variable: Log of all-EWM-causes mortality rate						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Contemporaneous reduced form effect	0.062***	0.050	0.12**	0.047	0.049	0.034	0.048
	[0.019]	[0.051]	[0.051]	[0.046]	[0.051]	[0.055]	[0.052]
Effect on mortality 1 month after		0.0019	-0.16**	-0.027	-0.035	-0.0011	-0.00094
		[0.050]	[0.078]	[0.082]	[0.086]	[0.098]	[0.091]
Effect on mortality 2 months after			0.11*	-0.058	-0.026	-0.055	-0.093
			[0.059]	[0.089]	[0.10]	[0.11]	[0.100]
Effect on mortality 3 months after				0.13**	0.052	0.12	0.18*
				[0.057]	[0.097]	[0.11]	[0.10]
Effect on mortality 4 months after					0.014	-0.11	-0.18
					[0.049]	[0.099]	[0.11]
Effect on mortality 5 months after						0.097*	0.16
						[0.057]	[0.099]
Effect on mortality 6 months after							-0.036
							[0.053]
Observations	152,927	183,510	214,043	244,552	275,071	305,602	336,113
Cumulative effect	0.06***	0.05**	0.07***	0.09***	0.05*	0.08**	0.08*
	[0.02]	[0.02]	[0.03]	[0.03]	[0.03]	[0.04]	[0.04]

No significant heterogeneity by sex

	Dependent variable: Log of mortality rate			
	All causes	All EWM causes	Group I EWM: Circulatory system diseases	Group J EWM: Respiratory system diseases
	(1)	(2)	(3)	(4)
Heating price proxy $\times$ Male	0.0033	0.013	0.041	0.0047
	[0.022]	[0.026]	[0.033]	[0.030]
Heating price proxy	0.033^{*}	0.058^{***}	0.055^{**}	0.086^{***}
	[0.019]	[0.017]	[0.024]	[0.023]
Observations	305,041	300,311	290,631	275,347
Mean mortality rate	957.0	605.3	398.9	294.3
Implied effect for male population	0.04^{**}	0.07^{***}	0.10^{***}	0.09^{***}
	[0.02]	[0.02]	[0.03]	[0.02]

Heterogeneous effects by age groups

	Dependent variable: Log of mortality rate		Dependent variable: Mortality rate	
	All causes	All EWM causes	All causes	All EWM causes
	(1)	(2)	(3)	(4)
Heating price proxy	0.041*	0.070**	10.5	9.72**
	[0.022]	[0.028]	[6.50]	[4.37]
Heating price proxy × 65–74	0.030	0.042	112.8	94.9*
	[0.034]	[0.041]	[70.8]	[56.4]
Heating price proxy × 75+	-0.015	-0.027	254.8*	262.0**
	[0.025]	[0.038]	[133.1]	[121.5]
Observations	442,251	412,486	460,020	460,020
Mean mortality rate	3989.4	2970.5	3835.3	2663.5
Implied mortality effect for 65–74 population	0.07***	0.11***	123.32*	104.62*
	[0.02]	[0.03]	[70.54]	[56.52]
Implied mortality effect for 75+ population	0.03	0.04**	265.30*	271.71**
	[0.02]	[0.02]	[133.95]	[121.41]

Winter/non-winter specification

- We use non-winter months as an additional comparison group
  - Change in sample: All months
  - Prediction: Price of heating affects mortality more in winter than in other warmer months

$$
\begin{aligned}
log(m_{jt}) \quad = \quad & \alpha + \lambda_1 \, \mathrm{ShareGas}_{jt} \times \log(\mathrm{RelPrice}_{jt}) \times \mathrm{Winter}_t \\
& + \lambda_2 \, \mathrm{ShareGas}_{jt} \times \log(\mathrm{RelPrice}_{jt}) \\
& + \lambda_3 \, \mathrm{ShareGas}_{j,2000} \times \mathrm{Winter}_t + \lambda_4 \log(\mathrm{RelPrice}_{US,t}) \times \mathrm{Winter}_t \\
& + \theta_1 Z_j \times \log(\mathrm{RelPrice}_{US,t}) \times \mathrm{Winter}_t + \theta_2 Z_j \times \log(\mathrm{RelPrice}_{US,t}) \\
& + \theta_3 Z_j \times \mathrm{Winter}_t + \gamma_j + \tau_t + \delta X_{jt} + \epsilon_{jt}
\end{aligned}
$$

- We also use HDD to define the additional dimension. In this spec, we control for the county's average HDD in winter in parallel to HDD
  - Cold places are systematically different from warm places

◂ Specification

Winter/non-winter mortality results using winter

	Dependent variable: Log of mortality rate			
	All causes	All EWM causes	Group I EWM: Circulatory system diseases	Group J EWM: Respiratory system diseases
	(1)	(2)	(3)	(4)
Heating price proxy	-0.0088	-0.015	0.0082	-0.0060
	[0.0096]	[0.015]	[0.016]	[0.020]
Heating price proxy × Winter	0.039**	0.073***	0.043**	0.10***
	[0.015]	[0.019]	[0.019]	[0.027]
Observations	367,905	366,668	362,930	353,692
Mean mortality rate	872.6	527.8	343.5	232.7

Winter/non-winter mortality results using temperature

	Dependent variable: Log of mortality rate			
	All causes	All EWM causes	Group I EWM: Circulatory system diseases	Group J EWM: Respiratory system diseases
	(1)	(2)	(3)	(4)
Heating price proxy	0.054*	0.090**	0.095**	0.088*
	[0.028]	[0.037]	[0.036]	[0.046]
Heating price proxy × HDD	0.043*	0.090***	0.065*	0.10**
	[0.024]	[0.032]	[0.034]	[0.039]
Observations	367,905	366,668	362,930	353,692
Mean mortality rate	872.6	527.8	343.5	232.7

▸ Without county average HDD

Without controlling in parallel for average winter HDD

	Dependent variable: Log of mortality rate			
	All causes	All EWM causes	Group I EWM: Circulatory system diseases	Group J EWM: Respiratory system diseases
	(1)	(2)	(3)	(4)
Heating price proxy	-0.0038	-0.0072	0.014	0.0042
	[0.010]	[0.018]	[0.020]	[0.021]
Heating price proxy × HDD	0.033*	0.058**	0.033	0.074**
	[0.018]	[0.027]	[0.030]	[0.034]
Observations	367,905	366,668	362,930	353,692
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Robustness checks

	Dependent variable: Log of all-EWM-causes mortality rate		
	Baseline specification (1)	Winter/non-winter specification using winter (2)	Winter/non-winter specification using HDD
Winter defined as December to March	0.050** [0.019]	0.065*** [0.020]	n/a
Winter defined as December to February	0.052** [0.024]	0.074*** [0.027]	n/a
Use residential gas price, averaged over 2nd and 3rd lags	0.054** [0.025]	0.039 [0.030]	0.065 [0.048]
Use annual residential gas price	0.084** [0.033]	0.095*** [0.032]	0.065 [0.052]
ShareGas defined as $gas/(gas + electricity)$	0.045** [0.017]	0.066*** [0.020]	0.082** [0.039]
Exclude states with share of gas or electricity $< 75\%$	0.058*** [0.019]	0.072*** [0.021]	0.090** [0.043]
Exclude fracking states	0.055*** [0.018]	0.068*** [0.018]	0.097*** [0.030]

Robustness checks

	Dependent variable: Log of all-EWM-causes mortality rate		
	Baseline specification (1)	Winter/non-winter specification using winter (2)	Winter/non-winter specification using HDD (3)
Exclude Great Recession	0.040**	0.066***	0.083**
	[0.019]	[0.019]	[0.032]
Control for Log(LIHEAP per capita)	0.058***	0.073***	0.090***
	[0.018]	[0.019]	[0.032]
Control for all pollutants	0.057***	0.073***	0.091***
	[0.018]	[0.019]	[0.032]
State-level regression	0.090***	0.068***	0.100**
	[0.021]	[0.020]	[0.043]
State-level regression, using only within-division variation	0.097**	0.047	0.11
	[0.040]	[0.041]	[0.093]
Weight by population in 2000	0.046***	0.037***	0.036*
	[0.012]	[0.011]	[0.021]

Home energy uses