UNIVERSITY OF CAMBRIDGE

4CMR Foreseeing Mitigation

Do Homes That Are More Energy Efficient Consume Less Energy?

Summary

- In the UK, the residential sector consumes 29% of total energy and is responsible for 25% of CO_2 emissions.
- Yet, there is significant debate around what factors best explain residential energy consumption, and therefore what factors to target for reducing CO_2 emissions.
- Using structural equation modelling (SEM) it is possible to use the fundamental structural relationship between variables to calculate the direct, indirect and total effects between different variables and residential energy consumption.
- In order of importance, the variables that explain residential energy consumption are: number of occupants, household income, floor area, SAP rating, winter weekly heating patterns and internal temperature difference.

Structural Equation Model

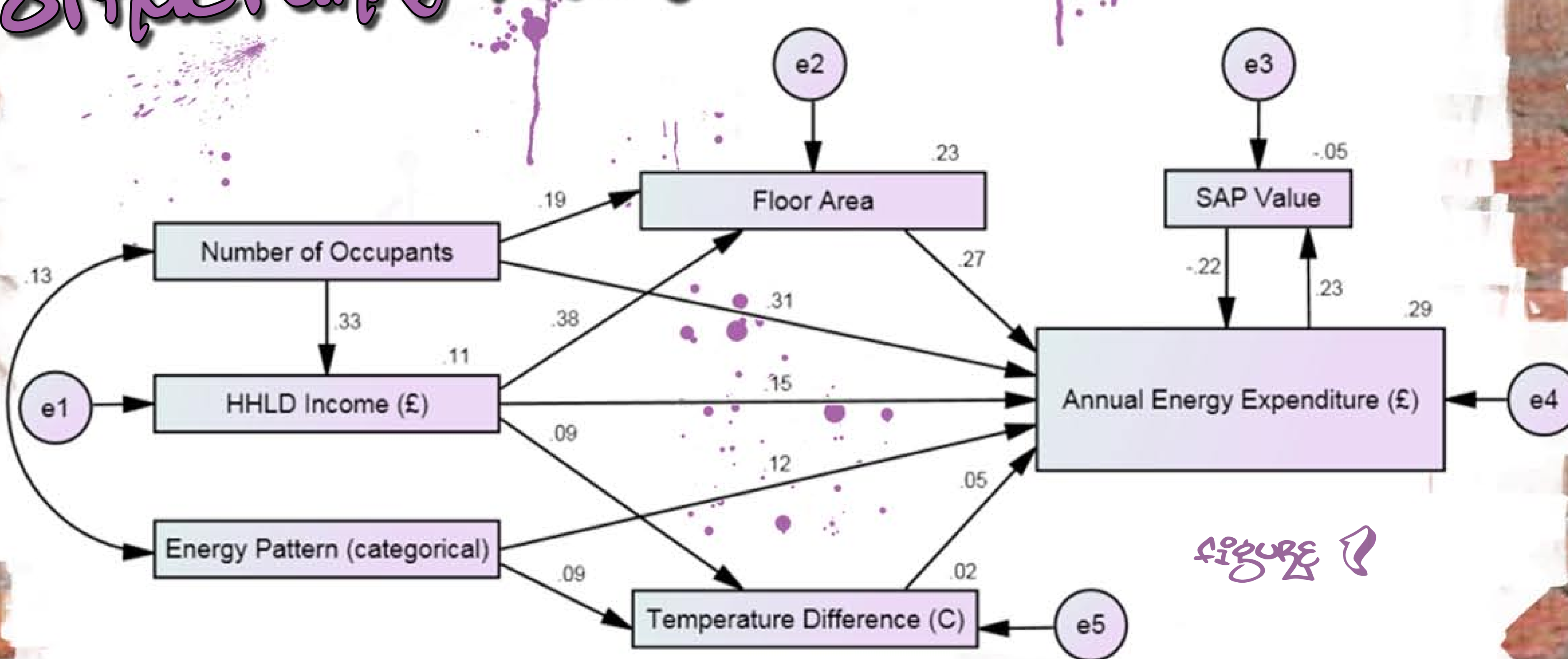

Figure 1

*numbers represent standardised regression weights

Methodology

- Data used in the model came from the 1996 English House Condition Survey (EHCS) and corresponding Fuel and Energy (FES) survey.
- The final dataset consisted of 2531 unique cases, each representing a single dwelling, and included variables for measuring the physical characteristics of the property (SAP rating), social and demographic information and metered gas and electricity consumption over eight consecutive quarters.
- The following explanatory variables were tested by the model: Number of occupants, household income, floor area, SAP rating, temperature difference, energy pattern, dwelling energy expenditure, age of head of household, degree days, urban (dummy), owner occupier (dummy) and an employment status (dummy).
- **Outliers** were removed and distributions having long right-hand tails were truncated to 5 standard deviations.
- **Missing values** accounted for less than 5% of data and were replaced using expectation maximsation methods.
- **Grossing weights** were applied to the sample and the callibrated sample size was used to caclulate standard errors.
- **Normality transformations** on each variable were completed and it was found that model variables were robust to small deviations from normality.
- The causal (structural) relationship between model variables was based on prior theory and research. On this basis, an over-identified model was created to test the significance and exaplantorty power that different model variables have on one another.

Results

Table 1

			Standardised Coefficients	Unstandardised Coefficients		Significance		
			β	B	Std.Err	C.R.[1]	P(sig.)	Label
HHLD Income	<---	Occupants	0.329	2463	(221.8)	11.1	***	W1
Floor Area	<---	Occupants	0.188	4.362	(0.677)	6.44	***	W2
Temperature	<---	Energy Pattern	0.087	0.354	(0.126)	2.80	.005	W8
Floor Area	<---	HHLD Income	0.381	0.001	(0.000)	13.0	***	W4
Temperature	<---	HHLD Income	0.092	0.000	(0.000)	2.95	.003	W6
Annual Energy Expenditure	<---	Occupants	0.306	64.52	(6.094)	10.5	***	W3
Annual Energy Expenditure	<---	HHLD Income	0.145	0.004	(0.001)	4.76	***	W5
Annual Energy Expenditure	<---	Energy Pattern	0.123	28.27	(6.205)	4.56	***	W7
Annual Energy Expenditure	<---	Floor Area	0.271	2.464	(0.276)	8.93	***	W9
Annual Energy Expenditure	<---	Temperature	0.046	2.584	(1.514)	1.71	.088	W10
Annual Energy Expenditure	<---	SAP Value	-0.216	-3.924	(0.869)	-4.52	***	W11
SAP Value	<---	Annual Energy Expenditure	0.235	0.013	(0.003)	4.08	***	W12
Occupants	<-->	Energy Pattern	0.128	0.213	(0.053)	4.05	***	C1

1. C.R is the critical ratio (B / Std.Err) and is also known as the t-statistic.
2. Estimates are based on the calibrated effective sample size (1025)

Model Fit Statistics

Table 2

	N	dof	χ^2	P-value	GFI	PGFI	TLI	CFI	RMSEA	SRMR	Stability Index
Correlation method	1025	8	7.30	0.504	0.998	0.285	1.00	1.00	0.001	0.016	0.048

Discussion

- Most of the conclusions from this analysis can be made through careful interpretation of the results presented in Figure 1.
- Several variables were shown to be statistically insignificant and therefore not included in the final model [age of head of household, employment status (dummy), owner occupier (dummy), urban home (dummy) and Heating Degree Days (HDD)] .
- As shown, household occupancy has the largest direct effect on annual energy consumption. In addition, occupancy is mediated by both floor area and household income and consequently this leads to a large total effect on energy consumption as well (β=0.419**).
- Surprisingly, household income explains much less of the variation than both floor area and occupancy. However, as household income has large explanatory power over floor area and internal temperature difference, the total effect of household income on dwelling energy consumption is both large and statistically significant effect (β=0.241**).
- When a simple bivariate regression is done to show the effect of SAP on energy consumption it is shown that SAP has very little explanatory power on the amount energy consumed in dwellings (β=0.042**).
- This can be explained by simulteneity bias and is the result of a reciprocal relationship between energy consumption and SAP. In other words, homes with a propensity to consume more energy have higher SAP rates. At the same time, homes with a proponsity to consume less energy have lower SAP rates.

(** significant at 99% level)

Conclusion

It has been shown, through the application of a structural equation model, the relative importance of different explanatory variables that confound on residential energy consumtion. Most importantly, we show that SAP has a non-recursive relationship with energy consumption and that SAP, ceterus paribus, does explain a large part of lower energy consumption. However, there are many other factors that can not be ignored when designing policy for reducing residential energy consumption.

Author: Scott Kelly
Supervisor: Dr. Michael Pollitt