PREDICTING THE DIVERSITY OF INTERNAL DWELLING TEMPERATURES USING PANEL REGRESSION METHODS

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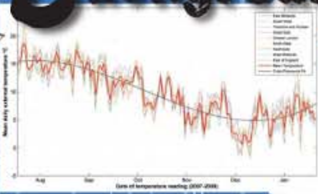
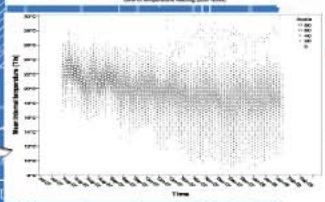
Abstract

Using panel methods, a model for predicting daily mean internal temperature demand across a heterogeneous domestic building stock is developed. It represents the first time a panel model has been used to estimate the dynamics of internal temperature demand from the natural daily fluctuations of external temperature combined with important behavioural, socio-demographic and building efficiency variables. The model is able to predict internal temperatures across a heterogeneous building stock to within ~0.71°C at 95% confidence and explain 45% of the variance of internal temperature between dwellings. The model confirms hypothesis from sociology and psychology that habitual behaviours are important drivers of home energy consumption. In summary, the model can be used as a tool to predict internal temperatures and for making statistical inferences about the importance of different covariates for explaining energy demand.

Background





40% of total UK energy is consumed in buildings

of this → 60% is used for heating

of this → 20% is used for hot water

of this → 20% for lights and appliances

90% of all UK homes now have central heating radically changing how people use energy

Gill and Tierney (2010) show that behaviour explains 50%, 37% and 10% of the variance in heat, electricity, and water consumption respectively.

"Yet, despite the importance of behaviour, there is still not a single building stock model that adequately incorporates the effects of human behaviour when estimating energy demand"

Contribution

i) This is the first time a panel method has been used to predict mean internal temperatures from a large sample of heterogeneous dwellings.

ii) It presents a novel method for including social and behavioural variables and their influence on internal temperature over a heterogeneous building stock.

iii) It offers a practical solution for energy demand modellers wishing to incorporate improved estimates of mean daily internal temperatures into bottom up models.

iv) It allows statistical inferences to be made about different physical, behavioural, socio-demographic and technical factors from a heterogeneous building stock and the proportion of variance that these different factors contribute towards explaining internal temperature.

In 2011 there were 22.2 million dwellings in England, by 2033 there will be 27.5 million

Data sources

A stratified random survey was carried out by the CaRB consortium by M. Shipworth with sampling and face to face interviews conducted by the National Centre for Social Science Research. The survey was carried out between July 2007 and February 2008. Of the 427 households who opted to participate in the study 266 dwellings had internal temperature measurements recorded at 45 minute intervals over 184 days. A wide range of physical characteristics for each building were collected as well as many social demographic and behavioural attributes of the occupants. External temperatures were not recorded at the time of the survey. Therefore a secondary dataset was created from the British Atmospheric Data Centre (BADC) to capture the mean daily external temperature for each region included in the study.

Emperical model

$$Tin_{it} = \alpha + \Gamma_{it}\beta_1 + \Psi_{it}\beta_2 + \Theta_{it}\beta_3 + (\nu_i + \varepsilon_{it}); \qquad i = 1, \ldots, N \qquad t = 1, \ldots, X$$

Tin_{it} is the mean internal daily temperature associated with dwelling, i at time period t.

Γ_{it} is a matrix of intransmutable variables (i.e. external regional temperatures and dwelling location).

Ψ_{it} is a matrix of behavioural and demographic variables.

Θ_{it} is a matrix physical building characteristics.

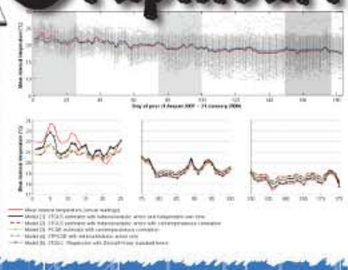
α is a constant intercept term.

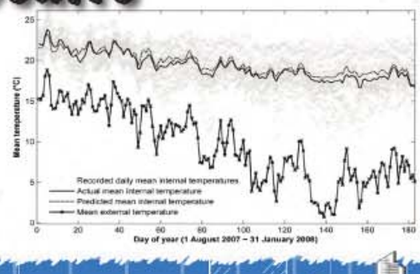
ν_i is the between entiry error term.

ε_{it} is the idiosyncratic error term.

Dummy variables were created to represent nominal unordered categorical variables. The dummy variable trap was avoided by creating a comparison category for each multi-category group.

Graphical results





Factors in the model

Heating controls

Room thermostat (dummy); Thermostat setting (categorical); Thermostatic Radiator Valve (TRV) (dummy); Central heating hours reported (continuous); Regular heating pattern (dummy); Automatic timer (dummy);

Sociodemographics, behaviour and tenure

Household size (discrete); Household income (ordered categorical); Child<5 (dummy); Children<18 (disctete); Age<64 (dummy); Age59-64 (dummy); Age64-74 (dummy); Age>74 (dummy) ; Owner occupier (dummy); Privately rented (dummy); Council tenant (dummy); Housing Association (dummy); Weekend heat (dummy); Weekend temperature (dummy) ;

Physical charateristics and heating systems

Detached House (dummy); Semi-Detached (dummy); Terraced house (dummy); Not a house (dummy); Gas Central heating (dummy); Non central heating (dummy); Electricity is main fuel (dummy); Additional gas heating in living room (dummy); Additional electricity heating (dummy); Additional other heating in living room (dummy); Year of construction (categorical); Roof insulation thickness (categrocial); Extent of double glazing (categorical); Wall U-Value (categorica) .

Heating effects

- The presence of a thermostat reduces internal temperatures while higher thermostat set-poins increase internal temperatures.
- Automatic timers do not have a statistically significant effect on temperatures.
- Regular heating patterns and more heating hours increase temperatures.
- Internal temperatures increase with both occupancy and income.
- Babies and the elderly both increase increase temperatures by 0.5°C on average.
- Owner occupiers have the lowest internal temperatures while council owned properties have the highest, ceterus paribus.
- Roof insulation, double glazing and wall insulation increase tempareutres.
- Detached homes have the lowest temperatures, while semi-detached have the highest.