Models for Understanding Residential Electricity Use

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Introduction / Motivation

- In 2006, US generated 23% of world electricity; and US per capita use is top-10
- Residential sector is **largest share** of electricity use in the US
- Residential sector pays **highest average price** for electricity and provides largest share of revenue to power generators
- In 2005, households spent about $200 billion on energy including $125 billion on electricity
- Household electricity use: almost 2/3rds is for **appliances & lights**

Introduction / Motivation

- Electricity use has economic & environmental impacts; understand demand to inform policy & consumer choice
- Income & price are generally predicted by micro-economics to be drivers of demand
- But, work here uses tests of *mediation models* to confirm hypothesized mediation pathway
  - household income drives presence of luxury/expendable appliances (stereos, televisions) and further moderates the level of their use
- These results emphasize the specific pathway or mechanism of residential electricity consumption
  - use extremely simplified demand model

Literature

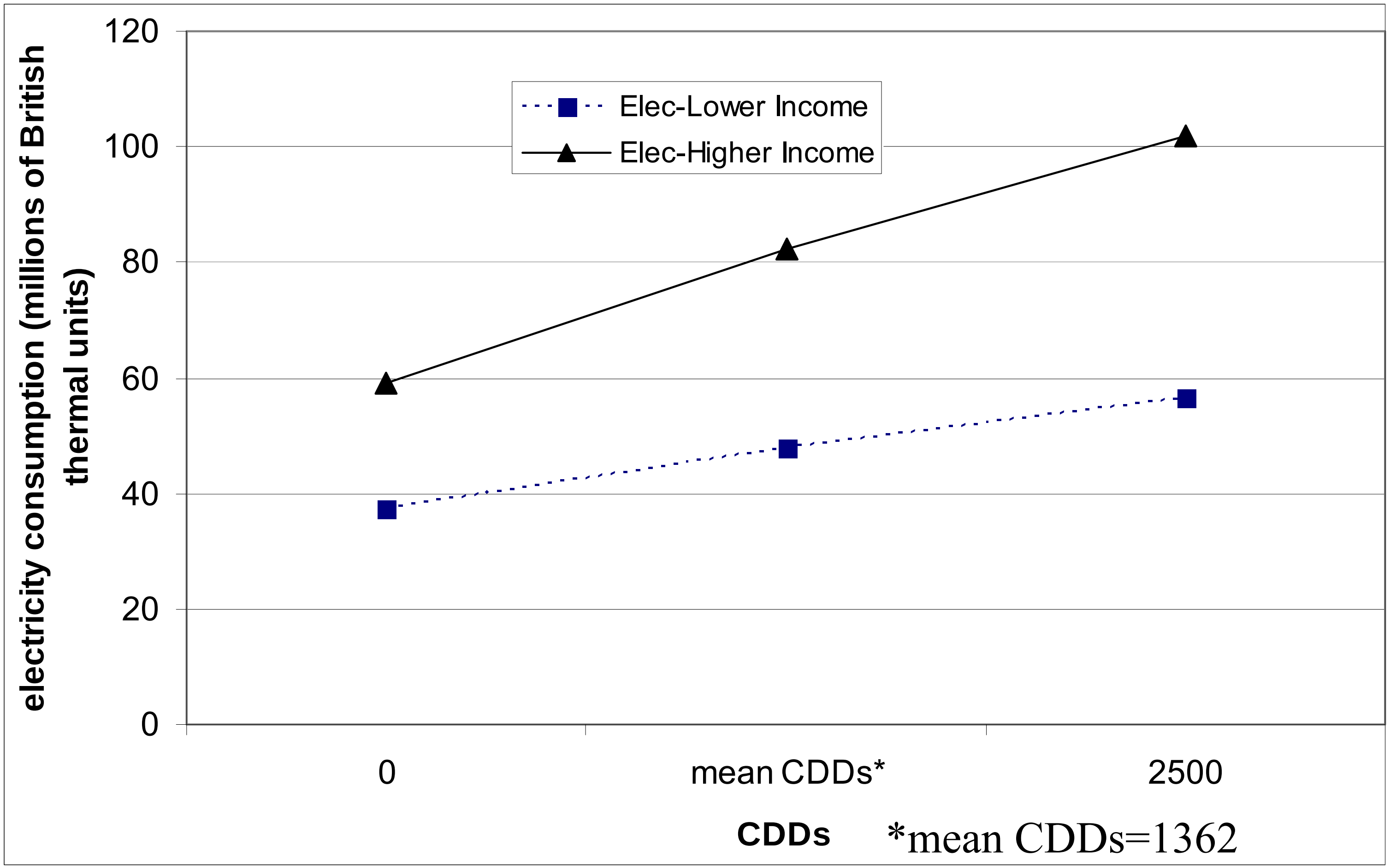
- Engineering approach: electricity use affected by stock of buildings, technologies
- Fisher & Kaysen ('62), seminal econometric study of demand
  - residential sector, function of income and price
  - Separately investigated long-run demand for appliances.
- NBER, Reiss & White ('01): electricity is regulated industry so pricing is generally nonlinear and reflects tariffs
  - tariff systems cannot change fluidly.
  - pricing tariffs or tiers designed for specific consumers (for ex., discounts for lower-income consumers)
  - consumers self-selecting or self-assigning along nonlinear pricing
- Pathway analysis & mediators
  - For ex., health-related prevention and treatment research
- Economic application: *how much* of income effect transmitted via appliances

Data

- EIA RECS (Residential Energy Cons Survey)
  - About every four years; 2001 used; n = 4822
  - Population = all housing units occupied as primary residence
  - 106,989,000 in Current Population Survey (CPS)
  - excludes group quarters: barracks, dormitories & nursing homes.
- Household electricity consumption minus space & water heating & AC → electricity consumption primarily for lighting and appliances ('Elec')

Note: Income & CDDs interact

$$Elec = i + b_1 * Income + b_2 * CDD + b_3 * (Income * CDD) + e$$



CDDs: the number of degrees the average daily temperature (ADT) is above base temperature of 65 degrees Fahrenheit. Sum of daily degree-days (base 65 degrees) are first calculated as follows: ADT = (daily high + daily low)/2 *AND*:

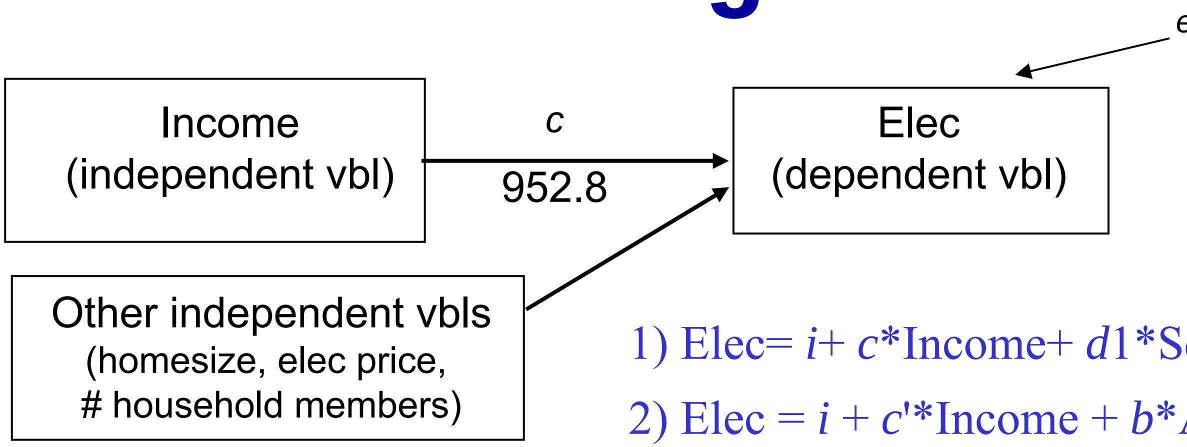
CDD(daily) = ADT – 65, if ADT > 65 and, CDD(daily)= 0, if ADT <= 65

Data

- **Elec**: dependent variable

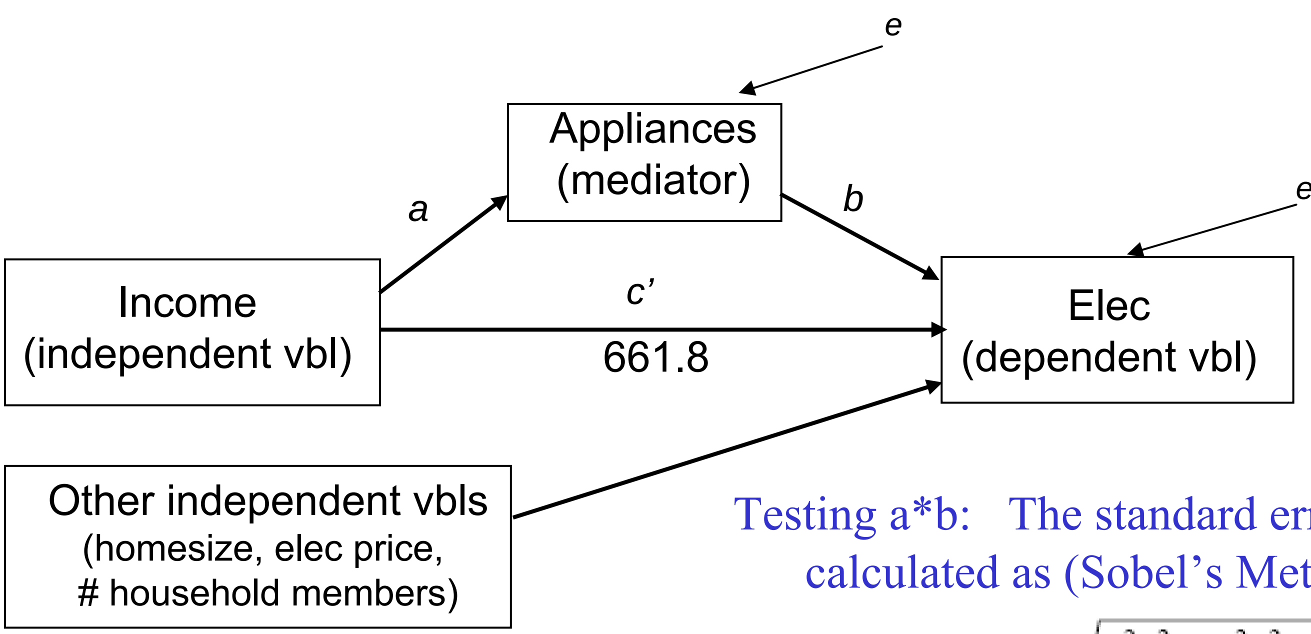
- **Income**: household income, taken directly from the survey data
- **Appliances**: summed survey data for component stereos, VCRs, TVs including big screen TVs, and aquariums
- **Price**: indicator for electricity price calculated as: electricity cost/consumption (DOLLAREL/(BTUEL)
- **People**: in the household
- **Sqft**: home size

Modeling: mediation



1) Elec= i+ c*Income+ $d1$*Sqft+ $d2$*Price+ $d3$*People+e

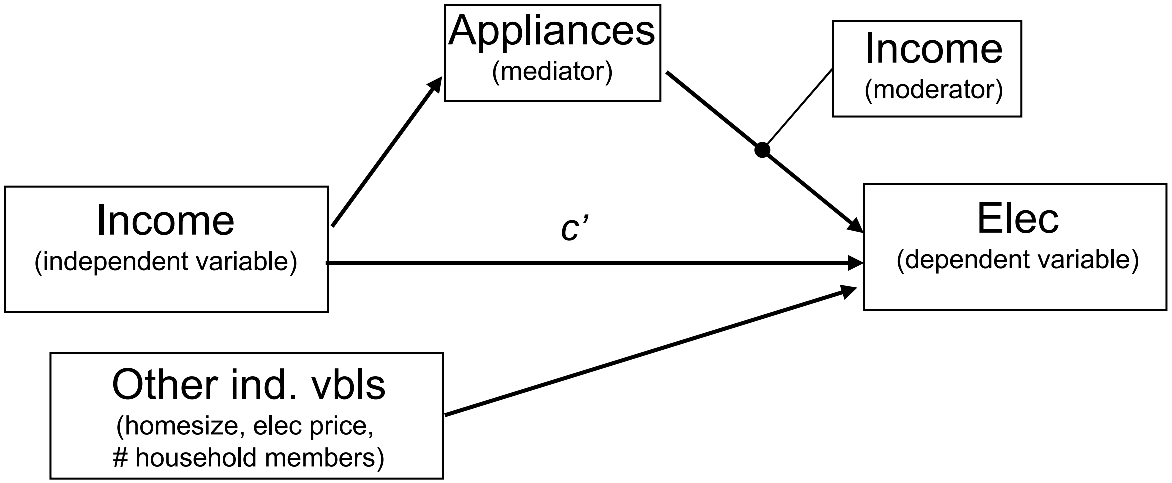
2) Elec = i + c'*Income + b*Appliances + $d1$*Sqft + $d2$*Price + $d3$*People + e



Testing a*b: The standard error of a*b or se_{ab} is calculated as (Sobel's Method):

$$se_{ab} = \sqrt{b^2 s_a^2 + a^2 s_b^2 + s_a^2 s_b^2}$$

Modeling: moderated mediation



Equation 5: Elec= $i + c'$*Income + b_1*Appliances + b_2*(Appliances*Income) + d_1*Sqft + d_2*Price + d_3*People + e

Global F-value: 613.74 Pr > F: <.0001 R^2: 0.4334

parameter	estimate	standard error	t-value	P > |t|
Intercept	17704.5856	1015.32190	17.44	<.0001
Income	229.6292	136.74945	1.68	0.0932*
Appliances	550.7658	201.61144	2.73	0.0063
Income*Appliances	105.7290	27.75354	3.81	0.0001
Sqft	4.2554	0.20970	20.29	<.0001
Price	-471941.5224	17468.38141	-27.02	<.0001
People	2232.6318	117.00099	19.08	<.0001

Modelling Updates

- At first, address heteroskedasticity with White's procedure
- Bayesian analysis of heteroskedasticity:
  - Bayesian regression (conjugate) VS
  - Allow variance of model error terms to vary by observation

$El_i \mid \boldsymbol{\beta}, \mathbf{X_i} \sim N(\mu_i, 1/\varphi)$

$\mu_i = \mathbf{X_i}\,\boldsymbol{\beta}$

$\varphi \sim Gamma(0.001, 0.001)$ (ie, flat)

$\boldsymbol{\beta} \mid \varphi \sim MVN(\mathbf{0}, \mathbf{0.001}/\varphi)$

(*better model,* using DIC deviance info criterion)

$El_i \mid \mathbf{X_i} \sim N(\mu_i, 1/\varphi_i)$

$\mu_i = \mathbf{X_i}\,\boldsymbol{\beta}$

$\varphi_i \sim Gamma(\alpha, \delta)$

$\alpha \sim Gamma(0.01, 0.01)$,

$\delta \sim Gamma(0.01, 0.01)$

$\boldsymbol{\beta} \mid \varphi_i \sim MVN(\mathbf{0}, \mathbf{0.001})$

Modelling Updates: RECS 2005

- Same models yield similar results with 2005 data
  - Adj. R-squares smaller (note, coefficients)
  - White's test same; no Bayesian
- Expanded 'entertainment' appliances – boomboxes, small stereos
  - Playstations: more digital youth means demographics matter?
  - Pools and hot tubs tricky
  - Survey challenges: ipods, chargers, wireless routers
  - Appliance design: memories on digital TV, radios, etc.
- Another "mediator": square footage (not moderated mediation)

Conclusions, future research

- (appliance mediation ~30% of income effect)
- Income targeting to promote efficiency?

- Improve demand model & price effect!
- Appliance variable (intensity, useage)

Thank You,

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