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# US Residential Energy Demand and Energy Efficiency

## A Stochastic Demand Frontier Approach

**Massimo Filippini[*♠], Lester C. Hunt[#]**

[♠] Swiss Federal Institute of Technology, Centre for Energy Policy and Economics (CEPE)
[*] Università della Svizzera Italiana, Istituto di microeconomia e economia pubblica
[#] Surrey Energy Economics Centre (SEEC), Department of Economics, University of Surrey

## Problems and Goals

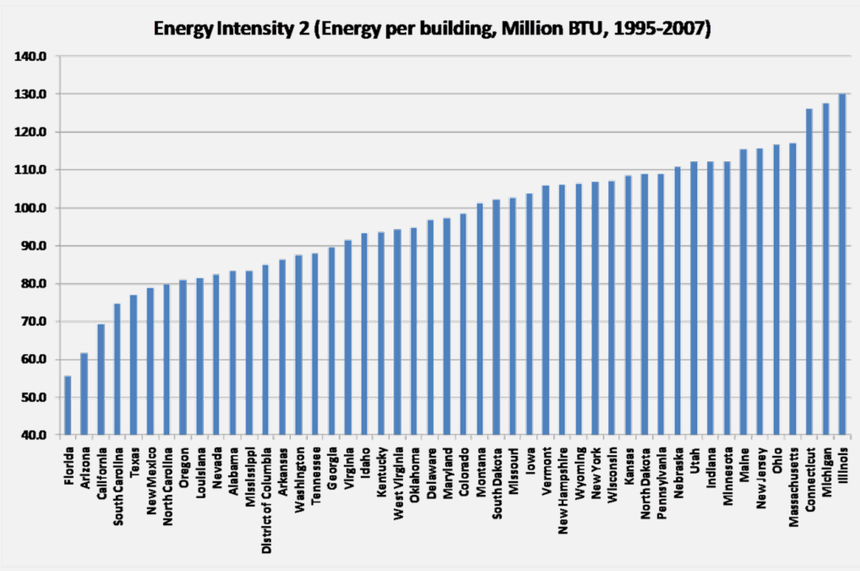
- Energy efficiency has a critical role in addressing energy security, environmental and economic issues
- All countries are implementing energy efficiency policies
- Similarly, all US states are implementing energy efficiency policies although with different approaches
- The promotion of energy efficiency policy is also a very important activity of the IEA (International Energy Agency) and of the EIA (Energy Information Agency)
- How to measure the level of energy efficiency?

## Strengths and Limitations of the Energy-Intensity Indicators

(http://www.eia.doe.gov/emeu/efficiency/ee_ch3.htm )

- .."Four energy-intensity indicators were presented in this chapter that may be used as the basis for the measurement of energy efficiency. All four indicators are imperfect…."
- …"No single energy-intensity indicator for the residential sector stands out as clearly superior to the others. The choice of indicator depends on the questions asked and on data and resource availability…."

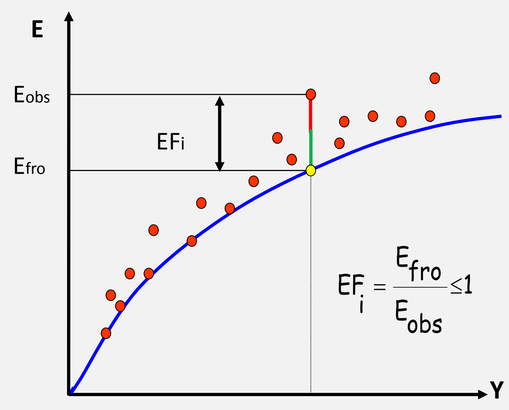
- Energy-Intensity Indicators for the Residential Sector
  - Million Btu per Building Million Btu per Household
  - Thousand Btu per Square Foot
  - Million Btu per Household Member




## Goals of the Paper

- To estimate the residential level of energy efficiency for US states using an alternative approach based on two branches of the literature:
  - frontier estimation
  - energy demand modelling
- An aggregate residential energy demand frontier function is estimated

## An Aggregate Frontier Energy Demand Model




**Energy efficiency measures the ability of a country to minimize the energy consumption, given a level of Y**

## Panel Data Stochastic Frontier Models

*POOLED MODELL* (Aigner, Lovell and Schmidt, 1977)

$$\ln C_{it} = \ln C(y_{it}, w_{it}) + u_{it} + v_{it} \qquad u_{it} \geq 0$$

*RANDOM EFFECTS MODELL* (PITT & LEE, 1981)

$$\ln C_{it} = \ln C(y_{it}, w_{it}) + \alpha_i + v_{it} \qquad \alpha_i \geq 0$$

*TRUE RANDOM EFFECTS MODELL* (GREENE, 2005)

$$\ln C_{it} = \ln C(y_{it}, w_{it}) + \alpha_i + u_{it} + v_{it} \qquad u_{it} \geq 0$$

## Model Specification

$$e_{it} = \alpha + \alpha^{y} y_{it} + \alpha^{p} p_{it} + \alpha^{hs} hs_{it} + \alpha^{hdd} hdd_{it} + \alpha^{cdd} cdd_{it} + \alpha^{sh} sht + \alpha^{DR1} DR1_{it} + \alpha^{DR2} DR2_{it} + \alpha^{DR3} DR3_{it} \; \alpha^{DT} DT_{t} + u_{it} + v_{it}$$

- $E_{it}$ : residential energy consumption per capita
- $P_{it}$ : the real price of residential energy
- $Y_{it}$ : Income per capita
- $Hs_{it}$ : Household size
- $CDD_{it}$, $HDD_{it}$ : cooling and heating degree days
- $DC_{it}$ : share of detached houses
- *DRi* : regional dummies (West, Midwest, Northeast and South)
- *Dt* : time dummies
- $u_{it}$ : energy efficiency assumed to be half-normal distributed

## Data

- Balanced Panel Data Set
  - 48 US states (i = 1, …, 48)
  - 1995 to 2007 (t = 1995-2007)
- where:
  - E = per capita residential energy consumption in Btu (British Thermal Units)
  - Y = real per capita income (thousand US 2000)
  - P = real price of energy $ per million of BTU (2000=100)
- Data Sources

U.S. Energy Information Administration
Independent Statistics and Analysis

BEA
BUREAU OF ECONOMIC ANALYSIS
U.S. DEPARTMENT OF COMMERCE

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

## Efficiency Levels and Rankings

| | *Estimated Underlying Energy Efficiency (Pooled Model)* | | *Energy Intensity 1 (Energy per capita)* | | *Energy Intensity 2 (Energy per building)* | |
|---|---|---|---|---|---|---|
| | *Level* | *Rank* | *Level* | *Rank* | *Level* | *Rank* |
| California | 0.974 | 1 | 25.162 | 1 | 69.252 | 3 |
| Florida | 0.946 | 29 | 25.656 | 2 | 55.649 | 1 |
| Iowa | 0.973 | 2 | 44.219 | 28 | 103.778 | 29 |
| Massa-chusetts | 0.917 | 41 | 48.428 | 41 | 116.997 | 45 |

## Average Correlation Coefficients

- Energy Intensity I and Energy Intensity II : **0.90**
- Energy Efficiency and Energy Intensity I (per person consumption): **-0.65**
- Energy Efficiency and Energy Intensity II (per building): **0.61**

## Spearman Rank Correlation Coefficients

- Energy Intensity I and Energy Intensity II : **0.93**
- Energy Efficiency and Energy Intensity I (per person consumption): **0.21**
- Energy Efficiency and Energy Intensity II (per building): **0.22**

## Conclusions

- This research is a fresh attempt to isolate core energy efficiency for a panel of 48 US states, opposed to relying on energy intensity indicators
- By estimating a measure of 'underlying energy efficiency' by combining the approaches taken in energy demand modelling and frontier analysis
- The estimates for core energy efficiency using this approach show that although for a number of states the change in energy intensity over time might give a reasonable indication of efficiency improvements; this is not always the case
- It is argued therefore that this analysis should be undertaken to avoid potentially misleading advice to policy makers
- So that looking at relative energy intensity across states might give a misleading picture, unless the influences discussed above are controlled for first