An Examination of Post-Recession Trends in Residential Electricity Consumption and Household Income

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POST-RECESSION
NATIONAL-LEVEL TRENDS
(2010-16)
Change in kWh consumption (2016 vs. 2010)

While Commercial and Industrial Sectors saw post-recession kWh growth, the Residential Sector experienced a 2.4% decline.

U.S. Residential Electricity Consumption

- Overall 2.4% decline 2010 to 2016
- YOY Declines in 3 of 6 years (2010 to 2016)

Sources: EIA
Other Post-recession national trends (2010-16 unless otherwise noted)

• **Electricity Price**
  • Real residential electricity price declined 1.3%

• **Weather**
  • Cooling degree days increased 7%
  • Heating degree days declined 13%

• **Stagnant Income Growth**
  • Median Real HH Income only increased 8.8% (1.4%/yr.), and did not surpass 1999 levels until 2016
  • Bottom Quintile mean real HH income only increased 6.9%
  • Top quintile mean real HH income increased 14.7%

• **Energy Efficiency**
  • International Energy Agency (IEA) indicates that as of 2016, U.S. households decreased energy expenditures by 10% relative to 2000 levels due to efficiency improvements

Source: [https://www.iea.org/topics/energyefficiency/globaltrends/](https://www.iea.org/topics/energyefficiency/globaltrends/)
STATE-LEVEL ANALYSIS
(2010-16)
Panel Data Regression Analysis
- 2010 to 2016 State-Level Annual Data (Lower 48 states)
- Fixed Effects vs. Random Effects

Questions to Address
- Which economic variable(s) were significantly associated with changes in residential electricity consumption?
  - Median Household Income
  - Personal Income per Capita
  - GDP per Capita
- What Other Variables were statistically significant?
  - Electricity Price
  - Degree Days
  - Energy Efficiency Score
    - Does including efficiency score, change the coefficient size/significance of economic variables
- Which Model is Preferred?
  - Fixed-Effects
  - Random-Effects
Data Sources

• State-level (lower 48) annual data from 2010 to 2016
• kWh consumption: Energy Information Administration (EIA)
• GDP: Bureau of Economic Analysis (BEA, Chained 2009$)
• Personal Income: BEA (Chained 2009$)
• Median Household Income: U.S. Census Bureau (2016$)
• Population: U.S. Census Bureau
• Degree Days: National Oceanic and Atmospheric Administration (NOAA)
• Energy Efficiency Scores: American Council for an Energy-Efficient Economy (ACEEE, scores range from 0 to 50 in increments of 0.5)
Variables and expected coefficient sign

• **Dependent Variable**
  • kWh per capita

• **Key explanatory variable**
  • Economic variables (inflation-adjusted)
    • Median Household Income
    • GDP per capita
    • Personal Income per capita

• **Control Variables**
  • Weather: Total Degree Days
  • Electricity Price (inflation-adjusted)
  • Energy Efficiency Score
State-Level: Distribution of Res. kWh/capita

- 2010 to 2013
- 2014 to 2016

Density

kWh per capita

2,000
4,000
6,000
8,000
# Summary Statistics

<table>
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<tr>
<th>Variable</th>
<th>Observations</th>
<th>Mean</th>
<th>Coefficient of Variation</th>
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### Correlation Matrix (First Differences)

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Models

1. Fixed-Effects

\[ kWh_{\text{cap}}_{it} = \alpha_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \cdots + \epsilon_{it} \]

\(kWh\_cap\): Residential electricity consumption per person (the natural logarithm is used)

\(\alpha_i\): State-specific intercepts; \(i\): State; \(t\): Time period; \(x\): Time-varying covariates; these include the efficiency scores and the natural logarithms of the following variables: Median Real Household Income (MHHI); Real Gross Domestic Product per person (GDP\_cap); Real Personal Income per person (PI\_cap); Total Degree Days (TDD); Electricity Price.

2. Random-Effects

\[ kWh_{\text{cap}}_{it} = \mu + \beta_1 x_{1it} + \beta_2 x_{2it} + \cdots + (u_i + \epsilon_{it}) \]

\(\alpha_i = \mu + u_i\); \((u_i + \epsilon_{it})\): Composite error term
Initial Regression Findings

- Hausman test prefers fixed-effects over random-effects in all specifications.

- Lead and lags of economic variables are insignificant, possibly due to a short number of periods.
### Regression Results (Fixed Effects)

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|          | -1.2193   | -1.23     | -1.6257   | -1.1528   | -1.2007   | -1.5876   |
| Observations | 336       | 336       | 336       | 336       | 336       | 336       |
| R-squared (D) | 0.9961    | 0.9961    | 0.9961    | 0.9963    | 0.9963    | 0.9963    |
| R-squared (N) | 0.6889    | 0.687     | 0.6889    | 0.7035    | 0.7035    | 0.7063    |

Standard errors in parentheses

* p<0.10   ** p<0.05   *** p<0.01

D: R-squared from using each coefficient for each covariate plus each dummy variable for the states
N: R-squared which subtracts out the effects of the groups (state dummy variables)
Conclusions

• National-level trends (2010-16)
  • Residential kWh declined while other sectors increased kWh
  • Weak income growth, lower real electricity prices, improved energy efficiency

• State-level regression analysis sought to estimate which economic variables were significant predictors of changes in electricity consumption, accounting for several control variables.
  • Fixed-Effects specification preferred to Random-Effects, with the following findings:
    • Economic variables significant at either 90% or 95% level, regardless of whether efficiency score is included
    • All control variables are significant
      • Electricity Price (Absolute Coefficient size 50% to 100% as large as economic variables)
      • Degree Days (Largest Coefficient of the natural log explanatory variables)
      • Efficiency Score
      • Time Trend (Still significant after including efficiency score, w/similar coefficient size)
Future Work

• Examine other Efficiency Measures
• Update Data
• Regions
  • Control for regional differences
  • More granular data (e.g., county-level)
• Examine other Economic Measures