Estimating Aggregate Energy Consumption Effects of Energy-Efficiency Programs in California

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Overview

- Key findings/ recommendations (synopsis)
- Background
- Proposed pilot project

Key Findings

1. Appropriate metrics are estimates of “absolute” consumption in watt-hours and therms – kilo- , mega- , giga- - depending on the level of aggregation
   - In particular, various “energy intensity” metrics are *not* the right approach for the CPUC’s purposes

2. Econometric methods are both viable and appropriate for estimating these metrics, and would complement current methods
   - Econometric estimates would have substantial uncertainties but these can be rigorously defined and analyzed (in contrast to other approaches)
   - Improving precision / reducing uncertainty would require changes in data collection procedures

Defining Macro Consumption Metrics

- D. 10-10-033 States: "Macro Consumption Metrics are tools of evaluation that use econometric models to assess the aggregate impact of energy efficiency policy on energy consumption. These metrics are distinguished from other methods of impact evaluation because they do not rely on the sum of a series of more granular studies." [Footnote 19, page 12]

- Modify to: Macro Consumption Metrics are tools of evaluation that use econometric models to assess impacts of energy efficiency policy on energy consumption. These metrics are distinguished from other methods of impact evaluation by a focus on changes in consumption for measuring energy efficiency and direct estimation of impacts aggregated across end users and uses without the need for a series of more granular studies.

Background 1: Aggregate "energy efficiency" metrics

- The standard efficiency policy and regulatory paradigm is firmly based upon engineering & physics – specifically, the 1st Law of Thermodynamics – relating energy service outputs and fuel inputs
  - Examples: SEER, COP, etc.
- Various energy "intensity" metrics have been proposed and used in attempts to generalize this concept of efficiency

- Examples:
  - Energy per GDP
  - Energy per unit of manufactured output (for industrial sectors)
  - Energy per: capita, or household, or dwelling (residential sector)
  - Energy per: Floor-space, or building, or unit of economic output (for commercial sectors)

Limitations of "intensities"

- However, these are not "generalizations" of technical efficiency:
  - The aggregate relationships between "energy" and "output(s)" are both more complex, and different in principle, from 1st Law efficiencies
  - Aggregate "intensities" are only weakly correlated with the penetration or specific types of efficient technologies
    - Example: The "Rosenfeld Curve" of per capita electricity use in California

US EIA study

- The definitive analysis of avenues for defining and measuring aggregate "energy efficiency" was conducted by the U. S. Energy Information Administration (EIA) in the 1990s. Findings included:
  - Even within a specific sector, e.g., residential, different metrics not only differed quantitatively but could have different signs over a given time period – i.e., were not consistent as far as "increasing" or "decreasing"
  - Metrics for different sectors were generally not directly comparable, or "integrable," e.g., residential electricity per household vs. industrial electricity per value of shipments

Summary of Background 1

- The standard physics/ engineering concept of "efficiency" does not scale up beyond the level of individual technologies or devices
- Various aggregate "energy intensity" metrics are neither generalizations of technical efficiency, nor good estimates of dis-aggregate deployment of efficient equipment
- Moreover, these intensity metrics are not suitable for cross-sectoral aggregation or comparison

Background 2: Analytical complexity in California energy regulation

- We now have multiple agencies using different models & methods to analyze, develop, and implement energy policy in California, including
  - CEC demand forecasting system
  - ASSET and SESAT of Itron, for CPUC
  - E-DRAM general equilibrium model of ARB
  - E-Three's "calculators," for CPUC

- The type, number, and uses of such models has been increasing along with the proliferation of policies over the past decade
- This has resulted in a “Tower of Babel” situation – different methods and results have become difficult, at best, to compare and articulate
- For what it’s worth: This state-of-affairs has long been present at the national level, and there are few if any signs of its being successfully addressed

The gist

- ***No new "metric" or model can "fix" this situation***
  - Indeed – ala the Hippocratic Oath – we want to avoid aggravating it
- Thus, *simplicity and transparency* are highly desirable in both the top-down metrics, and the method of their measurement and/or estimation

The NPCC

- The methods and procedures of the Northwest Power and Conservation Council (NPCC) are particularly instructive in this regard:
  - The NPCC is responsible for what used to be called "Integrated Resource Planning" in the Pacific Northwest, encompassing
    - Supply, demand (efficiency), renewable and non, carbon-reducing, etc.

- This agency uses an elaborate suite of complex methods and models, but apparently does not suffer from the analytical confusion currently plaguing California
  - *Our conclusion is that this is because of institutional and political differences, not technical or methodological ones*

- The example of the Demand Analysis Working Group (DAWG):
  - This is an important project that, in addition to informing our proposal, also illustrates the nature of the underlying problem: It is taking a sustained, serious effort to arrive at a common multi-stakeholder understanding of the results of *existing models and methods*

Background 2-prime: Current state of EE program evaluation around the country

- This was the subject of an authoritative review last year by Itron, LBNL, and Schiller Consulting, prepared for the U. S. DOE
- Relevant findings include:
  - This type of evaluation is very much a work-in-progress – not clear that there is an identifiable "best practice"
  - The general problem we are addressing here – aggregate program impact assessment and attribution, in a complex policy environment – remains essentially *terra incognita* in the EE evaluation realm

Summary of Background 2 (and prime)

- Top-down metrics by whatever definition or approach cannot, per se, simplify the current complexity and complication of California's energy regulatory and policy analysis system
  - To maximize the value-added of new metrics, simplicity and transparency should be priority design criteria
- The problem at hand is at or beyond the current state-of-the-art in EE program evaluation as it is currently practiced
  - There is at least one example – the NPCC – of an analysis system that is complex but apparently not contentious – but this provides limited guidance for California barring wholesale re-organization of regulatory jurisdictions and authorities

Background 3: Econometric program evaluation

- Long history in
  - health policy (smoking, obesity, nutrition)
  - education policy (head-start, charter schools, outcome inequality)
  - employment (job training, minimum wage, schooling)
- Benefits
  - Well-defined measures of uncertainty and tests of hypotheses
  - Designed to directly account for market effects
  - Easily implemented and transparent
  - Established methods to address selection & endogeneity

Recent Applications to EE Policy

- Controlled Experiments
  - Wolak (2011) - District of Columbia, Dynamic Pricing
  - Costa and Kahn (2010) – California, Home Energy Report
    - Randomly selected households mailed HERs
  - Pseudo-experiment: Allcott(2010) – Chicago, Energy Smart Pricing Plan
    - Volunteer households randomly assigned to treatment & control groups
- "Natural Experiments"
  - Chong (2011) - California, Energy Efficiency Building Standards
  - Jessoe and Rapson (2011) - Time-of-Use Pricing
  - Jacobsen and Kotchen (2010) - Florida, Energy Efficiency Building Codes
    - Predicted change in EE smaller than but not statistically significantly different from engineering estimates

Uncertainties in Econometric Estimation: Data

- Data Limitations
  - Billing data is not easily and immediately accessible for analysis
  - Economic and energy-use data is not available at the desired level of disaggregation
  - Data on commercial and industrial energy use is sparse
  - Sample size and coverage issues

Uncertainties in Econometric Estimation: Policy

- Policy Landscape
  - many complicated, overlapping policies
  - programs changing over time
  - no measure of uptake for many programs
  - differences between intention and implementation
  - programs rolled-out over time
  - voluntary uptake introduces selection issues

Uncertainties in Econometric Estimation: Methods

- Methodological Limitations
  - Reduced form estimates do not have a causal interpretation outside controlled experiments, except under <u>VERY</u> special conditions
  - Regression methods can confound multiple effects if they are correlated
    - Any bias may or may not be able to be signed or bounded

Econometric Estimates of EE Savings

- What can be estimated "well"?
  - Total CA EE savings using a panel of states
  - Total sector-specific CA EE savings using a panel of states (i.e., residential)
  - Program/policy-specific EE savings for some policies
  - Effects of prices, assuming prices are regulated
  - Effects of weather
- What can be estimated "poorly"?
  - EE savings attributed to categories (e.g., Codes and Standards)

Data Collection

- Single repository, digitized, with identifying information removed
- Tracking of program participation
- Data on program attributes, roll-out, timing, announcements, etc
- Development of controlled or pseudo-controlled experiments prior to program roll-outs

Consumption Based Metrics

- Comparable across sectors
(i.e., residential, industrial, commercial)

- Easily scaled up or down to different levels of aggregation

- Meaningful for CO2 emission levels

- Comparable across many transformations
(e.g., total volumes, per annum, per capita, per IOU, per program)

Proposed Pilot Project

Three self-contained phases (“steps”)

– Maybe implemented individually or as a whole

1. Aggregate EE Savings Estimates from U.S. Government data
2. Program attribution of EE Savings
3. Feasibility Study for hybrid “top-down”-“bottom-up” approach

Step 1: Aggregate EE Savings

Estimate CA EE savings in total and by sector by simple linear panel regression methods

*Electricity_it = α + β1*price_it + β2* economic_it + β3* weather_it + β4_program_it + β5*state_i + β6*time*

Price, economic, weather, etc. are vectors of explanatory variables including interactions and quadratic effects

- Data set will be constructed from multiple, publically available sources
- Construction requires minimal data cleaning and geographic matching
- Identification comes from differences both across states and over time

Step 1: Primary Data Sources

- Electric Utility Demand-Side Management Data Files (Form EIA-861):
  - annual utility level data (@3700 utilities), 1990-2009, all U.S. states and territories
  - sales, revenues, & number of consumers total and by sector
  - measures of DSM by sector and total
  - utility characteristics
- National Center for Atmospheric Research
- U.S. Census: macroeconomic indicators

Step 2: Program Attribution

- Similar approach to step 1
- Aggregate programs and policies from CPUC database to IOUs, Codes and Standards, etc.
- Perform estimation using simple linear panel regression models
  - Compare across utilities within CA and over time
  - Variation across utilities will identify some effects
- Fully disentangling effects of each category may not be possible
- Better estimates might be obtained by estimation of individual program/policy effects followed by aggregation, but unlikely to be feasible

Step 3: Feasibility Study for Coordination and Combination with Existing Methods(s)

- How can we combine bottom-up & top-down approaches to:
  - reduce uncertainty?
  - estimate additional quantities?
  - mitigate data limitations?
- Define and test a procedure for using the proposed metrics in conjunction with existing models and (aggregate) measures
- The core task will be creating an analytical framework for comparison of econometric estimates with those generated by other means

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