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BOTTOM-UP AND TOP-DOWN APPROACHES FOR ASSESSING DSM PROGRAM IMPACTS

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Introduction: Examine two approaches for estimating energy savings from DSM

- <u>Bottom-up approaches</u> using program level data
- <u>Top-down approaches</u> using aggregate data across programs for a geographic region (e.g., state, province, etc.)

  ***<u>Note</u>**: – There are different types of top down approaches, this paper focuses on approaches estimating energy savings using aggregated data in regression-model frameworks.*

- Controversy in regulatory proceedings:
  - Claims made that bottom-up approaches over estimates DSM program impacts
  - This initiative stems from a recent paper (Rivers and Jaccard – 2011) that concludes that:
    - *"Demand-side management expenditures have had a minimal impact on electricity demand" with estimated savings being considerable less than those estimated by utilities using program-level estimation approaches*.
    - *"In sum, all of the models that were estimated suggest that demand side management expenditures have had minimal impact on electricity demand."*
- The core part of the paper is the re-estimation of a single Top-Down approach to illustrate how the assumptions embedded in the application influence the results.
  - Look at how changes in assumptions to other reasonable assumptions can substantively change the results.

Approach and Assessment

- The claim regarding Top-Down approaches (or a specific Top-Down Study) as a good method for evaluating the accomplishments of a portfolio of DSM programs needs to be grounded in an assessment of the strengths and weaknesses of both the Top-Down and Bottom-Up approaches:

    1. The issues addressed by each approach.
    2. The role of judgment across both methods.
    3. The potential for bias in each method.

- Different objectives -- the purpose of an evaluation can be to:
    1. Determine whether current activities and investments are reaching targets, i.e., providing the expected returns.
    2. Assess the current portfolio of DSM activities selected and determine whether adjustments should be made.
    3. Additionally, there may be ways to improve the program implementation processes – particularly quality control.

Bottom-Up Approaches

- Program implementers (often a utility) have an obligation to efficiently deploy program efforts AND to collect data that will allow for an overall assessment of the economics of their activities.
- Bottom-Up evaluations are program/portfolio focused:
  - Look at a program or portfolio of programs across a given time period.
  - M&V approach generally based on a sample of program participants or market entities.
  - Typically use a realization rate approach were in-field estimates of savings are developed in detail for a sample of participants.
  - Then, these in-field estimates are compared to the initial estimates for each participant site.
  - The realization rate is simply the ratio of in-field M&V based estimates to the initial tracking system estimates.
  - A realization rate of .90 indicates that 90% of the expected savings from the tracking system have been verified in the field M&V studies.

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Bottom-Up Example

- Consider a program targeted at large commercial buildings that has three components:
  1. Identify investments in efficient lighting
  2. Assess investments in major energy-using equipment – HVAC, ventilation, boilers
  3. Examine the building's energy management and controls system (EMCS)
- 200 buildings participated with a tracking system of all investments made with initial engineering estimates of expected energy savings.
- Detailed M&V plans are developed for a sample of 30 buildings (sampling can be complex with strata developed and proportional sampling).
  - If the infield M&V conducted on this sample.
  - Assume that 90% of the expected savings were verified by the in-field work; then, the realization rate for Gross Savings is .90.
  - ISSUE: This is gross savings and some of the savings may have occurred in the absence of the program.

Bottom-Up Approaches (cont.)

- A gross impact realization rate of .9 provides confidence that the equipment is working in the field, and that savings are being obtained from the equipment installed.
  - Therefore, monies spent by the DSM program did, in fact, install cost-effective equipment.
- The resource value of DSM requires a net-to-gross (NTG) calculation to determine what the net impacts of the program are, i.e., what changes have been made that are attributable to the program.
  - Free Riders – this occurs when some of the participants would have taken all or part of a program action even in the absence of the program.
  - Spillover – works in the opposite direction. Some actions offered by the program are taken by non-participants/participants even if theses changes are not formally entered into the program tracking system, i.e., they are left out of the program tracking system.
  - The EE literature has many examples of spillover that illustrate it exists and can be material.

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NTG Estimation Issue

- Gross impacts are estimated in a relatively straight forward manner.
  - There are challenges, but M&V methods based on equipment and building operations have been developed to produce reliable estimates.
- Free Rider (FR) and Spill-Over (SO) estimation probably best illustrates the issues Top-Down proponents have with Bottom-Up approaches.
  - The claim by is that these estimates are overly judgmental.
- FR can be estimated in several different ways:
  1. A control group – a perfect control group will act in the same way the participant group does, and their installation of energy use equipment can be used to estimate FR – and also SO.
  2. Sometimes adequate control groups can not be used; then, survey approaches of market actors are used to estimated the amount of energy efficiency that would have been obtained if the program had not been offered.
  3. Structured surveys can be used to estimated both FR and SO.

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Structured Surveys

- Not as good as using a randomly selected control group, but well designed surveys can develop range estimates of FR and SO.
  - Approach taken by the authors in past studies includes:
    1. Establishing existence first – does the FR or SO effect exist at all.
    2. Establish range:
       » First, ask how great the impact might be, i.e., 50% of program impacts as an upper bound.
       » Second, ask how small the impact might be, i.e., 5%.
    3. Determine confidence intervals -- Develop a best estimate of the impact once this thought process has been worked through, with some delineation of the likelihood of where within the range of impacts, the most likely value falls.
  - This approach produces estimates with uncertainty, but it does work as well as evaluations of other policy actions and business investment decisions.
- Bottom-up evaluators take the position that reasonable estimates of FR and SO are possible such that good investment decisions in DR programs and activities can be made.

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Top-Down Approaches

- These methods have been applied for some time, but have not generally been used to replace estimates of impacts from Bottom-Up approaches.
- Recently, more regulatory attention is being given to Top-Down approaches to assess setting DSM targets and policies.
  - Result – The inferences from Top-Down approaches need to be more seriously considered now given their results are now entering the policy debate.
- For this paper, a focus is on a Top-Down application by Rivers and Jaccard (2011). This study was introduced into a DSM review proceeding.
- While this is a specific application, it can be used to illustrate some of the general issues with both Top-Down and Bottom-Up approaches.

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Features of Top-Down Approaches:

- Econometric methods are used on aggregate data:
  - Uses DSM expenditure data for a region and develops a regression model to show how expenditures relate to reductions in energy use.
  - DSM expenditures are obtained from various sources, but in most instances (i.e., most that we have seen) the DSM data does not distinguish between energy efficiency and load-management expenditures.
    - Direct load control of air conditions is a common load-management program, but does not save energy and it can cause large expenditures.
  - Usually based on expenditures in a geographic are:
    - States in the U.S.
    - Provinces in Canada.
    - Allows for some alignment between expenditures on DSM and electricity consumption such that a relationship can be modeled.

One Specific Model

1. Observation on 10 Canadian provinces for 16 years for a total of 160 observations (roughly – some dropped due to data problems)

2. Dependent variable is the natural log (LN) of energy use per capita for a province in year "t"

3. The model is a partial adjustment model where the lagged value (i.e., the value in "t-1" is included as a dependent value.

4. The model is a "fixed-effects model" where a unique intercept is estimated for each province.
   – Fixed-effects models are common in evaluation as they allow for factors that are unique to each province and are constant over the time period being examined to be addressed by the model without explicit introduction of these variables into the equation (e.g., the mix of industry in a province).

5. This aggregation avoids many of the estimation issues in bottom-up approaches as you are looking directly at the end result; specifically, there is no need to explicitly estimate NTG factors.

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The Basic Model – Rivers and Jaccard

LN Per Capita Energy Use ***= B_1 (DSM expenditures per capita) +***

B_2 (LN energy use per capita lagged one time period) +

B_i (other X_i independent variables such as electricity price) +

Intercept specific to province k + error $term_{it}$

[The B_i's are regression coefficients in the equation above.]

- The fixed-effects province term provides for a unique intercept for each province.
  - controls for "constant" factors within the time period of the study.
  - The longer the time period the less likely the fixed effects term will adequately control for differences between provinces that are unobserved in the other independent variables.
  - There may be a need for annual fixed effects (a time variable).
  - So, now a judgment is needed – other top-down models have included annual fixed effects variables.

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Potential Issues in Regression Models

Potential Issues in Regression Models	
1. **Endogeneity**	One of the regressors is causally related to other independent regressors in the model.
2. **Autocorrelation**	The error terms for different observations are correlated.
3. **Heteroskedasticity**	The variance of the error term is not constant across observations.
4. **Multicollinearity**	Some regressors are highly correlated with each other.
5. **Specification error**	Relevant explanatory variables are omitted from the equation.
6. **Inclusion of Irrelevant variables**	If correlated with included key variables, the estimated variance on the coefficients of these variables will be biased upwards and statistical significance biased downwards.
6. **Errors in variables**	This occurs when there are errors in measuring the independent variables (e.g., the development of DSM expenditure data for a unit of time and geographic area that appropriately correlates to the energy use data for that area).

- Processes and procedures have been developed to address these and other issues in the econometrics literature, but the approach taken often requires judgment, with few perfect solutions.

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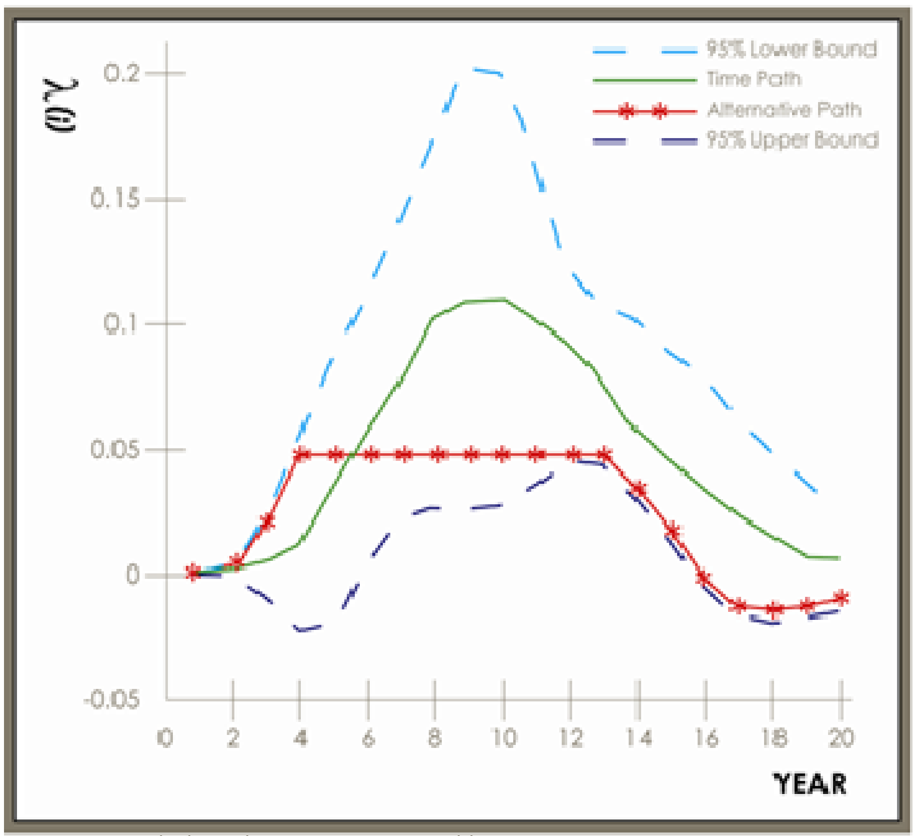
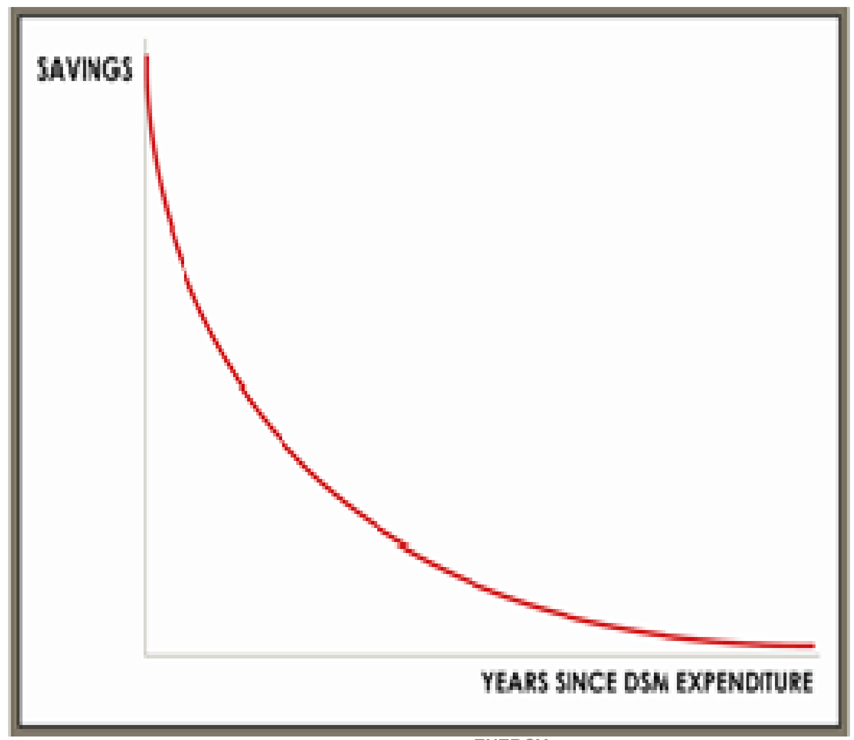
A key top-down issue – timing of DSM impacts

- **<u>First graph</u>** shows a non-linear relationship between DSM expenditures and when impacts occur – the peak at about 8 years out (see Arimura, 2011)
- **<u>Second graph</u>** illustrates the “enforced” time trend of the partial adjustment model chosen by Rivers and Jaccard (2011) – to the extent this time path does not match the actual relationship between impacts and expenditures, the ability of the model to appropriately estimate this relationship will reduced.





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Review of the Rivers-Jaccard Model

- A review of each Top-Down evaluation needs to be discriminating as judgment is used and assumptions may not be appropriate (or the most appropriate assumptions may be unknown).
- Three features of the Rivers-Jaccard model *(focusing on this model as it was a point of contention in a DSM portfolio review at a utility)*:

  1. Small data set to identify a change in energy-use per capita of around 2 to 3% of the total (effect size issue) – makes identification of the effect with reasonable confidence intervals difficult.
     - Errors-in-variables may create noise in the system that make it hard to identify such a small effect size.
  2. A decision was made not to include annual fixed effects were not used.
  3. The treatment of the dynamic effects of DSM expenditures on impacts was highly constrained – i.e., they were constrained to diminish exponentially over time rather than peak several years out from when the expenditures occurred.

Re-estimation of the Rivers-Jaccard Model

- The same data set was used in the re-estimation.
- Changes included:

1. A more flexible relationship between the timing of DSM expenditures and when the impacts take place.
2. Province-level fixed effects were accounted for by using variables that take the difference between LN MWh at "t" and LN MWh at time "t-1", following other specifications in the literature.
3. A dummy variable for annual fixed effects is incorporated.

- RESULTS:
  - Rather than the finding that: "Demand-side management expenditures have had a minimal impact on electricity demand" with estimated savings being considerable less than those estimated by utilities using program-level estimation approaches.
  - The re-estimation produced estimates consistent with the bottom up approaches used by the utility (in this case BC Hydro).
  - The small number of observations result in large confidence intervals.
  - NOTE: Top-Down approaches require large data sets which may be difficult to obtain.

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Conclusions

- Bottom-up and Top-down approaches both have strengths and weaknesses and broad-brushed judgments regarding the superiority of one over the other may not be appropriate. *(Important given the current debate in North America)*
- Top-down models are only useful for estimating the average effect of DSM across a number of utilities, states, provinces or other cross-sectional units.
- Top-down models can not address the relative performance of one utility's program versus another; or, suggest ways in which a program can be improved.
- Bottom-up models:
  - Use micro data that can provide information on the composition of a program's technologies and activities through the site M&V.
  - Structured methods to address NTG can through a preponderance of the evidence provide information at a level of confidence to assess the resource cost-effectiveness of DSM efforts.
  - They can serve the purpose of providing the insights needed by policy makers and planners to make good investments in DSM.

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Conclusions (cont.)

- Top-Down approaches:
  - Need to examine the data platform on which the model is being estimated to ensure it is appropriate for the goals of the study.
    - Sample sizes.
    - Errors in variables.
  - If the number of observations needed are not available and the data are not of sufficient quality; then, miss-leading results are likely.
  - The finding of no statistically significant effect between DSM expenditures and reductions in energy use is often interpreted as indicating that DSM does not have an effect on energy use ……
  - BUT, all this really says is that the model can not tell whether there is an effect or not – over interpretation of the results is a danger and models that find no statistically significant effect do not warrant the conclusion that DSM has had "minimal impact on electricity demand." (Rivers and Jaccard, p. 112)
  - As with most all studies, Top-Down models require that broad judgments be made – they also rely on a preponderance of the evidence approach.

Conclusions (cont.)

- Finally:
  - Both approaches have strengths and weaknesses.
  - Policy makers are more experienced interpreting Bottom-Up approaches, and econometric Top-Down approaches have not yet been fully vetted from a policy perspective.
  - They address different important questions:
    - Top-Down econometric methods address the average effects of DSM expenditures at an aggregated cross-sectional level.
    - Bottom-Up methods can address issues relating to a utility or other DSM program provider portfolio, sector and program level analyses.
  - Both methods are valuable, but appropriate contest and interpretation are needed with proponents of one method or the other not over-extending their conclusions to the detriment of DSM resource decisions.

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Key
CONTACTS

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