Sustainable Prosperity

Research Summary | July 2015 LOW-CARBON ECONOMY

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Sustainable Prosperity is a national research and policy network, based at the University of Ottawa. SP focuses on market-based approaches to build a stronger, greener, more competitive economy. It brings together business, policy and academic leaders to help innovative ideas inform policy development.

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Gauging the Role of Energy Substitution in Transitioning to Low-Carbon Economies

Changing our energy sources is fundamental in moving towards a low-carbon economy. Changes in the prices of different energy sources are one reason we substitute away from one source in favour of another. Recent analysis focuses on how the choice of energy inputs responds to change in relative prices using an unconventional approach in which simulated future data is used instead of historical data in order to gauge energy price responsiveness. This note draws on insights from this research[1] on responsiveness to price changes, insights that can inform policy and guide a smoother transition to a low-carbon economy.

Research Question

The responsiveness of consumers and producers to changes in energy prices is a key consideration of policy makers in assessing the ability of price-related policies to encourage different forms of energy use.

Substitution among productive inputs (components that firms use to create goods and services) plays an important role in understanding the costs of climate change policy, since substitution possibilities underlie resilience and adaptability to changes in an economy.[2] Assumptions about substitution between forms of energy and other inputs have a large influence on the results of economic models used to study costs. Rigidity in a model tends to magnify economic costs, whereas flexibility tends to reduce them.[3] In terms of substitution, producers and consumers can substitute, for example, carbon-intensive fuels for less carbon-intensive fuels and energy inputs for non-energy inputs (for example more energy-efficient equipment such as an electric vehicle.)

1 Described in an accompanying Research Report titled, "Substitution in Energy-Economy Models: Using a Hybrid Simulation Model to Estimate U.S. Energy Elasticities" by Adam Baylin-Stern. The report is available on the Sustainable Prosperity website at: www.sustainableprosperity.ca. The original Master's research is available at the following address: http://summit.sfu.ca/system/files/iritems1/12282.

2 Jorgenson, D., Goettle, R., Wilcoxen, P., & Ho, M. (2000). The Role of Substitution in Understanding the Costs of Climate Change Policy. *Pew Center Report.*

3 Flexibility versus rigidity in a given model tends to reflect the level of technological detail, behavioural realism, and level of macro-economic realism. Such model attributes have an impact on a model's forecast in terms of the resilience and adaptability of an economy.

Given the importance of substitution responses in greening an economy, there is substantial literature and quantitative analysis on the subject. Quantitative analysis on the subject is not in agreement, and accordingly, there is a continued need to assess the substitutability of economic inputs. It is not clear how best to quantify and estimate such a measure. What are the benefits of the unconventional approach using future data described in this report, and what are the impacts on estimates of substitution responsiveness?

Economic measures of substitutability normally take the form of the *elasticity of substitution*[4]—the change in demand for one input that comes about with a 1 percent change in the relative price of another input (or alternatively, for the same input if looking at how demand for something changes in response to changes in its own price).

Methods

Elasticity of substitution values are normally estimated by analyzing historical data. While this is the only real data that we have (looking forward, there is no counterfactual[5]), some have chosen to use forecasted 'pseudo-data' generated from simulation models to gauge responsiveness of inputs to price changes.

Historical data may not carry enough information to accurately portray *future* substitution potential. The future—with different technologies and fuels—may differ from the past in terms of price responses. Relying solely on revealed preferences from past markets is dubious when we know that market options are changing. Moreover, there are notable issues with past data, which (1) can be confounded by short-term economic shocks (which are difficult to filter out); (2) may not contain sufficient price variability to gauge responsiveness with statistical significance; and (3) lacks empirical evidence concerning our behaviour when faced with emission reduction issues. Basing our estimates of substitutability on forecasts can help to overcome these issues. Nevertheless, 'pseudo-data' is not without its drawbacks—notably, that response estimates originating from simulated data is dependent on the quality of the simulation model output.

By 'shocking' an energy-economy simulation model with a wide range of energy and capital prices, and observing the resulting shifts in use of individual energy inputs and capital, it is possible to gauge the responsiveness of productive inputs to shifts in the input prices. From the resulting model output—the set of 'pseudo data'—one can use the same econometric techniques that researchers typically apply to past data to estimate elasticity of substitution values. The resulting elasticity estimates incorporate modern technology options that are not present in time-series or cross-sectional historical data.

4 The concept of elasticity of substitution was first introduced by Hicks in 1932, and further developed by Allen: Hicks, J. (1932). Theory of Wages. London: Macmillan; Allen, R. (1938). Mathematical Analysis for Economics. London: Macmillan.

5 The counterfactual is an alternative to the real outcome. Looking forward, we do not know with certainty what would have happened in alternate future scenarios.

Such a 'pseudo-data' methodology was first applied by Griffin.[6] Others have since used similar methods: Bataille[7] used a Canadian application of the CIMS simulation model (a technologically detailed and behaviourally realistic energy-economy model), while SP Research Associate Adam Baylin-Stern's accompanying Research Report is based on a U.S. version of the CIMS model.[8] Recognizing the benefits of such a methodology, the CIMS-US model was also recently used for elasticity estimation to improve the representation of technological detail in the U.S.-based Electrical Power Research Institute's macro-economic model US-REGEN.[9]

Results and Findings

The research revealed interesting results about energy substitutability in the U.S., the model used to generate the forecasts, and the methodology used to elicit the elasticities of substitution:

- The results indicated by and large, that for a given level of production there is greater potential for substitution between different kinds of energy than there is for improvements in energy efficiency (indicated by measures of substitution between energy and capital across the U.S. economy).
- The findings highlight the importance of not over-relying on one particularly popular way to achieve GHG reductions. While the research using CIMS-US found modest potential for energy-efficiency changes as a response to varied energy costs, many estimates of its potential in transitioning to a low-carbon economy overstate the capacity for emissions reductions from efficiency improvements. Such analysis often ignores potential rebound effects. When investing in a higher efficiency television, one might purchase a larger television, offsetting some of the efficiency gain. Similarly, a consumer or firm might use cost savings from energy efficiency improvements to acquire additional goods or services that in themselves use energy (a "rebound"). Elasticity values representing a complementary relationship between energy and capital suggest a greater influence of rebound effects upon shifts to more energy-efficient capital.
- The results showed a variety of deviations from previous, historically based estimates.
- Using "pseudo-data" about the future may be a superior way to gauge the price responsiveness of different sectors of the economy to changes in the input prices that they face compared with the standard practice of using historical time-series data. This is because (1) certain technological possibilities that are not reflected by past data (e.g. the electric car) are present in forecasts and (2) it is difficult to separate economic shocks such as disruptions to fuel supply from the historical data source.

6 Griffin, J. (1977). The Econometrics of Joint Production: Another Approach. *The Review of Economics and Statistics* , 59 (4), 389-397;

7 Bataille, C. (2005). Application of a Technologically Explicit Hybrid Energy-Economy Policy Model with Micro and Macro Economic Dynamics (Vol. PhD Dissertation). Vancouver: Simon Fraser University.

8 Jaccard, M., Nyboer, J., Bataille, C., & Sadownik, B. (2003). Modeling the Cost of Climate Policy: Distinguishing between Alternative Cost Definitions and Long-Run Cost Dynamics. *The Energy Journal , 24* (1), 49-73.

9 PRISM 2.0: Estimating Energy Substitution Parameters for the U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) Model. EPRI, Palo Alto, CA: 2013. 1026862. [http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001026862]

A lot of uncertainty remains concerning measures of substitution response, and the benefits of simulated data are still subject to debate. Moreover, many economists augment their econometric estimations of elasticities with subjective adjustments, or by placing constraints on the values that result from econometric estimation. It is important to work to overcome the notable lack of consensus over estimates of price response.

Policy Linkages

There is a widely recognized need to transition to a drastically lower-carbon economy to minimize climate change. Better understanding the role and potential for energy substitution can help with the design of policies that encourage prosperous and equitable low-carbon economies.

Energy substitution is critical if we are to reduce greenhouse gas emissions and promote clean energy. Many of the best policy options available to encourage this energy shift—such as carbon taxes or trading regimes for emitting sources and subsidies or tax breaks for cleaner sources—are polices that rely on changing the relative prices of different forms of energy. Studies such as this modelling experiment are useful in improving our understanding of the likely magnitude and direction of energy substitution driven by policies like these.

The Sustainable Prosperity Research Report underlying this Research Note titled, "Substitution in Energy-Economy Models: Using a Hybrid Simulation Model to Estimate U.S. Energy Elasticities" includes select results from the above-mentioned energy-economy modeling study of price-responsiveness. The report is available on the Sustainable Prosperity website at: www.sustainableprosperity.ca.

The full text of Research Associate Adam Baylin-Stern's Master's thesis is available at: http://summit.sfu.ca/item/12282/etd7215_ABaylin-Stern.pdf