Welfare Gains and Distributional Dynamics: A “Carbon Charge” in New York State

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Structural Estimation 2019-1

Large-scale policies encouraging investment in renewable resources have become quite common

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France Will Save Billions By Investing in Renewables Instead of Nukes

December 12, 2018

By Bloomberg News Editors

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New York will invest $1.5 billion in renewable energy projects

REUTERS   Business   Markets   World   Politics   TV   More

GREEN BUSINESS NEWS   NOVEMBER 25, 2011 / 10:52 AM / 7 YEARS AGO

Denmark aims for 100 percent renewable energy in 2050

Mette Fraende   4 MIN READ

COPENHAGEN (Reuters) - Danish government proposals on Friday called for sourcing just over half of its electricity from wind turbines by 2020 and all of its energy from renewable sources in 2050.

[Union of Concerned Scientists

FACT SHEET

California's Renewables Portfolio Standard (RPS) Program

California's Renewables Portfolio Standard (RPS) has positioned the state as a global leader in renewable energy and helped attract billions of investment dollars to industries that have directly or indirectly supported the development of new generation sources. This clean, safe, and homegrown electricity has helped California reduce harmful air pollution and global

[*The RPS is a market-based policy requiring utilities to deliver 33 percent of their retail electricity from clean, renewable sources by 2020.*]

New York State should consider a welfare evaluation to decide on its “Carbon Charge”

- Should New York State implement a carbon tax now in its wholesale electricity markets based on a social- welfare evaluation?
- What are their distributional impacts? (i.e. who benefits more or bears a higher share of the cost?)
- Lever: Simulation model estimated using SMM. Uses data from the New York market.

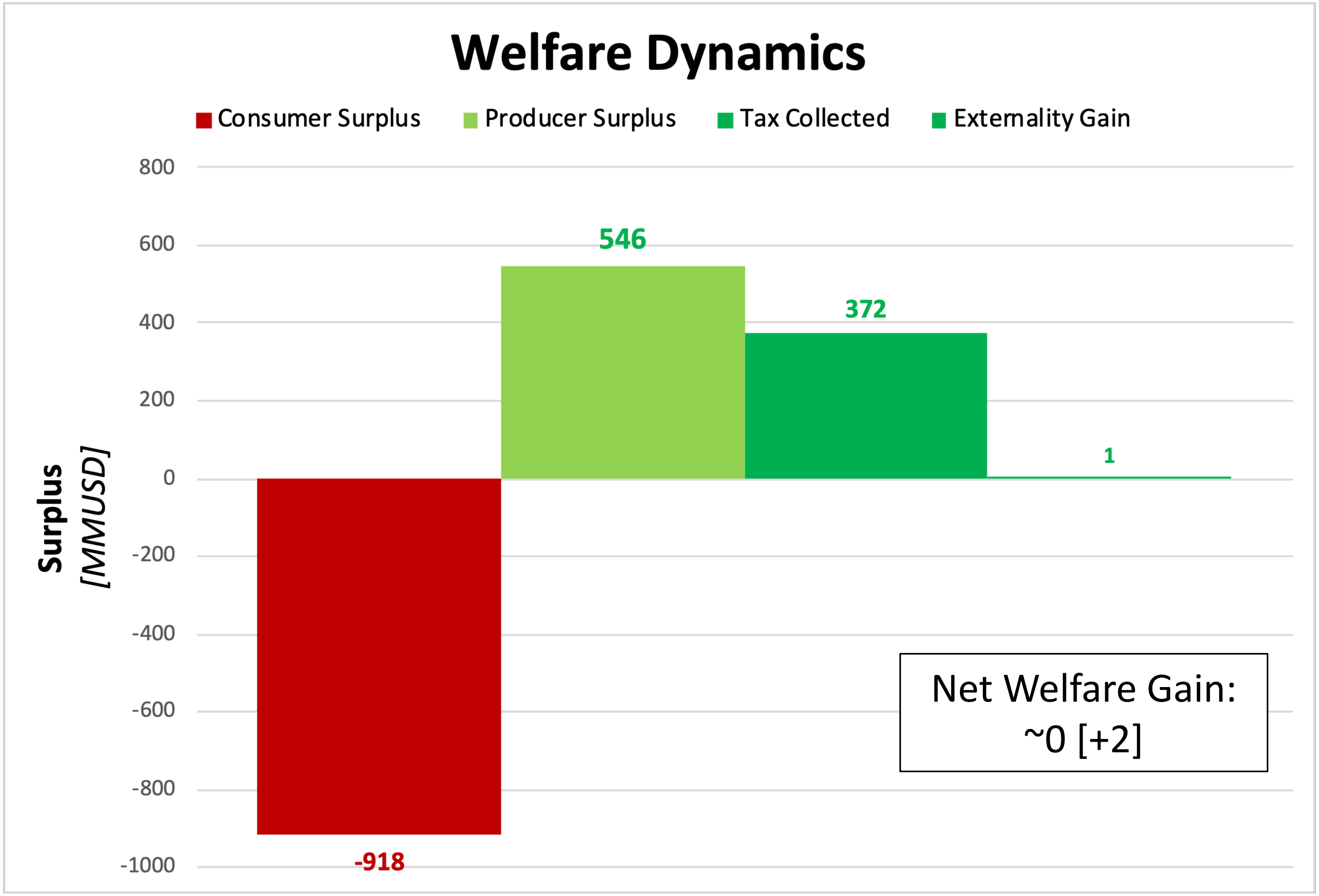
The distributional impacts of a carbon tax would be significant

Results:

- Carbon taxes can be beneficial. However, consumers may suffer, and producers may capture most of the welfare gains.

	Base Case	***Carbon Charge***	
Electricity Cost	35.99	54.58	*[$/MWh]*
Producer Surplus	1034	1581	*[MMUSD]*
Wind	45	68	
Nuclear	479	726	
Hydro	306	463	
Gas	205	323	
Consumer Expenditures	1777	2694	*[MMUSD]*
Tax Collected		372	*[MMUSD]*
Emissions	10366	10345	*[000 ton CO2]*
Externality Cost	0	0	*[MMUSD]*

Welfare gains are not evenly distributed



Analytical framework: the model

- Partial equilibrium with three demand sectors: residential, commercial and industrial.

Demand: $q_{sth} = \alpha_{sth} - \gamma_{sth}\, p_{sth}$ *[level – price response]*

Imports: $m_{th} = \alpha^{m}_{th} + \rho_{th}\ (p^{w}_{th} - e^{m}\tau)$ *[level – price response]*

Generation:

$$g_{ith} = \begin{cases} 0, & \text{if } p^{w}_{th} < mc_i(g_{ith}) \\ [0, K_i], & \text{if } p^{w}_{th} = mc_i(g_{ith}) \\ K_i, & \text{else,} \end{cases}$$

[Thermal]

$r_{jth} \leq \lambda_{jth} K_j$ *[Renewable]*

$h_{th} = \overline{h}_{th}$ *[Hydro, nuclear]*

Estimation Model

- Characterizing Equations

$$(i)\ Load_t - Power_t = 0$$

$$(ii)\ Power_t - \sum_{i=1}^{T} gen_i\, cap_i = 0$$

$$(iii)\ Price_t = c_{source,t} * gen_{T,\text{“}marginal\text{”}} * h_{heat\ rate}$$

$$(iv) gen_{i\ cost,\ t} - gen_i h_i c_{source,\ t} = 0$$

$$(v) c_{source,\ t} = \rho c_{source,\ t-1} + (1-\rho)\mu + \varepsilon$$
$$\varepsilon \sim N(0, \sigma)$$

- Variables:
  - Load (exogenous)
  - Price (endogenous)
  - Emissions (end.)
  - Cost of primary energy source (estimated), *c*
- Variables (*):
  - Generator, *gen*
  - Installed capacity, *cap*
  - Heat rate (i.e. efficiency), *h*
  - Emissions rate
- Parameters to be estimated
  - $\boldsymbol{\sigma}$
  - $\boldsymbol{\rho}$
  - $\boldsymbol{\mu}$

Moments considered

$$(\boldsymbol{i})\ \frac{\sum_{t=1} price_t}{t_{max}}$$

$$(ii)\ var\left(\frac{price_t}{load_t}\right)$$

$$(iii)\ corr(price_t, Load_t)$$

$$(iv) corr(price_t, price_{t+1})$$

Minimizing criteria

$$\hat{\theta}_{SMM} = \theta : \quad \min_{\theta} \ ||\hat{m}(\tilde{x}|\theta) - m(x)||$$

Parameter Vector

$$e(\tilde{x}, x|\theta) \equiv \frac{\hat{m}(\tilde{x}|\theta) - m(x)}{m(x)}$$

Error function (*defined as percentage*)

$$\hat{\theta}_{SMM} = \theta : \quad \min_{\theta} \ e(\tilde{x}, x|\theta)^T \, W \, e(\tilde{x}, x|\theta)$$

SMM Estimator

Estimation Results

- Estimated parameters:
  - $\boldsymbol{\rho}$: 0.56
  - $\boldsymbol{\mu}$: 3.87
  - $\boldsymbol{\sigma}$: 1.34
- Vector of Differences:
  - [0.18 -0.12 -0.35 -0.0015]
- Standard Errors of Parameter Vector
  - [0.00018, 0.00335, 0.00043]
- Number of Simulations, number of periods
  - 1200, ~3000

Assumptions

- Natural Gas-fired plants, wind, hydro and nuclear plants combined provide the entirety of the power demanded (~95% in 2017)
- Imports and exports remain at the level they were in the actual market run
- Adjusted capacity for thermal units to average summer derating factor
- Modified wind capacity to attain a constant output that resulted in the same capacity factor as in 2017
- Hydro and Nuclear units will have a constant output (NG will usually be on the margin, consistent with data)

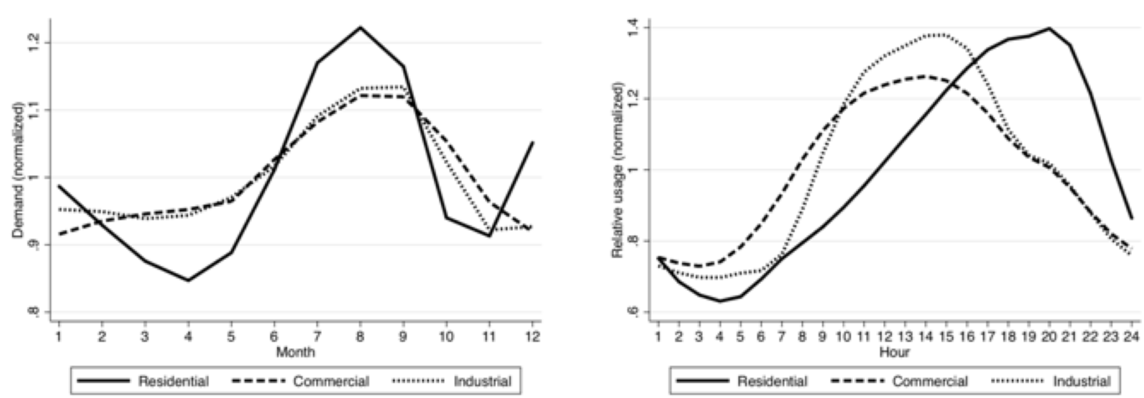
Improvements

- Demand can also be modeled as elastic
  - Consistent with literature, an elasticity of -0.2 could be assumed
  - Different sectors on the demand side consume electricity differently

Table 2: Demand elasticities and shares by customer class

Sector	Elasticity	Share
Residential	-0.15	0.41%
Commercial	-0.30	0.45%
Industrial	-0.50	0.14%

Figure 1: Consumption patterns across customer classes



(a) Electricity consumption across sectors over the year (b) Electricity consumption across sectors in the winter

Data

Generation facilities participating in NYS wholesale energy markets (~500) [NYISO]

Load Historic and Forecast: Seasonal Peak load and total consumption (2019 – 2030) [NYISO] ****First simulation only leveraged 2017 data*

Historic Load: Down to 5-minute granularity, 10 years [NYISO]

Social Cost of Carbon [Interagency Working Group on Social Cost of Greenhouse Gases]

eGRID: Plant level and State level emissions data [EPA, 2016]

Plant level efficiency/heat-rates [EPA, 2016]