Carbon price pass through in electricity with known prices

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Carbon Pricing, Electricity Markets and Output-Based Allocations

- Impacts of carbon pricing has become a central policy question in Canada and globally
- Electricity markets, at least in certain jurisdictions are ideal environments in which to study responses to carbon prices
- Rich, hourly electricity market data allows us to observe firm-level decisions with respect to carbon price pass through
- Fabra and Reguant (2014) shows how firms respond to emissions credit prices and that lump-sum credit allocations were not distortionary in the short run
- Alberta policy changes alter both carbon prices and output-based credit allocations
- Brown et al. (2018) have looked at the dynamics of such a market in a simplified, simulation model

Alberta's Power Market is an Ideal Laboratory

Alberta's power market:

- Alberta's power market is relatively small, isolated, and features a mix of generation technologies
- Our peak internal load for 2018 was 11,697 MW, while our lowest observed internal load was 7,819 MW
- We have relatively minimal intertie capacity. Alberta is connected to WECC (1325 MW export and 1500 MW import path-rating) via Montana and BC) and to Saskatchewan (150 MW path-rating) but significant hourly variability in capacity which helps us with identification
- Supply mix (2018) was 44.8% coal, 21.1% net-to-grid from combined heat and power plants, 18.5% natural gas, 2.9% hydro, 6.4% wind, 1.0% other sources including solar and 5.2% imports.

Alberta's Policy Changes as Treatments

Alberta's GHG policy changes:

- From 2007 to 2015, Alberta's *Specified Gas Emitters Regulation* imposed a carbon price of $15 per tonne with output-based allocations at a rate of 88% of a facility's historic emissions intensity if the facility's annual emissions were more than 100,000 tonnes per year
- In 2015, these parameters were changed to $20 per tonne with allocations equal to 85% of historic emissions intensities in 2016 and $30 per tonne with allocations of 80% in 2017.
- 2007-2017 system also had generous emissions credits for combined heat and power systems
- In 2018, the system changed again, to one with output-based allocations fixed for all generators (0.37t/MWh) including for net generation from combined heat and power.

Data Richness

We have data on:

- Hourly merit order (power offers) by unit with data on who held offer control for that unit at that time
- Hourly forecast and actual loads and prices
- Hourly weather for Edmonton, Calgary, and Fort McMurray
- Hourly imports, exports, and intertie capabilities
- Hourly wind forecasts including 3 and 7 day advanced forecasts.
- Plant-level emissions intensities and historic allocation rates under *SGER*

Carbon pricing impacts on power markets

Our results show that:

- ...

Carbon Pricing Policy and Power Generation Sources

Carbon Intensity of Alberta Power

Carbon pricing policy impacts on the merit order

Within-group, plant-level impacts of policies

Empirical Framework

- The goal of our empirical framework is to estimate the degree to which carbon prices pass through to merit order behaviour and thus to electricity prices
- We follow Fabra and Reguant (2014) which estimates:

$$\begin{aligned}\underbrace{p_{th}}_{\substack{\text{Cost}\\\text{pass-through}}} &= \underbrace{\rho\tau_t e_{th}}_{\substack{\text{Effect of GHG}\\\text{price times rate}}} + \underbrace{\beta_0 X_{th} + \beta_1 X_{th}^D + \beta + 2X_{th}^S}_{\substack{\text{Supply, demand and common}\\\text{factor adjustments}}}\\ &+ \underbrace{B_3 I_{th}}_{\substack{\text{Fixed}\\\text{effects}}} + \underbrace{\epsilon_{th}}_{\substack{\text{Error}\\\text{term}}}\end{aligned}$$

- Alberta policy changes alter both carbon prices and output-based credit allocations over time, which changes the empirical specifications in our case slightly
- We have hourly forecast prices and loads (3 hour leads) which we can use as supply and demand indicators
- We also have both forecast and actual temperature and wind

Empirical Framework

- Like Fabra and Reguant, we also have hourly bids by plant for up to 7 blocks - an individual supply function - which we can then use to estimate firm-level residual demand for the marginal producer

$$
\begin{aligned}
\underbrace{b_{ijth}}_{\substack{\text{Marginal bid of firm } i \\ \text{unit } j\text{, time } th}} &= \underbrace{\gamma \tau_t e_j}_{\substack{\text{Effect of GHG} \\ \text{price times rate}}} + \underbrace{\beta c_{jt}}_{\substack{\text{Marginal cost} \\ \text{estimates}}} \\
&+ \underbrace{\theta \hat{m}_{ijth}}_{\substack{\text{Approximate} \\ \text{markup}}} + \underbrace{\epsilon_{ijth}}_{\substack{\text{Error} \\ \text{term}}}
\end{aligned}
$$

- in our case, emissions prices vary over time as do allocation rates, so we need to modify both structures

Results

Discussion

Secanell group

- Design, procurement and installation of low and high temperature electrolysis fabrication and testing facilities
- Fabrication of single-cell low temperature electrolyzer prototypes using iridium and iridium oxide catalysts
- Demonstrated, for the first time, the use of inkjet printing as a feasible technology to fabricate low temperature electrolyzer cells (https://doi.org/10.1149/2.1101807jes)
- Development of a novel nano-pompon-like iridium catalyst superstructure for low temperature fuel cell electrolyzers (https://doi.org/10.1016/j.jcat.2019.01.018)
- Development of a novel technique for characterization of iridium catalyst degradation (https://doi.org/10.1016/j.jcat.2019.01.018)
- Development of novel micro-structures for high temperature solid oxide electrolyzers and fuel cells (https://doi.org/10.1016/j.electacta.2018.02.055)

The project currently involves 5 PhD students and 1 MSc, 5 faculty (1 in MECE, 3 in CHEME and 1 in Chem). We are also collaborating with Ionomr, a firm in BC (https://ionomr.com/).

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