Power Trade, Welfare, and Air Quality

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Overview

In this paper we study electricity trade between the Ontario wholesale electricity market and other national and international jurisdictions incorporating New York, Michigan, Minnesota, Manitoba and Quebec wholesale electricity markets. The Ontario market has several unique features relative to the other electricity markets (in terms of volatility and trade volumes), and we have detailed firm and market level data that are suitable to study environmental and welfare issues related to electricity trade. The Ontario market has significant interconnections with large regulated (Manitoba and Quebec) and liberalized (New York, Michigan, Minnesota) markets by the transmission grid over which the electricity trade occurs. The Ontario market has very volatile prices (the most volatile relative to the other restructured markets in the neighborhood) and relies on trade activities to clear its real-time market in its 5-minute wholesale electricity auctions. The main goal of electricity traders (generation firms and merchant firms) is to benefit from price differentials within the interconnected markets. The available trade capacity, which essentially poses a trade barrier, between Ontario and its neighboring jurisdictions is often 4,000 MW which is almost one-sixth of the total available production capacity, and is capable of satisfying almost two-ninths of the average electricity demand in Ontario. The market value of wholesale electricity sales (revenue for producers) in Ontario is \$7.9b, \$8.3b and \$8.8b through 2006-2008, resp. The value of the trade (value of imports and exports combined) is nearly \$0.8b, \$1b, and \$1.7b, and the imports meet 3.8%, 4.3%, and 6.5% of the market demand in the same period. As we show in this paper, even if the trade quantities were small they could make a sizable contribution to the market outcomes and environment by avoiding price spikes and abating air pollution.

Methods

Our first goal is to model competition and then examine how trade changes equilibrium market outcomes and emission levels in the Ontario market. We calibrate a capacity constrained Cournot model using hourly changing market parameters such as available production capacities of generators, costs, and demand. We examine the effects of trade activities on major air pollutants such as SO2 and NOx gases which affect regional air quality and are responsible for acid rain and smog. We also report the effect of trade on CO2 emissions. In particular, we quantify changes in market prices, firm outputs and emissions as the actual and counterfactual trade scenarios unfold. We also measure hourly and aggregate changes in total surplus (consumer and producer surplus) as these trade scenarios materialize. We study two counterfactual scenarios; the first one is referring to zero imports or exports and the second one is dealing with doubling their observed values. These scenarios aim to illustrate the effects of reduced or increased trade activity. Zero import or export scenario mimics the autarky market setting. Doubling imports or exports is an interesting and feasible scenario in the Ontario market setting, signifying higher trade volumes. Indeed, we observe significant changes in trading activities over time. For example, there has been a steady increase in maximum hourly export levels which have doubled over the 2002-2011 period. This has been accompanied with significant investments in transmissions between Ontario and the neighboring jurisdictions allowing for large trade volumes.

Results

We show that our competition model has a high predictive power. For instance, in March 2008 we find that the hourly mean absolute error between our price estimations and the actual realizations is \$2.48. It is \$14.99 between the auctioneer's (The Independent Electricity System Operator, IESO) price estimations and the realizations. In terms of the mean absolute errors (MAE), the model price predictions are on average 3.5 times better than the IESO predictions in a year. Also our price predictions are close to the actual market prices and the model replicates the hourly equilibrium prices with 94.4% accuracy.

We measure; a) greenhouse gas emissions along with other gases offset in Ontario due to the trade between the Ontario market and its neighbors; and b) the impact of trade (imports and exports) on the market dynamics and the total surplus in Ontario. We find that when the imports double from the current levels, the NOx emissions reduce around 14%, and the market prices decrease 5.4% in Ontario. Furthermore, in autarky situation in which the Ontario market participants would not import from any neighboring markets, CO2, SO2, and NOx emissions would increase by 12%, 22%, 16%, resp. The Ontario market price would increase 5.8%, and price volatility (standard deviation) would increase 12%. The welfare gain (change in consumers and producers surplus) from electricity trade increases by 50% as a result of trade compared to autarky (that is, when there is no imports). The same efficiency gain also applies when imports double from its current existing levels. This welfare gain incorporates the social cost of NOx and SO2 air pollution as firms internalize the permit prices of these pollutants in their cost calculations. We also compute the welfare loss when market prices are negative and find that the loss is very small during the study period. The negative prices are frequently observed since 2008 with significant magnitudes, which pose concerns for the market observers and participants. For example, from 2008 to 2013 the negative prices have occurred more than 1100 hours with some three digit values (the lowest one was -138.8$/MWh). However, in these hours one would expect significant welfare losses.

We also calculate the dead-weight loss (DWL) in the existing market structure with respect to the efficient allocation for each hour from April 2007 to March 2008 in the Ontario wholesale market. We sum up the hourly DWL to find the total welfare loss (change in consumer plus producer surpluses) in the market in a year. We find that the total deadweight loss in the year is almost $342 million, and this represents only 4.2 percent of the total wholesale energy cost ($8.2 billion for the year) in the wholesale market, and suggests that the imperfect competitive nature of the Ontario market could be tolerable.

Conclusions

Our findings have some implications on the recent Renewable Energy Laws implemented by many states and countries. In connection with the current phenomenon of green energy investments such as wind power generation, for example, Kaffine et al. (2013) find in an econometric estimation that emission savings from wind power in Texas (ERCOT) are 1.3 lbs for SO2, 0.79 lbs for NOx, and 0.52 tons for CO2 per MWh wind generation. Our emission savings in Ontario due to trade have the similar impact as in Texas. Governments give large subsidies to the green energy producers including wind and solar generators. These subsidies are often suboptimal and inefficient, and distort the market outcomes as they are determined by regulatory agencies. However, we argue that trade activities could be used as an alternative mechanism and be fostered via transmission investments to abate air emissions. Furthermore, trade brings about efficiency because imports and exports are priced in the (wholesale) market.

Although our predictions for the market and firm levels are close to the realizations and are better than the system operator's predictions, we observe some differences at the generators level, which can naturally be expected. The main difference in production stems from the allocation of hydro resources, which ultimately affects the distribution of outputs from coal plants and other generation sources. This difference is not a surprising result as the actual productions are affected by the network constraints, interconnection capacities, generation specific constraints (ramp-up and ramp-down rates, start-up and shut down costs), dynamic considerations in power generation process (especially in hydropower reservoir management), and uncertainties in demand and supply sides, which have been ignored in the model. In the model we also made a number of simplifying assumptions such as smoothed cost curves and linear demand. All these factors can explain the minor differences between the actual and model outcomes.

Although we show how emissions vary with respect to change in import/export levels, a natural question arises with respect to the emission savings from trade: do we really expect emissions reduction in the region? The answer would be "yes". First, Ontario heavily imports from hydro-based Quebec and Manitoba markets. For example, during 2002-2008 Ontario's imports from Quebec have increased on average 18% per year. Second, there is no cap and trade program in Ontario and power producers only need to purchase government issued permits to be able to produce from fossil-fuel-fired generators. The absence of this program can cause reductions in emissions. Third, it is not only Ontario that benefits from trade but also other big markets such as New York and Michigan who heavily import from the neighboring hydro-based Canadian markets to reduce their costs and abate the air pollution. Fourth, trade is also beneficial for Quebec and Manitoba markets such that during their off-peak periods they import low cost and clean base-load production (such as nuclear and wind) from Ontario, New York, and Michigan markets (each has more than 25% nuclear generation in their production portfolios) so as to sell their valuable hydro generation to these markets during peak times. Consequently, power trade could give rise to economical and environmentally friendly transactions in the region.