Energy Economics 67 (2017) 423–438

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Power trade, welfare, and air quality☆

Talat S. Genc [a,*], Abdurrahman Aydemir [b]

[a] Department of Economics, University of Guelph, Guelph N1G2W1, ON, Canada
[b] College of Arts and Social Sciences, Sabanci University, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 12 February 2016
Received in revised form 6 May 2017
Accepted 15 August 2017
Available online 25 August 2017

JEL classification:
F18
L13
L94

Keywords:
Electricity trade
Interconnected markets
Imperfect competition
Air emissions
Welfare
Microdata

ABSTRACT

We use detailed microdata from all generators in the Ontario wholesale electricity market to investigate cross-border electricity trade and its impact on air emissions and welfare (consumer and producer surpluses) in Ontario. Using the technical characteristics of the generators and financial data we run a competition model every hour. We examine how trade expansion across different parts of the interconnected power grid affects the efficiency in the Ontario market. We show that there is a significant welfare gain from power trade. The air emissions savings are also considerable. For instance, when hourly imports double from current levels CO_2 emissions decrease around 13%, and market prices reduce 5.4%. In autarky, CO_2, SO_2, NOx emissions increase 12%, 22%, 16%, resp., the prices go up 5.8%, and the price volatility rises 12%. However, the impact of negative wholesale prices on market outcomes is small.

1. Introduction

While restructuring of the electricity industries has been evolving in many countries, cross-border electricity trade over interconnections has been growing, and it becomes an interesting issue to investigate. There is a significant electricity trade among the Canadian provinces, as well as, cross-border trade between Canadian provinces and the US. For example, Canada, a net exporter of electricity to the US, exported 51,108 GWh electricity and imported 17,490 GWh power from the US in 2009.[1] International electricity trade among the European countries has also increased significantly over the years. Despite the growing importance of electricity trade across jurisdictions the implications of trade on market outcomes has not been well studied. This paper examines how electricity trade, between Ontario and a pair of regions in Canada and the US, impacts market prices, electricity consumption, air quality and total surplus in Ontario.

A number of papers have examined various issues in the restructured electricity markets including Green and Newbery (1992), Von der Fehr and Harbord (1993), Borenstein et al. (2000), Joskow and Kahn (2002), Hortacsu and Puller (2008), Holland and Mansur (2008), Bushnell et al. (2014), Genc (2009), Genc and Reynolds (2011), Fowlie et al. (2012). These papers cover market power analysis, optimal bidding behavior, transmission investments, forward contracting, the role of auction institutions on the market outcomes, the effects of environmental regulations, the impact of market structure on welfare, and the environmental issues stemming from power generation. In this literature, electricity trade analysis and the impact of electricity trade in a market framework has not been addressed. In a recent paper, Mansur and White (2012) focus on market performance of two different electricity market designs. They provide evidence that auction-based wholesale market design (in the PJM Interconnection in 2004) improves economic efficiency relative to the bilateral trading system.

Electricity has unique features relative to other tradable goods that make power markets an interesting case to study. Once generated electricity is almost non-storable in a large scale, it needs continuous matching of demand and supply, and the wholesale electricity price can be negative due to network constraints and imbalances between supply and demand. Moreover, unlike other tradable goods electricity transfers are continuous and simultaneous called wheeling through transactions: in almost all trading hours a market can both import and

☆ We thank the editor, anonymous referees, and Ross Baldick, Mike Hoy, Rene Kirkegaard, Steve Kosempel, Esra D. Kaygusuz, and the seminar participants at the Independent Electricity System Operator (IESO), the Fields Institute, Guelph, SUNY-Buffalo, Sabanci, ITU Energy Institute, INFORMS Conference, and IAEE International Conference for valuable comments.

* Corresponding author.
E-mail addresses: tgenc@uoguelph.ca (T.S. Genc), aaydemir@su.edu.tr (A. Aydemir).

[1] National Energy Board—http://www.neb.gc.ca/clfnsi/rnrgynfmtn/sttstc/lctrctyxprtmprt/lctrctyxprtmprt-eng.html.

https://doi.org/10.1016/j.eneco.2017.08.014
0140-9883/

export energy between jurisdictions. The reasons for simultaneous exports and imports are related to the expectations in price differentials between the interconnected markets, and uncertainties in demand (e.g., temperature related) and supply conditions (e.g., unscheduled generator failures).

Electricity trade can impact generation behavior of power producers, and the mixture of power portfolios that firms hold and invest. Trade can also cause substitution of fuel resources across markets as the most polluting technologies are usually the most expensive technologies (e.g., oil and gas).[2] Thus, electricity trade not only has implications for prices, consumption and total surplus but also for emission levels. Although electricity trade across jurisdictions has been expanding the extent to which it affects prices and total surplus (welfare) has not been estimated. Similarly, the impact of electricity trade on emissions in a given market is unknown. This paper contributes to the literature by investigating how electricity trade affects the market dynamics and the air quality in a given economy. Our paper is related to the papers by Borenstein et al. (2000) and Wolak (2012), who examine competitiveness benefits of transmission expansions and demonstrate that transmission congestion softens the competition and transmission expansion (or perception of uncongested transmission) enhances the amount of competition (see also Mansur and White, 2012). Similar to their findings, we also show how increased trade activities facilitated by transmission expansion would lead to lower market prices.

Electricity generation is the most air polluting industry (in terms of greenhouse gas emissions, GHG) in many parts of the world and is associated with climate change. The key air pollutants relevant to the electricity industry are carbon dioxide (CO_2), sulfur dioxide (SO_2) and the nitrogen oxides (NOx). These pollutants, which affect public health and the environment, are monitored by the environmental policy agencies. The impact of electricity trade on emissions has policy implications on meeting environmental targets and investing in transmission network. Several environmental protocols (like Kyoto, Copenhagen) and Renewable Energy Laws (also known as Green Energy Acts) have aimed to abate air pollution. We argue that electricity trade could serve to the same purpose and alleviate the emissions. A market that heavily depends on dirty production technologies could import cheap and clean energy from a neighboring jurisdiction using cleaner technology and reduce its emissions (e.g., the New York market imports clean and cheap hydroelectric energy from the Quebec market). There are a few studies in the literature addressing the impact of merchandise trade on environmental pollution (Antweiler et al., 2001; Cole, 2004; Grether and De Melo, 2004; Frankel and Rose, 2005; Levinson, 2009; Peters et al., 2011). However, this paper contributes to the growing literature by focusing on trade where exports and imports of the same product (electricity) is simultaneous and by quantifying their impact on air pollution in a given economy.[3] The paper also discusses the impact of different production technologies causing pollution.

In this paper we study electricity trade between the Ontario wholesale electricity market and other 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 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-min wholesale electricity auctions.[4] 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 about 4000 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.

We focus on a region (Ontario) and examine its trade implications in its market. We do not track how electricity trade impacts other regions because of several reasons. First, the other markets have different market structures than Ontario. Some (Manitoba and Quebec) are still regulated. The restructured ones (New York, Michigan, Minnesota) have different market rules and price clearing mechanisms (some use uniform pricing, others use discriminatory pricing) than Ontario, and do not release actual production and available capacity data, which are required in actual welfare and emissions calculations and model predictions for various trade scenarios. Furthermore, to examine impact of imports on emissions levels in all markets that are interconnected, one needs to have very detailed generator level data incorporating their technical characteristics, marginal cost functions, and market level data including demand functions, and generators' actual outputs, among others, in every market. This sort of data is not available for the region interconnecting Ontario, Manitoba, Quebec, New York, Minnesota, and Michigan wholesale electricity markets. Even if someone could obtain such novel data encompassing this region, for example, Michigan, or New York, or Quebec is also separately linked and trading with their neighboring electricity markets other than the above mentioned markets. Therefore, a number of markets that are interconnected through the networks (will incorporate almost all markets in Canada, the USA, and Mexico) will increase, and hence, e.g., the net emission impact of New York's export to, say Ontario, will not be tractable at all. In terms of emissions the paper focuses on gases such as NOx and SO_2 that are known to have primarily local effects, as well as CO_2 which has a global impact. Our main contribution is that this paper quantifies the impact of imports and exports on market prices, total market (consumers and producers) surplus, generation behavior, and air emissions levels, which all have policy implications in transmission investments and meeting national and international emissions targets.

Among the 563 generators in the Ontario market there are many small generators which are owned by independent firms and are treated as fringe players who are price-takers. There are a few large firms whose installed capacities are above 1000 MW, and we assume they are dominant firms and are able to exercise market power. Therefore, we employ dominant firms with competitive fringe model in which firms decide what portion of their available capacities to be offered to the market for a given hour. All power generators including the fringe

[2] Coal is exception as it is relatively cheaper and highly dirtier technology in Ontario. However, due to the environmental protocols, the Green Energy Acts and public pressure, there is an aversion to coal plants and many countries aim to either phase out all of their coal generators or partially substitute them with natural gas and/or green technologies. Ontario has shut down its coal-fired generation units in late 2015.

[3] Related to air pollutants, Amor et al. (2011) calculate CO_2 emission savings from electricity trade between hydropower based Quebec and the adjacent markets using exports and imports data. They heuristically identify the marginal electricity production technology in each jurisdiction to be able to determine the marginal technology which is replaced by the exports/imports. They calculate that Quebec exports avoided 28.3 Mt. of CO_2 emissions.

[4] The real time market is settled every 5 min; however buyers (e.g., distribution companies and large industrial consumers) pay the hourly price called Ontario Hourly Energy Price (HOEP), which is the average of 5 min prices in an hour. The price volatility in Ontario is higher than the ones in neighboring jurisdictions such as New England, New York and Pennsylvania-New Jersey-Maryland Interconnection.