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Carbon pricing with an output subsidy under imperfect competition: The case of Alberta's restructured electricity market

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ABSTRACT

In this paper, we examine the use of carbon pricing and an output-based subsidy in a market with imperfect competition. We consider a carbon pricing policy in Alberta's electricity market as a case study. This policy consists of two phases. In the first phase, the carbon price is increased with the output subsidy being based on a fraction of facility-level emission intensity. In the second phase, the output subsidy is altered to be uniform across assets and based on the emissions intensity of an efficient natural gas asset. Using a model of oligopoly competition, we simulate the short-run impacts of the two phases on electricity prices, emissions, and unit and firm-level profitability. We find that the mechanisms by which electricity prices and emissions change in response to carbon pricing differ depending on whether the market is perfectly competitive or oligopolistic. We demonstrate that by differentiating the effective carbon price across technologies, changing the basis of the output subsidy has substantially larger price and emissions effects than increasing the carbon price for all generators. The estimated effects of carbon pricing vary as the firms' generation portfolios change.

1. Introduction

Mitigating climate change has become an increasingly important and contentious economic issue. Environmental regulations that place a price on carbon dioxide emissions have been proposed or implemented in many jurisdictions. The effects of carbon pricing on the electricity industry has been a focal point in these discussions because of its sizable production of greenhouse gas (GHG) emissions. For example, in the U.S. in 2014, 30% of GHG emissions came from electricity production, while in Europe electricity, gas, steam, and air conditioning accounted for 27% of GHG emissions in 2013 (EPA, 2016; Eurostat, 2016).

A complication regarding the introduction of carbon pricing in market-based restructured electricity markets is the presence of imperfect competition. It is well recognized that certain features of wholesale electricity markets, including the inelasticity of demand and the inability to store electricity, create a strong potential for market power (e.g., see Borenstein et al., 1999). Imperfect competition complicates the design of carbon pricing, as it influences how such pricing effects wholesale prices and emissions (Sijm et al., 2012). Carbon pricing in electricity markets has often been introduced alongside some form of output-based subsidy or permit allocation. Recent literature has shown that in the presence of an additional

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market distortion, such as imperfect competition, a two-part policy that includes a price on emissions and a subsidy on output can be welfare improving (e.g., see Gersbach and Requate, 2004). However, empirical evidence on the effects of output-based subsidies coupled with carbon pricing is limited.

In this paper, we simulate the effect of changes to carbon pricing and output-based subsidies in Alberta's wholesale electricity market. Under the initial carbon pricing policy, generators face a carbon price ($/t$CO_2$e) and receive an output subsidy ($/MWh) that is based on their historical baseline emissions intensity (tCO_2e/MWh). Within the electricity sector, in the short run, a generator's emissions intensity is inflexible. Consequently, under the initial policy, the structure of the output subsidy implies that all firms face an identical effective carbon price per tonne of CO_2e. The changes occur in two phases. In 2017 (the first phase), the carbon price doubles from $15/t$CO_2$e to $30/t$CO_2$e and the output-based subsidy falls to be a smaller proportion of an asset's baseline emissions intensity. This triples the effective carbon price for all generators, keeping it constant across generating units. In 2018 (the second phase), the proposed policy holds the carbon price at $30/t$CO_2$e while each generating unit's subsidy per unit of output is determined according to the emissions intensity of a benchmark natural gas asset. As a result, the effective carbon price becomes an increasing function of a unit's emissions intensity, with the average coal plant paying 150% more per tonne than a simple cycle natural gas plant.

In order to carry out this analysis, we develop a model of the restructured wholesale electricity market in Alberta, using data for the period from 2014 to 2015. In our imperfectly competitive Cournot model, five large strategic firms and a competitive fringe compete to supply electricity. We then use our model to simulate the short-run market effects on equilibrium prices, quantities, and emissions of both phases of the proposed policy change, under our Cournot model and also assuming perfect competition.

We find that the estimated effects of the carbon pricing policy on market outcomes, firm behavior, and emissions vary substantially by the nature of competition. Under perfect competition the price effect and emissions reductions primarily depend on the level of market demand and the technology of the marginal asset before and after the carbon pricing change. Our results demonstrate that, in addition to these factors, under Cournot competition the price effect and emissions reductions reflect strategic considerations such as the distribution of generation technologies between the large firms and a price-taking fringe and whether the fringe's generation units are operating at maximum capacity. Similar to Mansur (2007), for each policy simulation we find that carbon emissions are lower and prices are higher under Cournot competition as the relatively dirtier large firms withhold output to elevate market prices.[1]

In our analysis, the change in the basis of the output subsidy in the second phase reduces emissions by more than four times as much as the first stage, which triples the effective carbon price for all generators. By differentiating the effective carbon price by technology, the second phase leads to greater substitution from coal to natural gas assets. However, this greater emissions reduction is accompanied by a larger percentage increase in prices, and a corresponding larger reduction (increase) in the profitability of coal (natural gas) assets. These findings demonstrate that the design of the output subsidy can have substantial effects on the performance of environmental regulations in restructured electricity markets.

Our research makes a number of contributions. Previous analyses of emissions taxes with output subsidies have been either theoretical or utilize perfectly competitive multi-sector general equilibrium models (Bernard et al., 2007; Böhringer et al., 2017). By estimating generation unit level production decisions, we are able to identify and examine the differential effects of uniform increases in the effective carbon price versus changes to the basis of the output subsidy. As well, we contribute to the growing literature that accounts for firms' abilities to exercise market power when investigating the price effects of carbon pricing policies in electricity markets. Our analysis is particularly timely as the federal government of Canada has adopted, as its backstop for provincial carbon pricing policies, a combination of carbon pricing and output subsidies based on product-level best performance (Government of Canada, 2017).

The remainder of this paper will proceed as follows. The relevant literature is reviewed in Section 2. The Alberta electricity market and carbon pricing policy are discussed in Section 3. A model of Alberta's wholesale electricity market is given in Section 4. Our empirical methodology and data are presented in Section 5. Section 6 presents the results of our empirical model. Section 7 concludes.

2. Related literature

2.1. Economic theory of emissions taxes with imperfect competition

It is well known that in a perfectly competitive output market, the proportion of an emissions tax that is passed on to consumers depends on the relative elasticities of the demand and supply curves; the price effect will be greater as demand becomes less elastic and supply becomes more elastic. In the context of a wholesale electricity market, suppose there are two technologies, coal (C) and natural gas (NG), with aggregate capacities of k_C and k_{NG}. Suppose that initially the marginal costs of the two technologies are c_{NG} and c_C, where $c_C < c_{NG}$. The emissions tax increases the marginal cost of technology j by

[1] This result arises because the strategic firms in Alberta own the majority of the coal units that often set market prices, while fringe competitors own cleaner natural gas units. Emissions could be higher in the presence of market power in other jurisdictions with different generation portfolios, asset ownership structures, and the relative costs of coal and natural gas.