Economic and Environmental Consequences of Market Power in the South-East Europe Regional Electricity Market

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Overview

Two major historic processes of the last four decades have shaped current electricity markets worldwide. First, the unbundling of vertically integrated utilities resulted in imperfectly competitive electricity markets characterised by oligopolistic ownership structures (Wilson, 2002). Second, concerns about the effect of greenhouse gases (GHGs) on climate change led to carbon pricing through transferable property rights, e.g., allowances or permits. As with any other market, that for carbon allowances can also be subject to the exercise of market power. Kolstad and Wolak (2003)'s empirical study suggests that NO_x permits might have been used as a vehicle for producers to exert market power by offering electricity at higher prices in the California market in 2001. Moreover, if a dominant power producer can additionally withhold NO_x permits, then it may further increase its profit while driving up the permit price for rivals as demonstrated in a leader-follower case study of the Pennsylvania-New Jersey-Maryland (PJM) Interconnection (Chen et al., 2006). We are interested in the economic and environmental effects of market power on electricity and permit markets in regional electricity markets where participants are not all subject to the same CO_2-reduction policies. An example is the South-East Europe Regional Electricity Market (SEE-REM), which comprises both EU members subject to the emissions cap of the EU Emissions Trading System (ETS) and non-EU members exempt from such a cap. In a perfectly competitive setting, Višković et al. (2017) demonstrate that between 6% and 40% of the CO_2 emission reduction in the ETS portion of SEE-REM may be leaked into the non-ETS portion as non-ETS producers with a relatively dirty generation portfolio receive the price signal to increase their exports. In this paper, we examine how a dominant firm, i.e., Enel with ca. 20% of the SEE-REM market share, can (i) gain an economic advantage and (ii) affect carbon leakage by manipulating both the electricity and permit prices.

Methods

We use a game-theoretic model with firms, consumers, and an independent system operator (ISO). Each firm owns several plants and maximises its profit via its production decisions. Consumers are represented by nodal inverse-demand functions, which could be viewed as the results from solving their utility-maximisation problems. The ISO decides the welfare-maximising imports/exports at each node. Transmission constraints and loop flows are represented via a direct-current approximation, and generation portfolios are based on installed capacities and hydropower availabilities for the year 2013. We reflect seasonal variations in demand and hydropower output. The electricity market is cleared by equating nodal net supply and demand, and the price of CO_2 emissions is determined endogenously through a binding constraint that caps emissions from ETS units. Since we investigate the effect of market power in both electricity and permit markets, we have (i) a baseline perfect competition model (PC), (ii) a bi-level model with a Stackelberg leader that manipulates only the electricity prices taking the PC permit prices as given (S-T), and (iii) same as (ii) except that the Stackelberg leader manipulates both the electricity and permit prices (S). PC is a mixed-complementarity problem (MCP), which we solve as a quadratic program. By contrast, S-T and S cannot generally be solved directly and require reformulation first as a mathematical program with equilibrium constraints (MPEC) in which the lower-level equilibrium problems are replaced by the followers' first-order Karush-Kuhn-Tucker conditions. Next, the MPEC is rendered as a mixed-integer quadratic programming problem using strong duality and disjunctive constraints to remove the MPEC's non-convexities.

Results

In each of the three market settings, we impose emission-reduction scenarios varying from no cap on ETS emissions to a 40% binding cap on ETS emissions. Under PC, a binding cap on ETS emissions curbs ETS production. As the cap tightens, the price differential between ETS and non-ETS areas of SEE-REM increases, thereby enticing non-ETS production and leading to higher non-ETS emissions. Consequently, there is carbon leakage between 39%-11% for caps of 10%-40% reduction, respectively, compared to the baseline (Višković et al., 2017). The leader's strategy under S-T depends on the marginal technology, which changes with the stringency of the environmental regulation. When natural gas is the marginal technology, which occurs at lower carbon-tax levels from a 20% reduction, the leader withholds production from its dominant technology (coal) in order to raise electricity prices and profits. Higher electricity prices entice ETS natural-gas (including the leader's) and non-ETS production, which partly replaces the share vacated by the leader's coal plants. As a result, ETS (non-ETS) emissions fall below (rise above) the corresponding PC level. Since the reduction in ETS emissions offsets the increase in non-ETS emissions, carbon leakage is lower under S-T vis-à-vis the corresponding PC setting. For a carbon tax such that coal reaches cost parity with natural gas from a 40% reduction, the leader adopts an opposite strategy coal-wise by expanding coal production in order to set equilibrium prices. Higher electricity prices entice ETS coal and non-ETS production resulting in ETS and non-ETS emissions as well as carbon leakage above the PC level. Under S, the leader holds back more coal compared to that in S-T in order influence the permit price. A lower abatement cost results in higher ETS natural-gas production and ETS emissions compared to that in the corresponding S-T setting leading to higher carbon leakage. When coal reaches marginal-cost parity with natural gas with a 40% reduction, the leader expands coal to a lesser extent compared to that under the corresponding S-T setting as it does not want to increase the permit price. Contrary to S-T, since the ETS fringe cannot increase coal production because of the cap, it increases natural-gas production. This leads to lower ETS emissions and carbon leakage compared to the S-T setting. Generally, the leader is able to reap higher profits when it has the ability to manipulate both markets, except in the case of a tighter cap when its expansion of coal production is limited by the effect that it might have on the permit price.

	ETS Emissions [Mt]			**Non-ETS Emissions [Mt]**			**Carbon Leakage [%]**		**Permit Price [€/t]**	
Reduction Scenario / Market Setting	**0%**	**20%**	**40%**	**0%**	**20%**	**40%**	**20%**	**40%**	**20%**	**40%**
PC	177.82	142.26	106.69	40.44	47.91	48.33	20.99	11.10	20.02	35.77
S-T	176.83	141.25	110.39	40.53	47.93	48.34	20.47	11.72	20.02	35.77
S	176.83	141.46	106.10	40.53	47.94	48.33	20.95	11.04	17.81	35.77

	Dominant Firm's Profit [M€]			**Social Welfare [M€]**		
Reduction Scenario / Market Setting	**0%**	**20%**	**40%**	**0%**	**20%**	**40%**
PC	1,286	1,057	870	40,455	40,154	39,069
Change in S-T from PC	+14	+15	+46	-24	-39	-114
Change in S from PC	+14	+35	+38	-24	-62	-39

Conclusions

Carbon leakage is 11%-39% of ETS emission reduction under PC. In S-T, the leader's capacity withholding results in ETS emissions below and non-ETS emissions above PC levels. However, carbon leakage is lower vis-à-vis PC as the ETS emission reduction offsets the non-ETS emission increase. Finally, in S, the leader's propensity to lower the permit price increases ETS emissions and exacerbates carbon leakage compared to S-T.

References

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