The Impact of Imperfect Competition in Emission Permits Trading on Oligopolistic Electricity Markets

Tanachai Limpaitoon

University of California, Berkeley, USA

Yihsu Chen

University of California, Merced, 5200 N. Lake Rd., Merced, CA 95343, USA

National Graduate Institute for Policy Studies (GRIPS), Tokyo, Japan

Shmuel S. Oren

University of California, Berkeley, 4141 Etcheverry Hall, Berkeley, CA 94720, USA

Growing concerns regarding climate change have led to regulatory environmental policies including renewable portfolio standard (RPS) and emission trading programs, such as cap-and-trade (C&T) that rely on market-based mechanisms to mitigate greenhouse gas (GHG) emissions and/or promote renewable energy production. Such policies, implicitly or explicitly penalize emissions and in doing so affect the relative cost of different generation technologies and existing power resources. In restructured electricity system where market forces and security constrained economic dispatch drive the utilization and profitability of alternative generation resources, the efficacy and consequences of such environmental policies are affected by complex interactions due to congestion and market power which could lead to unintended consequences. In particular, one concern over C&T is the possibility that some firm's ability to exercise market power in electricity markets can be enhanced by their market power in the permit markets. Such market power may manifest itself when a dominant firm can deliberately withhold permits in order to raise other firms' production cost or withhold generation capacity to drive up electricity prices. Indeed, empirical analysis of the 2000–01 power crisis in California identified such behaviors. The potential of such adverse market outcomes will depend on the specific network characteristics, location of different plant types in the network, ownership structure and the rules governing the enforcement of environmental policies.

In this paper we explore the strategic interactions in an electricity markets where GHG regulation takes the form of C&T. We model such interactions as a Nash-Cournot game over a power grid represented as a DC network governed by Kirchhoff's laws. Load is represented by elastic (linear) demand functions at each bus and generation assets (with quadratic cost functions) are owned by strategic firms who can control multiple units at different nodes. The market equilibrium is characterized by a "simultaneous move" game where generation firms select the output levels of their own production units so as to maximize their profit given the equilibrium prices at the respective nodes, while the independent system operator (ISO) controls imports and exports at each node through locational price markups so as to maximize the system social welfare subject to network flow constraints. In addition to fuel cost, each generator incurs the cost of the emission permits needed to cover its production. The price for the permits is determined endogenously in the permit market. In this setup, generation firms exercise market power in the electricity market by accounting for the impact of their output decisions on the reference energy price but are price takers with respect to the locational markup set by the (ISO). Likewise, they exercise market power in the permit market by accounting in their output decisions and their permit procurement (or sales) decisions for the impact of these decisions on the permit prices. The equilibrium prices, production quantities and permit trades are determined in our model by solving a Linear Complementarity Problem (LCP) consisting of the optimality (KKT) conditions for the competing firms, the ISO and by the permit market equilibrium conditions. Because the supply of permits is inelastic we represent the residual supply function for permits, perceived by each firm through a conjectural variation approach and employ an iterative process in order to achieve consistency of the conjectured residual supply functions for permits.

The model described above is applied to a case study of the California market using a reduced 225 bus network of the California system within the Western Electricity Coordinating Council (WECC). California has recently implemented a cap-and-trade program (C&T) under California Global Warming Solution Act or AB 32, and this study addresses an important concern regarding the impact of initial permits allocation. The case study is primarily focused on characterizing the equilibrium when emission permits are initially allocated for free to generation firms. This is because permits allocation in California under AB 32 is intended for various reasons other than efficiency and equity (e.g., mitigating price impact). The study is aimed at understanding how such permit allocation may affect potential strategic behavior of firms.

Our analysis shows that when an efficient firm (less polluting and low production cost) is “grandfathered” a substantial number of permits, it has incentives to strategically withhold the “unused” permits in order to place upward pressure on permit price, hence driving up the electricity price. The degree to which firms strategically withhold permits may be lessened, when a stringent cap is imposed, a situation in which permit prices tend to be relatively expensive. The effect of the degree of competition in the permit market on social welfare is ambiguous and depends on the cap level. Finally, patterns of transmission congestion can be influenced by trading activities in the permit market. However, given that the scope of a C&T policy covers more than one sector, the case study may underestimate the price elasticity of emission permits, therefore inflating permit prices. Along with the adoption of other complementary measures to mitigate potential for market power, the possible market outcomes, as we argue, are likely bounded by our simulation results.

Our approach, however, is subject to several limitations. The scope of C&T policy in the analysis is restricted to an electricity market. If other sectors are considered, the supply curve of permits will be more price-responsive, limiting the impact of market power that can be exercised by electricity generation firms. Also, our model does not take into consideration neither permit banking and borrowing nor intertemporal demands patterns. The permit price should be determined by the supply and demand conditions over an extended time period, such as a typical compliance period of one year, or over a longer period if banking and borrowing over multiple periods are considered. One possible remedy is to extend the model to a multi-period setting in which firms take into account seasonal electricity demand in making the decision on permits banking and borrowing under the cap that declines over time. Such modeling can further investigate potential market issues associated with holding limits as well as timing and compliance.