Generation Capacity Expansion in Electricity Markets under Rivalry and Uncertainty

Derek Bunn[1]

Michail Chronopoulo

Bert De Reyck[2]

Afzal Siddiqui[34]

We propose to extend the traditional real options approach to electricity capacity expansion by investigating game-theoretic issues emerging from the competition between agents, each with a portfolio of electricity production technologies. Such a framework will take into account not only the feedback effect of capacity expansion on the price of electricity and the dependence of the value of a generation unit on the presence of others (Gahungu and Smeers, 2011) but also the strategic aspects of capacity expansion in a quasi-analytical framework.

Gahungu and Smeers (2011) develop a real options capacity expansion model for power generation in a competitive market with several technologies taking into account that investing in a given technology actually depreciates the option value of investing in others. Assuming several technologies with asymmetric investment and variable costs, they use optimal plant dispatch to compute the instantaneous welfare of the social planner, and the vector of Lagrange multipliers of capacity constraints to evaluate the profit flow of each type of plant. Results indicate that the investment trigger for each technology increases with the volatility, while allowing for the capacities of the different technologies to increase, the investment trigger of a technology increases with its own capital stock as well as with the capital stock of other technologies.

Incorporating strategic interactions in a real options setting typically mitigates a firm's incentive to delay investment. Smets (1993) first combined real options valuation techniques with game theory, thus developing a continuous-time model of strategic real options exercise under product market competition, assuming that entry is irreversible and stochastic demand. Huisman and Kort (1999) reconcile real options with game theory to illustrate how the decision-analytic incentive to postpone investment is counteracted by the strategic motivation to pre-empt one's rival in order to enjoy first-mover advantage. Extensions to this line of research include two sources of uncertainty (Paxson and Pinto, 2005) and uncertain technology innovation (Weeds, 2002).

We explore the application potential of real options theory in this new context of capacity expansion in the electricity sector by accounting not only for dependency between the cash flows of competing technologies but also for competition from a rival. Although market equilibrium can be determined analytically in stylised real options models, in a more general setting with asymmetric costs, multiple supply and demand nodes, and pipeline capacity restrictions, analytical solution of a system of equations is not possible. Therefore, a convex programming approach cannot be adopted to find the market equilibrium, while complementarity problems provide a viable modelling approach. Hence, in order to extend the framework of Gahungu and Smeers (2011) to account for competition, we will cast this problem as a mixed complementarity one. While Gahungu and Smeers (2011) indicate that the incentive to delay investment increases both with greater uncertainty and capital stock, whether a strategic context would promote a greater herding tendency or erode the option value of waiting is an important open research question, which becomes of even greater interest when considering the particular nature of the portfolios and the ability to diversify them.

1 Management Science and Operations Subject Area, London Business School, London, UK
2 Department of Management Science and Innovation, University College London, London, UK
3 Department of Computer and Systems Sciences, Stockholm University, Stockholm, Sweden
4 Department of Statistical Science, University College London, London, UK