UNIVERSITY OF CAMBRIDGE
Electricity Policy Research Group

The robustness of agent-based models of electricity wholesale markets

EPRG Working Paper 1213

Cambridge Working Paper in Economics 1228

David Newbery

Liberalized electricity markets are frequently bedevilled by the persistence of a dominant incumbent generator, even if the industry has been unbundled and entry made potentially contestable. The EU has embarked on a project to create an Integrated Electricity Market by facilitating cross-border trade to increase competition within each Member State, although progress towards efficient use of interconnectors through market coupling has been until recently very slow. With the Third Package, the creation of the Agency for the Cooperation of Energy Regulators, ACER, and commitment to deliver the Target Electricity Model by 2014, progress has recently accelerated, so that market coupling now extends over a wide area in Central West Europe, larger even that the PJM Interconnection. It is therefor of considerable importance to examine the impact of these various reforms on the extent of market power, to test whether the reforms have been successful in mitigating such power, or whether further structural reforms are necessary.

This is difficult, as it is hard to model generator behaviour in such markets, and even harder to model strategic behaviour with transmission constraints (and most interconnectors are heavily congested). It is therefore attractive to adopt an agent-based modelling strategy that can handle such complexity. In such models, agents typically learn by testing out deviations from past strategy choices to see if they can increase profits, and continue to experiment until further improvements can no longer be found.

A key question facing such modelers is whether the resulting equilibrium is indeed a Nash equilibrium in the space of actions allowed in the formulation of the game. In cases where the Nash equilibrium is unique, researchers find that at least for simple models in which agents offer supplies that are a mark-up on marginal costs, adaptive learning converges on the Nash equilibrium.

UNIVERSITY OF CAMBRIDGE
Electricity Policy Research Group

The obvious problem with agent-based modelling where agents are assumed to learn about the profit consequences and adapt their strategies to increase profits is that the action space over which they make choices may be too restrictive and may allow other more sophisticated agents to exploit this type of learning. A good defence of adaptive learning would be to show that the equilibrium of the form of learning were robust against more sophisticated players choosing from a wider set of actions. One proposed agent-based model known as Q-learning has agents choosing a mark-up on their marginal cost schedule, thus departing from competitive behaviour. Models in which agents choose mark-ups on marginal costs are popular among agent-based models of electricity markets. This paper examines the robustness of such models and finds that they are indeed robust against a variety of deviations by more spohisticated players.

The paper first shows that, in a model in which all generating companies have linear marginal costs and face linear demand, the Nash Cournot equilibrium (in which agents choose outputs) leads to a higher equilibrium price than the slope Nash equilibrium in which agents offer a linear supply schedule that has the same zero intercept as the linear marginal cost schedule but has an optimal slope higher than the marginal cost schedule. That in turn results in a higher equilibrium price than the mark-up equilibrium in which agents offer to supply at an optimal fixed mark-up above marginal costs, which is above the competitive price, provided marginal costs are strictly increasing (otherwise both strategies collapse to the competive equilibrium).

The paper next shows that if all other agents have adopted the optimal mark-up on marginal costs, or have chosen the optimal slope of their offers, then a sophisticated firm that chooses its optimal output (as in the Nash Cournot case) cannot improve upon following the same strategy as the other firms. To test that this is not just because the deviating firm is offering a less competitive alternative, the paper considers the case in which the other firms choose the optimal slope of their offers, and the deviating firm offers the more competitive fixed mark-up over its marginal costs. Again the deviant cannot improve upon following the same strategy as the other firms. These mark-up strategies are therefore robust against firms that can choose from a wider range of strategies, and avoid the criticism that simple learning would lead to equilibria that would be vulnerable to deviations by more sophisticated players.

Contact dmgn@cam.ac.uk
Publication May 2012
Financial Support Imperial College