Available online at www.sciencedirect.com
ScienceDirect
Energy Economics 30 (2008) 1728–1759
Energy Economics
www.elsevier.com/locate/eneco

A critical survey of agent-based wholesale electricity market models

Anke Weidlich *, Daniel Veit

University of Mannheim, Chair of Business Administration and Information Systems, Schloss, 68131 Mannheim, Germany

Received 3 July 2007; received in revised form 7 January 2008; accepted 7 January 2008
Available online 16 January 2008

Abstract

The complexity of electricity markets calls for rich and flexible modeling techniques that help to understand market dynamics and to derive advice for the design of appropriate regulatory frameworks. Agent-Based Computational Economics (ACE) is a fairly young research paradigm that offers methods for realistic electricity market modeling. A growing number of researchers have developed agent-based models for simulating electricity markets. The diversity of approaches makes it difficult to overview the field of ACE electricity research; this literature survey should guide the way through and describe the state-of-the-art of this research area. In a conclusive summary, shortcomings of existing approaches and open issues that should be addressed by ACE electricity researchers are critically discussed.

Keywords: Agent-based computational economics; Simulation; Electricity market modeling

1. Introduction

Because of the technical nature of the traded good, electricity markets rank among the most complex of all markets operated at present. Supply and demand have to be balanced in real time, considering transmission limits and unit commitment constraints. The electricity sector is characterized by multiple interlinked markets: fuel markets, markets for day-ahead scheduling and those for real-time dispatch or balancing energy, bilateral trading and auxiliary markets e.g. for emission allowances. Many energy firms are vertically integrated and act on several markets simultaneously, thus further complicating their trading strategies. Besides, and given the

* Corresponding author.
E-mail addresses: weidlich@uni-mannheim.de (A. Weidlich), veit@uni-mannheim.de (D. Veit).

0140-9883/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.eneco.2008.01.003

oligopolistic structure of almost all electricity markets, participants have the potential to exert market power in many of these markets.

These complexities drive most classical modeling methods to their limits. Equilibrium models either do not consider strategic bidding behavior or assume that players have all relevant information about the other players' characteristics and behavior; they also disregard the consequences of learning effects from daily repeated interaction (Rothkopf, 1999). Game theoretical analysis is usually limited to stylized trading situations among few actors, and places rigid – oftentimes unrealistic – assumptions on the players' behavior. Human-subject experiments can be applied to electricity market research only with difficulties, because some expertise is necessary to realistically imitate the bidding behavior of a power generator. Thus, for many questions relevant in electricity market research, human-subject experiments are not an appropriate method.

Given the complexity of the electricity sector and also its high importance for a competitive economy, researchers and practitioners are increasingly willing to try new modeling methods in order to gain insights into various aspects of power markets. Agent-based (AB) modeling is one appealing new methodology that has the potential to overcome some shortcomings of traditional methods. Within the last ten years, more and more researchers have been developing electricity market models with adaptive software agents. This field of research is still growing and maturing. Some first attempts have already been revoked, others have gained popularity.

As the number of AB electricity models that have been published in journals starts to increase, and given the high attractiveness of agent-based approaches among researchers, this survey might help to get a sense of the state-of-the-art of the whole research field.[1] This literature review is supposed to guide newcomers or interested researchers through the intricate research field and points out the weaknesses and open issues that current approaches face. It is structured as follows: Section 2 gives a brief introduction to the methodology of Agent-Based Computational Economics (ACE); Section 3 presents the approaches and findings of relevant scientific papers in ACE electricity market research, and Section 4 summarizes the contributions made by the papers, points out some shortcomings of the current state-of-the-art, and suggests some lines of future work in the research field. Finally, Section 5 concludes.

2. Methodology of Agent-Based Computational Economics

2.1. Motivation for AB methods in economics

The electricity sector, and economies in general are characterized by difficult real-world aspects, such as asymmetric information, imperfect competition, strategic interaction, collective learning, and the possibility of multiple equilibria (Tesfatsion, 2006). Many of these factors can not – or only with difficulties – be accounted for with traditional economic modeling techniques. Analytical approaches usually have to put strong and constraining assumptions on the agents that make up the economic system under study, in order to set up elegant formal models.

When the concept of complexity came up, the focus in economic analysis shifted from rational behavior and equilibrium towards heterogeneity and adaptivity (a famous early example being the simulations of Axelrod, 1997). At the same time, the tremendous availability of computational resources made it possible to set up large-scale and detailed computational models that allow a

[1] We attempt to give a very broad overview of AB electricity market models and present the most relevant work in detail. The nature of a fast-growing and young research field entails the difficulty to account for all existing research; although great care has been taken to consider as many papers as possible, it cannot be guaranteed that the survey at hand is exhaustive.