Agent-based Energy Market:
Modeling Transitions in Climate-Economy-Energy System

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Nowadays, we face many complex challenges in climate-economy-energy (CEE) systems. European countries try to increase cross-border competition in energy market to have transition to a low-carbon economy by making right policies. This is driven by the desire to gain energy independence from limited fossil fuel energy sources and to mitigate greenhouse gas emissions, with an ultimate goal to avoid irreversible damage of climate change. Yet, it is widely accepted that climatic system is likely to react abruptly and shifts suddenly to a different state after a certain threshold of CO2 concentrations is reached. Economic systems are also likely to undergo non-marginal changes. There is no reason to assume that our behaviour, and in particular our economic choices on the energy consumption and production will remain the same. Therefore, one needs to quantitatively explore, trace and simulate non-marginal changes in energy markets to be able to design robust economic, energy and climate mitigation policies.

Energy policies enacted today can have long-lasting intergenerational impacts due to the long economic life of the energy capital stock. To be able to formulate an appropriate energy policy for this complex adaptive CEE system, policymakers should ideally have decision support tools that are able to foresee non-marginal changes in energy market – both in demand and supply sides – over the coming decades to plan ahead accordingly. Many macro models, that assume rational representative agent with static behavior, are designed to study marginal changes only. So there is a need for models that are able to capture non-linear changes and their emergence. In this research, our aim is to design and implement an agent-based energy market model in context of low-carbon strategy of the EU. This Agent-
based Model (ABM) is planned as an individual piece of software with ultimate goal of being a part of a hybrid Computable General Equilibrium (CGE)/ABM.

Unlike General Equilibrium Models (GEM) and Integrated Assessment Models (IAMS), an ABM have a high potential to simulate non-linear dynamics and responses in coupled CEE systems. Brown (2006) stated that “The ability to simulate individual actions of many diverse agents and measure the resulting system behavior and outcomes over time, means agent-based models can be useful tools for studying the effects on processes that operate at multiple scales and organizational levels, and their effects”. Later Macal and North (2010) asserted that ABM offers a way to model social system which is composed of agents who interact with and influence each other, learn from their experiences and adapt their behaviors so they are better suited to environment. Filatova and colleagues (2013) argued that the main added value of ABM as a simulation technique is in its ability to represent behavior of human actors more realistically, accounting for bounded rationality, heterogeneity, interactions, evolutionary learning and out-of equilibrium dynamics, and to combine this representation with a dynamic heterogeneous representation of the spatial environment.

Since ABMs are not directly used to model climatic systems (e.g. 2 degree Celsius threshold), there are no climate system thresholds considered directly. Irreversibility, however, is addressed in ABMs. The ABM of the carbon emission trading impact on shifting from carbon-intensive electricity production (Chappin & Dijkema, 2007) suggested that as soon as investments in new technology are made, the switch from the old technology is irreversible. Various scenarios produced by the ENGAGE ABM by Gerst and colleagues (2013) all produce irreversible transitions to low-carbon economy. While depending on a policy, the transition can be swift or more gradual, the return back to carbon-intensive economy is unforeseeable.

In our research project an agent-based energy market model plays a vital role within the coupled suit of models complimenting macro-economic and climatic models. It aims at reproducing and tracing non-linearities in energy markets, quantifying aggregated effects of behavioral changes on micro level, and capturing discontinuities (i.e. abrupt structural non-marginal changed in energy-economy systems) driven endogenously from within the economic agent-based model, as well as triggered by changes in the environment. We would like to explore the aggregated consequences of behavioral changes on the demand side of
energy markets, and the technology diffusion on the supply side. The quantities and prices of various energy sources and corresponding greenhouse gas emissions resulting from the microeconomic choices are some of the indicators (outputs) of an aggregated ABM market dynamics.

Any ABM market has a disaggregated representation of the supply and demand sides (Tesfatsion and Judd, 2006). The demand side in our ABM is represented by heterogeneous households with different preferences, awareness of climate change, and socio-economic characteristics. Their microeconomic choices could include switching between traditional and low-carbon energies or behavioral changes such as the reduction of household energy demand. These changes in individual households’ energy consumption could potentially lead to non-marginal changes in a regional energy demand as a collective response of interacting individuals to certain energy policies. Meanwhile, the supply side is presented by heterogeneous energy producers. The microeconomic dynamics on the supply side could include the diffusion of alternative energy technologies, i.e. the transition to low-carbon
We also consider the role of social networks and interactions on both sides.

This project is largely a work in progress. We hope to present the conceptual model and the first implementation at the ESSA conference. The future work will go on in the following two directions: (1) parameterizing and validating the ABM energy market, and (2) integrating it with a macroeconomic computational general equilibrium model (CGE) and a climatic model. We plan to use empirical data for our agent-based energy market model. Namely, the available EU statistical data, i.e. data on energy use in other sectors, current behavioral functions on demand and supply side (from the CGEs models we link to), past and current energy consumption by households as well as production and etc. We plan to run a survey for collecting data on behavioral change, which includes not only change in choices but also in preferences and opinions, potentially affected by social influence. The main goal of the survey is to elucidate the information on behavioral changes on the demand side (households) to feed it into the ABM. This implies a theoretically-grounded questionnaire, which traces energy consumption choices through time (i.e. past-present-future economic choices are to be captured).

Reference


