THE LOW-CARBON TRANSITION OF THE EUROPEAN ELECTRICITY SECTOR: AN AGENT-BASED APPROACH TO UNDERSTAND ACTORS' STRATEGIC INVESTMENTS IN ELECTRICITY GENERATION ASSETS

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Overview

Electricity production in Europe is still dominated by fossil fuels. This lead the European electricity sector to be the largest producer of greenhouse gas emissions in 2015, with a 26% share according to the latest Eurostat data. Therefore, to mitigate climate change and successfully achieve legally binding European and national decarbonisation targets, the electricity sector needs to be decarbonised, with renewables accounting for the largest share of electricity production. This transformation, which can be viewed as a "socio-technical transition", will not only require technological progress, but also a deep transformation of the surrounding socio-economic context, regulatory environment, businesses and user practices (Geels, 2002) to be sustainable in the long term. Moreover, substantial global financial investments are needed in the power sector – the IAE estimates that global annual investments of USD 420 bn are needed (IAE, 2016), of which 70% in renewables, while estimated annual investments of over EUR 100bn are needed in Europe alone to meet decarbonisation targets and guarantee security of supply (IAE, 2014). However, clean energy investments in Europe, 63% of which were provided by private sector actors in 2016 (Buchner et al., 2017), are declining, and incumbent utilities are facing strong financial pressures, putting their role as investors under question (Blyth et al., 2014), and raising the importance of other type of actors such as institutional investors and new financing niches (Bolton and Foxon, 2015). Therefore, to successfully stimulate investments in the power sector, and to prevent the lock-in of existing high-carbon technologies (Unruh, 2000), policies need to be based on a thorough understanding of the determinants of investment decisions of private actors (Gross et al., 2007), keeping in mind their heterogeneity, and their different micro-economic decisions.
In this context, my research aims to study private sector actors' strategic investment decisions. Most academic research analyses the drivers of private actors' investment choices using conventional investment analysis and neo-classical economic models, but there is a lack of studies exploring the influence of bounded-rationality, path-dependence and heuristic aspects on actors' strategic investment decisions, and taking into account actors' heterogeneity (Wüstenhagen and Menichetti, 2012; Bergek et al., 2013). Also, current scenario literature lacks attention to the role, actions and motivations of the actors involved in shaping the future of the energy sector (Hughes and Strachan, 2010) in modelling studies.
My research addresses these limitations by developing an agent-based model, to analyse the strategic investment decisions in new power generation assets of different types of electricity generators, and to study the aggregate effect of these decisions on the long-run evolution of the electricity sector to 2050. The questions that my research aims to answer are: "Under what conditions are generators of different types incentivised to invest more in new generation assets? ", "To what extent do generators non-optimal strategies and heterogeneity influence future investments?", and "What is the mix of investors and generators that leads to higher investments?". Case studies will be the UK, the German and the Italian electricity markets, to understand how different electricity sector's ownership and governance structures and type of players influence investment decisions.

Methods

The research questions are investigated by means of an evolutionary-agent based model. I have chosen to use an agent-based model, as this is a great tool to model heterogeneous and goal-oriented actors with different strategies (Axelrod, 1997, Gilbert, 2008). My agent-based model is grounded in evolutionary economics theory (Nelson and Winter, 1982), as this allows to account for the path-dependent nature of the energy sector, where assets have a long lifetime, and to model actors with bounded rationality, as it is in real world as actors take decisions under deep uncertainty and don't have perfect foresight. Moreover, with an agent-based model the future evolution the electricity sector can be studied as an emergent property resulting from the agents' actions and interactions, and not as a result of exogenously imposed targets (Tesfatsion, 2001), making it a powerful tool to model the evolution of complex adaptive and non-linear systems, such as the low-carbon transition of the electricity sector.
My model is developed in Netlogo, and it proceeds in yearly time-steps from 2012 to 2050. The main actors in my model are electricity generation companies of various types (incumbent utilities, independent power producers and new-entrants in the market). Each generator has a unique strategy, a different stock of assets and equity, and has a different view on future fuel, CO_2 and electricity prices and electricity demand. Electricity generators take short-term operational decisions on electricity production, and long-term strategic investment decisions. Other agents in the model are the government, the network operator and financial sector actors, addressing a gap in current literature,

and reflecting the potential important contribution of these last actors in achieving climate goals, as also acknowledged during COP 21 in Paris in 2015.

Compared to existing agent-based modelling studies that focus on the long-run evolution of the electricity market and on actors' strategic decisions, which only have one type of generators' agent, my model includes a variety of generators, different financial sector agents and different governmental agents. Hence, there will be greater focus on the heterogeneity of actors and on their strategies and behaviours. Moreover, none of the exiting agent-based models includes the financial sector as part of its agents, and in most models policy changes are exogenous, while in my model policy changes endogenously determined through feedback, and not pre-determined at the beginning of the simulation run.

Results

Results at this stage are preliminary, only for the UK market, and aimed at starting to answer the first two research questions. Government activity is measured by the strength of the CO2 price and by the degree to which the CO2 price is adjusted by the Government agent if CO2 targets are not met. Results show that total aggregated investments in renewable (RES) technologies (on-and offshore wind, biomass and PV) over the period 2012-2015 only increase by 29% between the Reference Scenario (where CO2 price reaches a level of GBP 100/Mt) and the scenario under which the CO2 price reaches the level of GBP 300/Mt. On the other hand, total aggregated investments in gas decline by 59%. Hence, especially RES investments are quite insensitive to CO2 price. Moreover, results show that it takes a CO2 price of at least GBP 175/Mt to have a total electricity production share from RES at 2050 of at least 50%, and it takes a CO2 price of GBP 300/Mt to reach an 80% production share from RES. Reasons for this unsensitivity can be found in generators' strategies. In fact, results show that the higher the interest rate that generators are charged, the higher the CO2 price needs to be to incentivise the upfront capital intensive RES investments, and while when generators pay an interest rate of 3.5% it takes a CO2 price of GBP 100/Mt to have a RES electricity production share of over 50% at 2050, it takes a CO2 price of GBP 200/Mt when generators pay a 10% interest rate. Also, the length of the forecast horizon which generators use to evaluate future investments impacts the degree to which CO2 price manage to switch investments from gas to RES. In fact, the longer the forecast horizon used by generators the less sticky RES investments are to changes in CO2 price, and the most market the shift between RES and gas investments.

Conclusions

Results show that the Government agent needs to provide a strong CO2 price signal to drive higher RES investments, and that the effectiveness of CO2 pricing in shifting investments from fossil fuels to RES heavily depends on generators strategies. Therefore, investigating the heterogeneity of generators' strategies through an agent-based model is really important to draft effective policies which will lead to a sustainable low-carbon transition of the electricity sector.

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