Investor Types, Technology Diffusion, and Decarbonization

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Overview

Technology-rich optimization models are widely used as tools of analysis to provide robust policy recommendations. Those models run different scenarios to advise decision-makers in the energy and power sector by informing them about the role of climate change and assessing the impact of potential changes in environmental policies (Cao et al., 2016). Modeling the temporal and spatial resolution, technology details, and economic behavior are some of the major future challenges facing detailed numerical energy system and power market models (Pfenninger et al., 2014). Some models are already able to depict complete hourly resolution of the year when applying a myopic approach (Poncelet et al., 2016). Others have a flexible spatial resolution below country-level scope which can be adjusted according to the research question (Martınez-Gordon et al., 2021). Others have fundamental technology richness and depict, for example, additional technological characteristics of storage such as maximum cycles and ramping constraints (e.g., Ringkjøb et al., 2018). However, those improvements only bring the models moderately closer when depicting reality while also driving them even further apart from each other. At the same time, one crucial driver of models' outcomes—the economic behavior of firms and investors, is not covered in these advancements. We address this gap in the existing research by elaborating on the role of economic behavior in technology-rich, bottom-up, optimization models. In this regard, we evaluate the impact of investor type heterogeneity using diverging investment cost specifications, financing cost, and discount rate on the development of the European power market until 2050. This leads to a substantially different pace and rate of adoption for specific generation technologies and decarbonization scope. For the European power market, 2050 wind (nuclear, gas-CCS) capacity ranges from 624 to 1,113 GW (84 to 194 GW, 383 to 502 GW) and 2050 CO2 emissions from 70 to 136 Mt, depending on the respective investor type. Accounting for equal shares of investor types leads to 2050 wind (nuclear, gas-CCS) capacity of 912 GW (140 GW, 428 GW) and CO2 emissions of 81 Mt. Technology-specific financing cost increase 2050 wind (nuclear, gas-CCS) capacity even to 1,069 GW (80 GW, 449 GW), leading to 86 Mt CO2 emissions.

Methods

We develop a theoretical framework to model investor type heterogeneity and test it in the EUREGEN model—a European power market partial equilibrium model that optimizes investments, decommissioning, and dispatch for generation, storage, and transmission technologies intertemporally until 2050—allowing to quantify the impact of investor type heterogeneity on capacity expansion, generation mix, and CO2 emissions. Three different investment cost specifications reflect three types of investors, which are active in the majority of power markets including utilities, social planners, and private or institutional investors. *Normal investors* apply an investment cost specification that carries the burden of investments in the period of investment (Weissbart and Blanford, 2019). Such a behavior best reflects public firms or heavily regulated (by a social planner) monopolies. *Capital cost investors* represent big institutional investors and funds that only pay for bound capital, a mix of own and debt capitals (Bachner et al., 2019). In turn, repayment is of little consequence for this type of investor, since capital cost investors can refinance themselves with their own revenues or new debt capital. Repayment, however, matters for the *annuity investors*, representing smaller and private firms and investors. We additionally change discount and interest rates for normal, capital cost, and annuity investors. The normal investor considers full investment cost in the period of investment, whereas capital cost (applying the weighted average cost of capital, WACC) and annuity (applying annuities) allocate investment cost over the depreciation time of investment. Thus, the normal investor faces the lowest discount rates because of the long-run orientation of public firms and the lowest interest rates since state ownership reduces financing costs. The annuity investor faces the highest discount and interest rates. Additionally, we apply technology-specific mark-ups on interest rates to reflect irreversibility as well as varying degrees of technological and regulatory uncertainty of conventional and renewables projects.

Results

Assuming that the market is represented by normal investors with 7% interest and discount rates leads to 362 GW wind capacity (29% of generation) in 2020 which increases to 974 GW (40%) in 2050 (see Figure 1). The capital cost investor with the same rates engenders 290 GW (23%) in 2020 and 949 GW (38%) in 2050. The annuity investor is even more modest with 206 GW (15%) in 2020 and 759 GW (32%) in 2050 of wind. The normal investor invests most into wind power and does so fundamentally earlier than the capital cost and annuity investors. The capital cost investor almost closes that gap until 2050, whereas the annuity investor delivers structurally lower wind power capacities and shares in the generation mix, respectively. Interestingly, normal and annuity investor invest similarly in nuclear (147 and 140 GW in 2050) compared to the capital cost investor (97 GW). Conversely, the capital cost investor delivers the highest gas-CCS capacity (459 GW in 2050) and solar capacity (587 GW) compared to the normal investor (384 GW, 487 GW) and annuity investor (425 GW, 440 GW). As a result, normal investors deliver the deepest decarbonization (70 Mt in 2050) and annuity investors the lowest (136 Mt in 2050). Next, we account for the effects of neglecting discounting. Considering a normal investor applying a 7% interest rate but neglecting discounting leads to early wind deployment (446 GW or 35% already in 2020). Differences to the case with discounting become even more dramatic by 2035 but level out in the long run. Patterns are reversed for capital cost and annuity investors. Neglecting discounting hampers wind deployment in the short and mid-run. However, differences level out again in the long run. Neglecting discounting fosters, in general, early investments for the normal investor because such a specification places a higher weight on later investment costs. In turn, capital and annuity investors allocate investment costs over time (and not just in the period of investment) and thus show reversed patterns because neglecting discounting in general makes investments more expensive (and thus fosters reliance on existing capacity).

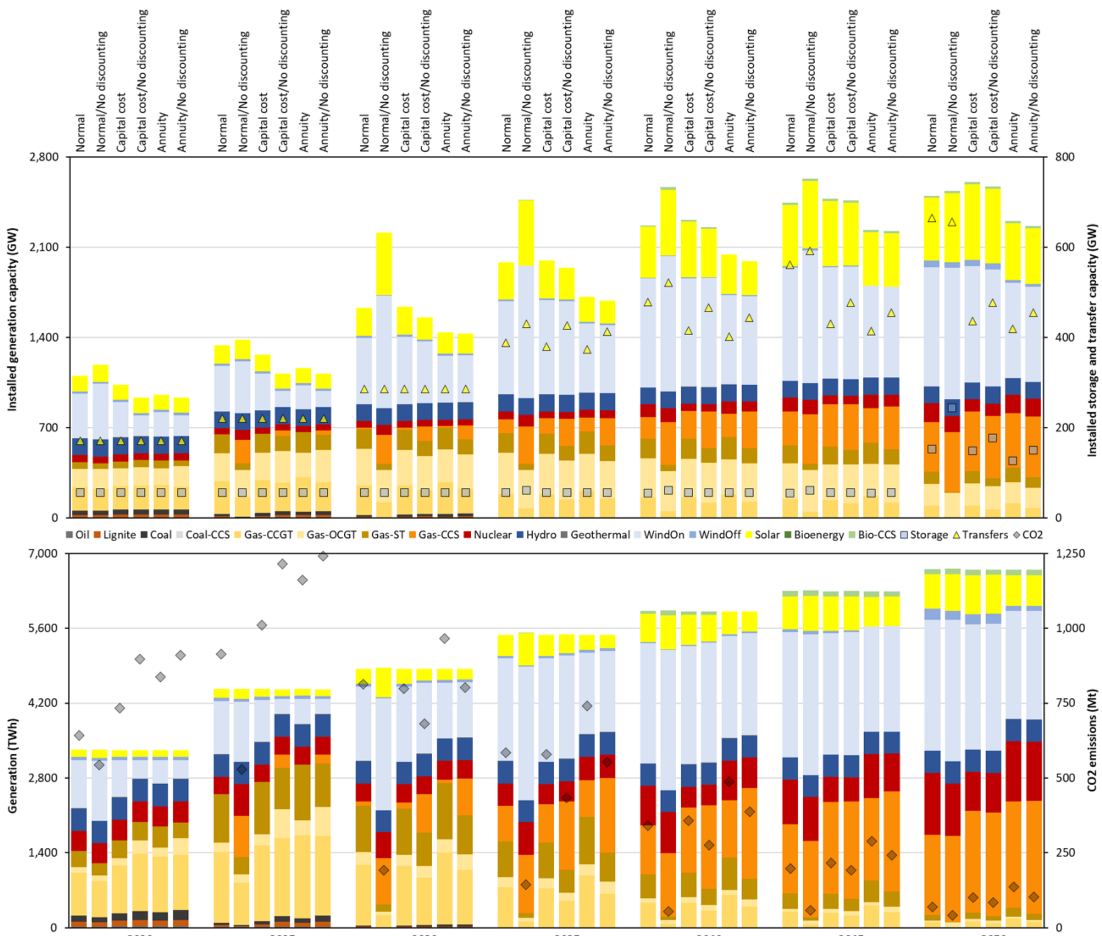

Figure 1: Impact of investor type and the role of discounting

Conclusions

Our analysis reveals one major shortcoming present, to our knowledge, in all the currently available bottom-up optimization models used to derive policy advice, namely, lacking representation of the heterogeneity of investors' behaviors, which leads to a substantially different rate and pace of generation capacity development of technologies such as wind, nuclear and gas-CCS. Hence, when modeling energy systems and power markets with a large degree of technological detail, such as is the case in bottom-up optimization models, we need to account for the underlying investor type heterogeneity. Thus, our results confirm that accounting for a more differentiated picture of electricity market investment with heterogeneous investor types can provide a starting point for tailor-made energy policies, thereby increasing the efficiency and effectiveness of public policies fostering the decarbonization of power markets.