USING RETROSPECTIVE MODELING TO INFORM CHOICES IN DEVELOPING BOTTOM-UP ELECTRICITY SYSTEM MODELS

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Overview

Bottom-up, optimization-based electricity system models are commonly used to generate electricity scenarios for policy support, especially at a national level [1]. If modeled scenarios are consistently different from historical transitions [2], we can get insights from retrospective modeling on how to improve the models [3,4]. In literature, most studies focused on retrospective modeling for one country or region, but there are practically no such studies for multiple countries in parallel, where quantitative accuracy indicators and techniques inspired by statistical analysis would be especially helpful to draw insights from large historical datasets for many countries. The commonly used electricity system models typically incorporated endogenous features, such as elastic demand and technology learning effects [5,6]. However, the retrospective performance of the models with and without these endogenous features are barely evaluated. This would be useful in order to provide evidence on which model functions and versions to use for best accuracy performance.

Methods

In this study, we conduct a retrospective modeling analysis, using a technology-rich, perfect foresight, cost-optimization modeling framework D-EXPANSE, incorporating price elasticity of demand and technology learning effect. For the first time, we retrospectively model national electricity sectors in 31 European countries over the 1990 – 2019 period [7]. First, multiple EXPANSE model versions are developed by setting up price elasticity and technology learning functionalities. Second, we compare the retrospective accuracy performance of multiple model versions for each country, aiming at quantifying the impact of endogenous functions on accuracy. The 34 model outputs, such as installed capacities or annual generations of various technologies, are assessed with five accuracy indicators: symmetric mean absolute percentage error, symmetric median absolute error, symmetric mean percentage error, root-mean-squared logarithmic error, and growth error [2] (Fig. 1). Finally, these quantified accuracy indicators of all model versions in each country are compared by applying statistical analysis methods.

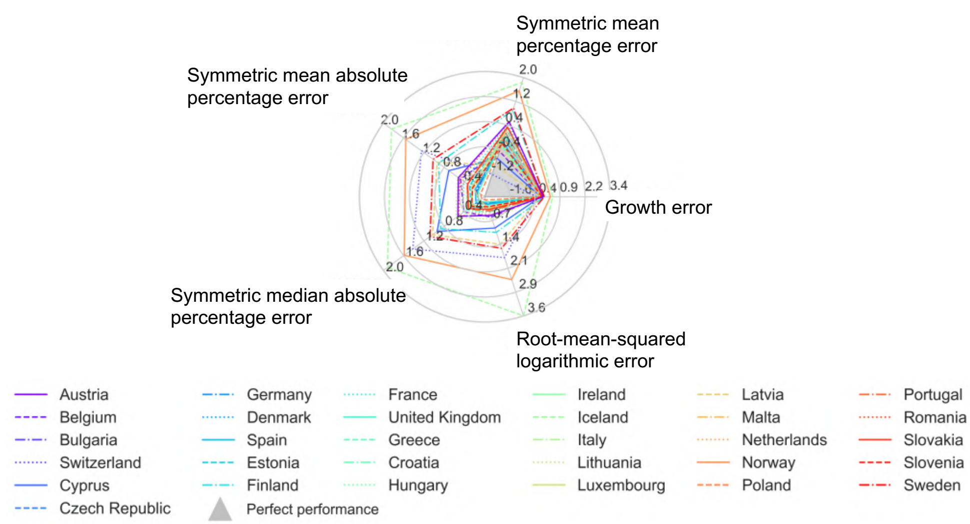

Fig. 1. Demonstration of the retrospective evaluation of a basic EXPANSE version in modeling average annual CO_2 emissions using five accuracy indicators in 31 European countries in 1990 – 2019.

Results

Based on the retrospective modeling and statistical analysis, we provide a comparison of different EXPANSE model versions in terms of accuracy performance in 31 European countries and gather new insights to what extent a country-specific combination of endogenous functions, depending on the specific domestic supply-demand equilibrium and technology deployment, will improve the model's accuracy the most. The results suggest that endogenous technology learning in cost-optimization models cannot always capture technology transitions or technology breakthroughs at a national level. Under-projection of renewable technologies are seen in many countries, especially solar PV. These under-projections of renewable technologies could be improved in some countries by setting the global learning effect. The elasticity of demand needs to be evaluated in country-specific occasions to get more accurate projections for some countries. By quantifying the model's accuracy at an annual time step, we also find that for certain technologies in some countries the deviations of the total technology mix from the real world are decreasing with time in the long term.

Conclusions

In this study, we present a retrospective modeling exercise with D-EXPANSE model for national electricity sectors in 31 European countries over the 1990–2019 period. We develop multiple model versions, with and without price elasticity of demand or technology learning functionalities, and use retrospective modeling for out-of-sample accuracy testing of these model versions. The results show which model versions have better accuracy performance when and, in this way, we gather first-of-the-kind evidence to forego subjectivity in the choice made by modelers when developing a new bottom-up model.

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