Optimal Electricity Generation Portfolios in the Presence of Fuel Price and Availability Risk

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Overview

The in Germany originated term of “energy revolution” is currently being addressed more often than ever even outside the German borders, posing the biggest challenge of the 21st century not only to Germany and Europe but to the entire world. A gradual insertion of renewable energy sources (RES) is planned as a transition process towards a secure, sustainable and environmentally friendly electricity generation. First steps in this process have already been implemented leading to first effects that have already been induced such as increased frequency and duration of negative electricity prices, additional system costs, falling CO_2 emissions etc.

This paper addresses the question of how an optimal electricity generating portfolio comprising both fossil and renewable technologies should look like if the decision maker wants to minimize not the classical overall LCOE, but the risk-adjusted ones in the framework of Markowitz´ Modern Portfolio Theory (MPT), subject to load-satisfying constraints. Thereby the well established relation of monotonically increasing system costs for increasing RES-shares is considered in the optimization, which represents the first contribution to the scientific literature.

While most of the scientific literature on MPT with application to electricity generating technologies focusses on only one source of uncertainty, be it in the form of price or availability risk, the current work takes both risk types simultaneously into account in the optimization, thus guaranteeing a fair(er) assessment of fossil and renewable technologies. This addition constitutes the second contribution to the scientific literature.

This paper contains a new model for determining optimal electricity generating technologies, an analytic solution to it and an application of the model via a parametrization for Germany as a case study.

Methods

The methods used in this paper are various. Most importantly, in line with Delarue et al (2011) and Gotham et al (2008), a model based on the in finance originally by Markowitz (1952) formulated model is developed for determining the optimal electricity generating technologies. Using the LCOE for several fossil and renewable technologies as an input, Markowitz’ mean-variance utility function is used as the objective function of a non-linear optimization model to capture the trade-off between expected costs (first moment) and variance or volatility (second moment) for several risk-aversion attitudes in the context of Delarue et al (2011) subject to load-satisfying constraints as in Gotham et al (2008).

This approach is extended on the one hand by adding additional systems costs caused by renewables integration leading to a non-linear, non-quadratic optimization model and on the other hand by merging fuel price and availability risks.

To do so and to conform with reality, other methods besides the main non-linear optimization method were used. First, classic regression analysis is implemented for estimating the correlation coefficient between the shares of RES as independent variable and the balancing and reliability costs as dependent variables, respectively. Second and in contrast to Gotham et al (2008) the number of load blocks used for discretelely including the Load Duration Curve (LDC) is determined optimally.

Results

The model shows on the one hand the effect of integrating system costs against the benchmark case without system costs and on the other hand the trade-off between lower fuel price costs and higher system costs.

In particular, wind power plants are chosen by the optimization model for diversification of the energy generation portfolio as it has no fuel price costs at all. This goes in line with previous studies. However, when additionally including availability risks such as forecast errors and volatility of wind speeds and subsequently accounting for higher systems costs, the diversification effect is reduced, but not entirely offset.

Moreover, the model shows that for high levels of risk aversion i.e. when stable overall electricity generation costs are desired, the additional systems costs only have a small influence on the choice of an optimal wind power capacity.

Conclusions

Unlike the current literature stream on modern portfolio theory and electricity generation, which considers renewable technologies as a hedge against fuel price risk because of their zero input costs, the present work additionally and explicitly accounts for one of the central characteristics of renewable technologies namely availability risk. The results stress the importance of considering both sources of risk in a single model as the diversification effect would otherwise be overweighted.

The current model proves to be a suitable tool for fairly including fuel price and availability risks in electricity portfolio selection.

References

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