QUANTIFYING ECONOMIC BENEFITS OF EUROPEAN ELECTRICITY SYSTEM INTEGRATION

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(1) Overview

European integration of the electricity system is argued to be an economically beneficial means for achieving key energy and climate policy targets, e.g. the long-term target to reduce greenhouse gas emission reductions by 80-95% relative to 2005, as endorsed by the European Union (European Parliament and the European Council, 2009; European Council, 2011). It is frequently argued that European electricity system integration constitutes a pivotal option to integrate high shares of renewables, leading to a reduction in GHG emissions. Also, it increases competition in the internal market for electricity, leading to lower prices. Further, it increases security of supply in the European Union through integrating remote areas, enabling a more diversified energy mix and reduced congestion. And, finally, progress in attaining these four climate and energy policy ends jointly contribute to the long-term European policy end of transitioning to a competitive low carbon economy. Despite these bold political statements, the respective arguments are given without any quantification, so the question is: How large are the economic benefits of European electricity system integration and what do they depend on?

(2) Methods

In order to quantify economic benefits of European electricity system we apply the model LIMES-EU+ (Haller et al., 2012). LIMES-EU+ is a partial electricity system model that is calibrated to the region of the European Network of Transmission System Operators for Electricity (ENTSO-E), that is the EU27 Member States plus Norway and Switzerland, and additionally covers the Middle East and North Africa (MENA) in order to enable an assessment of the merits of a Desertec-type interconnected electricity system. The objective function of the linear optimization model LIMES-EU+ is to minimize the total sum of discounted energy system costs (comprised of fuel, investment, fixed and variable operation and maintenance costs) jointly for all model regions between 2010 and 2050, given a number of boundary conditions like the constraint on annual CO_2 emissions. Endowed with perfect foresight, LIMES-EU+ iteratively yields a social planner solution that specifies in time steps of 5 years for each model region the optimal (i) dispatch and curtailment of installed electricity generation technologies, (ii) electricity import balance from neighboring model regions, (iii) investments into installed capacities of electricity generation technologies and (iv) investments into net-transfer capacities (NTCs) between model regions. In order to represent fluctuating feed-in of vRES and electricity demand occurring on sub-annual time scales, LIMES-EU+ uses a time-slice approach (cp. Ludig et al., 2011).

Different degrees of European electricity system integration are implemented in the model via restricting NTC expansion between neighboring model regions from one time step to the following one (ΔNTC). Additionally to we calculate for each NTC bound one scenario in which the option to connect the ENTSO-E regions to MENA regions (Desertec-tye connection) is at the model's disposal. The second scenario dimension in this analysis regards the development of variable renewable electricity generation (vRES) technologies' specific investment costs, which is highly uncertain (e.g. Yeh and Rubin, 2012) We consider three trajectories derived from literature estimates (Schröder et al., forthcoming) in the scenario definition: The two extremes of an optimistic (pessimistic) case in which vRES technologies' specific investment costs develop at the lower (upper) bound of the range, and a moderate case.

Table 1: Scenario definition matrix.

Electricity System Integration		Development of vRES Specific Investment Costs		
Δ NTC [GW/a]	Desertec (D)	Pessimistic (pes)	Moderate (mod)	Optimistic (opt)
= 0	-	0/pes	0/Mod	0/opt
≤ 0.25	-	0.25/pes	0.25/mod	0.25/opt
≤ 0.25	✔	0.25D/pes	0.25D/mod	0.25D/opt
≤ 0. 5	x	0.5/pes	0.5/mod	0.5/opt
≤ 0. 5	✔	0.5D/pes	0.5D/mod	0.5D/opt
≤ 1	-	1/pes	1/mod	1/opt
≤ 1	✔	1D/pes	1D/mod	1D/opt

(3) Results

This Section commences with characterizing the configuration of the European electricity system that evolves in the different scenarios and continues with the quantification of economic benefits of European electricity system integration by analyzing three endogenous model results as indicators for economic benefits of European electricity system integration: Total discounted system costs, CO_2 prices and electricity prices. A first observation is that the integration of the European electricity system is an investment option that is pursued in all scenarios the model is allowed to do so, with investments into NTCs not exceeding 1-2% of total discounted system costs in over the period 2010-2050. Overall, the scenario results indicate that NTC expansion constitutes a no-regret option as more NTC capacities lead to economically beneficial effects regarding the indicators total discounted system costs, CO_2 price, average electricity prices and the standard deviation (STDEV) of the electricity price distribution in all scenarios, particularly in the optimistic vRES investment cost scenarios, see Figure 1. A comparison of the impact of NTC expansion and vRES cost reduction indicates that for total discounted system costs and average electricity prices, the latter exert a significantly stronger effect. For CO_2 prices, their relative merits are in the same order of magnitude. However, their effects on the volatility of the electricity price distribution are complementary: While lower vRES investment costs lead to higher vRES shares and higher price volatility, more NTC capacities counter this effect through providing the possibility of balancing fluctuations in vRES feed-in between model regions.

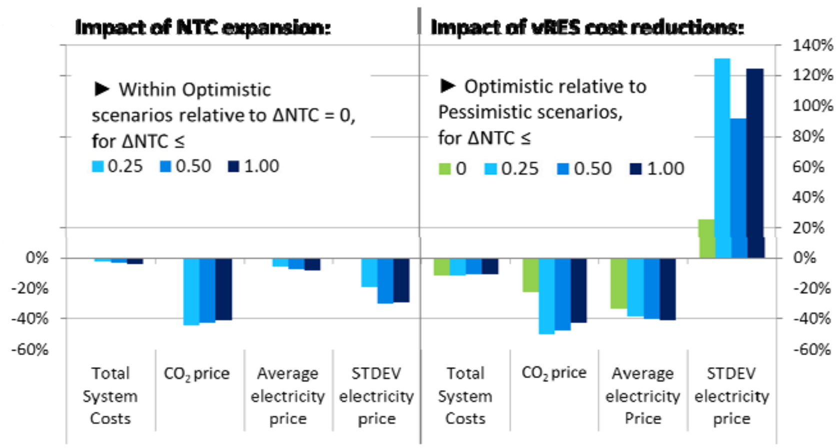

Fig. 1: Overview of the differential effects of NTC expansion (left) and reductions in the investment costs of vRES (right) on selected endogenous model results in 2040. Note that the technology mix is different in each scenario, and particularly between the different vRES investment cost scenarios inhibiting a ceteris paribus interpretation.

(4) Conclusions

According to the model LIMES-EU+, an integrated European electricity system (i) incurs slightly lower total discounted system costs (3-6%) over the period 2010-2050, (ii) reduces CO_2 prices by up to 60% and (iii) leads to a reduction of up to 10% in average electricity prices and up to 30% in the standard deviation of electricity prices, if vRES specific investment costs decrease according to optimistic figures in the literature and reduction targets of 80-95% CO2 emissions are respected until 2050. Thus, NTC expansion constitutes a no-regret option in the model. However, these results should be reconfirmed in future modeling exercises.

References

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