THE MARKET VALUE OF VARIABLE RENEWABLES

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Overview

The income that wind and solar power receive on the market is affected by the variability of their output. At times of high availability of the primary energy source, they supply electricity at zero marginal costs, shift the supply curve (merit-order curve) to the right and thereby reduce the equilibrium price of electricity during that hour. The size of this merit-order effect depends on the amount of installed renewable capacity, the slope of the merit-order curve, and the intertemporal flexibility of the electricity system. Thus the price of wind power falls with higher penetration rates, even if the average electricity price remains constant. This work quantifies the effect of variability on the market value of renewables using a calibrated model of the European electricity market. The relative price of German wind power (value factor) is estimated to fall from 110% of the average electricity price to 50% as generation increases from zero to 30% of total consumption. For solar power, the drop is even sharper. Hence competitiveness for large-scale renewables deployment will be more difficult to accomplish than often believed.

Research Topic

Solar and wind power are variable renewable energy sources (vRES). The market value of wind and solar power is the revenue they would earn if they sold their output on the market. It is affected by two intrinsic properties of vRES that dispatchable generators do not feature:

- The supply of vRES is *variable*. Electricity is not a homogenous good over time, thus the value of electricity depends on the point of time it is produced.
- The output of vRES is *uncertain* until realization. Deviations between forecasted generation and actual production need to be compensated for by other generators or load adjustments.

The effect of variability on revenues is sometimes called “profile costs”, because it depends on the shape of the generation profile. The effect of uncertainty is called “balancing costs”. Profile and balancing costs are not market failures, but represent the intrinsic lower value of electricity during times of high supply and the economic costs of uncertainty. This paper assesses the impact of variability on the market value of vRES and provides empirical estimates of profile costs.

There are two reasons why variability affects the market value of renewables. On the one hand, if the generation profile is positively correlated with demand or other exogenous parameters that increase the price, vRES receive a higher price. On the other hand, if installed vRES capacity is non-marginal, vRES supply itself influences the price: during windy and sunny hours, the additional generation shifts the merit-order curve to the right, reducing the equilibrium electricity price. The higher installed capacity is, the larger the price drop will be.

Methods

Two complementary methodologies are used in this paper to estimate vRES market values. First, historical market data from different European countries are collected. Next to presenting descriptive statistics, simple econometric methods are used to show that value factors have been reduced significantly with higher wind penetration.

The main methodological contribution of this paper, however, is a newly developed numerical model of the North-Western European electricity market. The model minimizes total system cost to supply given demand, which is the sum of capital costs for generations, transmission and storage, fuel and CO_2 costs, and other fix and variable costs. Decision variables are production of each generation technology, investments, and electricity trade between regions. Constraints include capacity limitations and constraints related to the provision of heat and ancillary services. Modeling investment endogenously allows estimating the short term, mid term, and long term equilibrium. The model is specified at an hourly resolution to realistically capture the characteristics of vRES.

Results

A core model result is that value factors fall quickly with higher vRES penetration. As the market share of wind power in Europe increases from zero to 30% of total electricity consumption, its value factor drops from 1.1 to 0.5.

This finding holds for electricity systems with limited amounts of flexible hydro power. That means that for wind power to become competitive, cost need to fall twice as much as estimated by studies that do not take the merit-order effect into account. Despite solar power being better correlated with demand, its value factor drops even faster, because generation is concentrated in fewer hours. Model results indicate that several factors and policies have significant influence on profile costs, such as CO_2 and fuel prices, interconnector capacity, and power plant flexibility. However, the effects are sometimes quite counter-intuitive: higher gas and coal prices, for example, can *reduce* wind income by inducing investments in lignite and nuclear power.

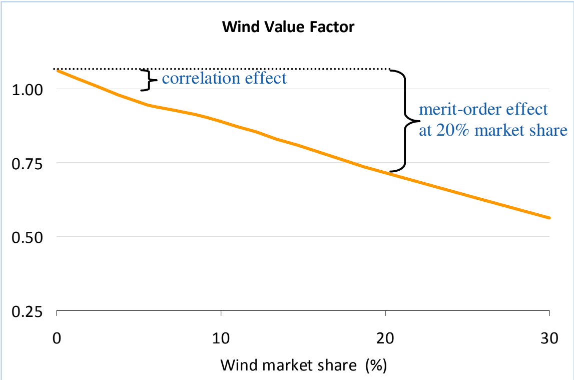

Figure 1: Modeled value factor of wind under benchmark assumptions. As penetration rates increase, wind power becomes relatively less valuable, compared to a constant source of electricity.

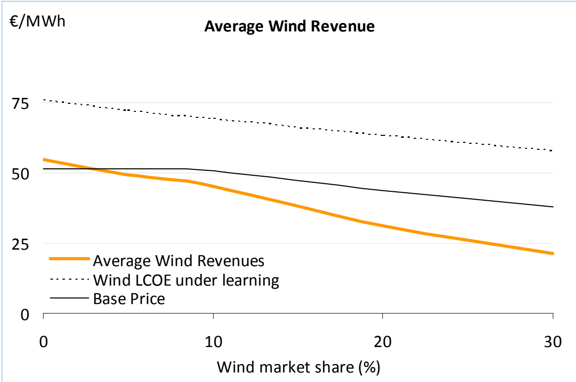

Figure 2: Average specific revenue of wind (orange), base price (black), levelized costs of onshore wind power (dotted) under benchmark assumption and a learning rate of 5%. Market income is reduced more quickly than costs, implying that wind power does not become competitive under the present assumptions.

Conclusions

Electricity systems with limited intertemporal flexibility provide a frosty environment for low-marginal-cost variable renewables like wind and solar power. If significant vRES capacity is installed, the merit-order effect depresses the electricity price whenever the primary energy source is available. This merit-order effect reduces the valance of wind and solar power. While today in Germany, wind power has a relative price of more than 0.9 of the base price, this value factor is estimated to drop to 0.5 as the wind market share grows to 30%.

Several factors have been identified that significantly impact the value factors of solar and wind power. The three most important drivers seem to be a) the CO2 price in combination with availability of low-carbon low-variable-cost dispatchable technologies (nuclear and CCS), b) long-distance interconnections, and c) the flexibility of must-run generators, especially CHP plants. Fuel prices and additional storage capacity have only limited effects on wind, but storage does increase the value of solar.

While keeping methodological shortcomings such as the lack of hydro modeling in mind, several policy conclusions can be drawn from these results. First, increasing the flexibility of the system through demand response, transmission investments and relaxed constraints on conventional generators should be a top priority for research, engineering, and policy. Results presented here indicate that making CHP generators more flexible could be a relative quick win. Second, at today's electricity system parameters and prices, wind and solar power will have a very hard time to become competitive on the market on large scale, even with quite steep learning curves. Research as well as policy should take the possibility of a limited role for solar and wind power into account. Finally, the results indicate how important it is to develop alternative low-carbon electricity sources to reach ambitious climate and renewable targets. This includes dispatchable generation, but also variable sources that are negatively correlated with wind and solar power.

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