Increasing or Diversifying Risk? Tail Correlations, Transmission Flows and Prices across Wind Power Areas

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Before wind power became a mature technology, generation tended to be built out in countries and regions that provided financial support, such as Denmark and Northern Germany in Europe and California in the United States. This often meant that wind power was geographically concentrated.

Wind power costs have come down dramatically in the previous decade, and onshore wind power is often competitive with traditional generation in many areas. This has meant that wind power capacity has been built up in many more locales, often in countries or regions adjacent to each other. Given available transmission capacity, such geographic dispersion can act as a form of diversification: Mitigating the risks that stem from wind power's intermittency. When there is less wind power in one place, power can be transferred from a neighboring area where the wind is blowing.

However, experience from other asset classes--both real and financial--have shown that risks that appear to be diversified away in normal times, may show strong correlations during extreme events. In the context of electricity markets with high penetrations of wind power, the risk that has been most explored is the systemic risk that may come from periods of low wind power generation leading to a shortfall of generation relative to load. Yet there is also a risk of too much wind generation. If wind is highly correlated across areas at high production times, then it could have the effect of driving down the price towards the short-run marginal cost of wind power--near zero. This price risk is born by wind power producers, but also owners of other generation assets that face lower-than-expected prices and more price volatility. There is also a risk born by the power system as a whole, as excess generation can lead to increased balancing costs and expensive curtailment. The extra uncertainty around prices and electricity market operations can lead to a higher cost of capital, with adverse effects on further investments.

In this article we study data from Denmark and Sweden: Two countries with large wind power penetrations, which are connected through both large physical transmission capacity as well as through the common Nordic electricity market. We use hourly data from 2016 and 2017 on wind power production, electricity prices, transmission capacities and flows. We particularly focus on the eastern price area in Denmark, called DK2, consisting of the island of Zealand, where the Copenhagen metropolitan area is located. This price area lies between and has large transmission links to both the western Danish area, which contains large amounts of wind, and the southernmost Swedish price area, which also has a high penetration of wind power.

We first present some descriptive evidence that suggests that for much of the distribution of wind power generation, geographic dispersion of wind power can have a diversifying effect. Correlations between wind power production--even in adjacent areas--are relatively weak. However, a marked difference appears in the 90th decile of the distribution of wind power production. Wind power production at the highest deciles in a given price area are strongly correlated with wind power production in adjacent areas. This suggests that the pattern of power flow, congestion in the network,

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and marginal price effects may be substantially different in these tail periods compared to average marginal effects.

To more formally explore the patterns of wind power distribution on prices and flows, we develop a flexible but also simple and robust methodology: A dynamic decile group model. We decompose the price and flow variables that serve as our dependent variable into deterministic and stochastic components. Then, instead of estimating an average marginal effect of wind power, we allow the effect of wind to vary by decile of production.

Our modeling reveals wind power's nuanced effects on pricing and exchange on the electricity market. Wind produced in DK2 at low deciles tends to have little to no effect on prices. Instead, the main effect of wind power in this area is a linear effect on net exchange towards the Swedish price area, which in turn is connected to the flexible hydro power in the Swedish northern price areas. However, at the highest decile, when wind power is highly correlated across areas and there is a high probability of congestion in the transmission network, wind power tends to have an out-sized effect on prices.

In summary, this article contributes to the literature on investment and integration of wind power in power markets in several ways: 1.) We provide evidence for geographic diversification of wind power production at moderate levels of production in the areas of the Nordic market with the highest penetrations of wind power. 2.) We provide evidence that this diversifying effect fails to hold at the highest quantiles of production when wind power production becomes highly correlated across adjacent areas. 3.) We devise a novel econometric model that takes into account the dynamics and seasonality in the power market time series while allowing the effects of wind power to vary over the distribution of production. 4.) We add support to previous findings of a disproportionately stronger effect of wind power on prices at the highest quantiles of production and extend these findings to show that these results are highly dependent on the pattern of transmission and congestion in the system.