Blowing Water Away: Increased Wind Power Production in a Stored Hydro Power System

Olvar Bergland
UMB School of Economics and Business
Norwegian University of Life Sciences
N-1430 Ås, Norway
olvar.bergland@umb.no

Cecilie Margrethe Jonassen
UMB School of Economics and Business
Norwegian University of Life Sciences
N-1430 Ås, Norway

Overview

The transition to a low-carbon future will lead to a substantial increase in electricity production from new renewable sources and phasing out of traditional thermal generation. Many of the new generating sources such as wind, solar and small-scale hydro are intermittent sources and can not be trusted for a reliable delivery of power without either energy storage or supplementary generating sources. Hydro based power generation can provide a viable and clean complementary source of power provided sufficient storage, generating and transmission capacity. From a European perspective hydro power in Norway and Sweden can serve in this capacity.

The interaction between thermal generation and hydro power has been discussed, among others, by Førsund (2007) and Bobtcheff (2011). Førsund (2011) presents and discusses a dynamic model where a reservoir based hydro system is used to absorb and even out the stochastic nature of wind power production.

The purpose of this paper is investigate the effect of a substantial increase in stochastic wind power production into a combined thermal and hydro system with reservoirs. We use a structural model of demand and supply in one country with thermal and wind production connected through limited transmission capacity with another country with exclusively stored hydro production. By changing the scale of wind production and the capacity of transmission between the two countries the model we are able to trace the effects of expanded wind production and system integration on prices, quantities, and consumer's and producer's surpluses.

Methods

We estimate a structural econometric model for supply and demand in Western Denmark, representing a combined thermal and wind production system, and for supply and demand in Southern Norway, representing a pure reservoir based hydro power system. The supply function for the hydro producers depends on the water value, or the shadow price on stored water, which in turn depends on the current reservoir content relative to normal reservoir content for the season. A specification consistent with the theoretical model by Evans, Guthrie and Lu (2013).. This gives us a dynamic model of the hydro system. Using historical data for wind production, water inflow and demand drivers such as temperature and daylight we are able to simulate the power production, consumption and prices as well as the direction of the power flow between the two countries. Furthermore, the model gives detailed information about changes in consumer's and producer's surplus in the two countries. The model can be used to simulate, among other things, the effects of increased wind power production capacity, reduced thermal production capacity and expanded/contracted transmission capacity between the two countries.

Results

By increasing the production of wind power the average price falls in both countries. The consumer's surplus increases in both countries, while producer's surplus decreases for thermal producers. The effect on hydro producers is not unambiguous;

for small increases in wind power production the hydro producer's surplus increases, while for larger increases the price effect of the outward shift in the supply also leads to a decrease in producer's surplus for the hydro producers. Furthermore, the amount of spilled water (overflow of the reservoirs) is increasing with increased wind power production. Larger transmission capacity between the countries evens out price variations and differences, and reduces the amount of spilled water.

If the expansion of wind power is combined with a more active retirement of thermal production capacity the prices remain higher in both countries. Both the price variability in the country with wind production and the amount of spilling in the hydro based country depends strongly on the (relative) transmission capacity between the two countries.

Conclusions

The empirical analysis shows that with hydro power systems with sufficient reservoir capacity and sufficient transmission capacity between the two countries, large scale introduction of stochastic wind production can be absorbed resulting in only small increases in price volatility. However, the increased wind production results in more frequent periods where water is spilled due to overflow of the reservoirs. The reservoir capacity is valuable as a “storage” of wind power, but the increase in production of power tend to reduce prices as long as the thermal production capacity remains. A decrease in thermal capacity along with an expansion in wind production is possible without a sharp increase in price volatility as long as the transmission capacity is sufficient large.

References

Bobtcheff, C. (2011). Optimal Dynamic Management of a Renewable Energy Source under Uncertainty. *Annals of Economics and Statistics*, 103/104, 343-372.

Evans, L. G. Guthrie and A. Lu (2013). The Role of Storage in a Competitive Electricity Market and the Effects of Climate Change. *Energy Economics*, 36:405-418.

Førsund, F. R. (2007). *Hydropower Economics*. Springer.

Førsund, F. R. (2011). Phasing in Large-Scale Expansion of Wind Power in the Nordic Countries. *Working Paper*. CREE, Oslo.