TRADED IN FOR A YOUNGER MODEL:
WHEN SHOULD WIND FARMS BE REPLACED?

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(1) Overview

When does it make sense to replace an old turbine with a better one? With most of Europe constrained for space, firms face a choice between developing new wind farms at poor sites (if the best have already been exploited) or repowering an existing site with better wind conditions. The disadvantage of the second option is that it sacrifices the output that the existing turbines could have produced. We use a large wind speed data set to assess the productivity of wind farms in the UK, isolating the effects of different sites, different vintages and ageing. This will allow us to calculate which vintages of wind farms could profitably be replaced with state-of-the-art machines, and when this should happen.

(2) Methods

We use hourly wind speeds from NASA's MERRA data to estimate the output that a perfect wind farm would produce at a given location, according to the available wind resource and its turbine power curve. The technique is explained by Staffell & Green (2013), and allows us to reveal the underlying technology-driven effects, answering the questions: How fast are wind farms losing performance due to ageing? How fast is turbine technology improving? Are we running out of the good locations to put our wind farms?

We estimate the output from the 281 wind farms operating in the UK between 2002 and 2012, and compare this to reported outputs over this period. We perform two regressions, comparing the reported output against estimated yield from the actual turbine models installed at each site, and against the estimated yield from modern turbines in these locations. Fixed effects are used to account for individual farms (to control for local site conditions such as turbulence, wake effects within the farm, and the like), and for the age of the turbine (to measure the impact of wear and degradation).

(3) Results

We find that our source of wind speed data validates well for individual sites and for the UK fleet as a whole, as in Fig 1. There is a gap of around 25% between actual and "ideal" performance, due to the effects listed above.

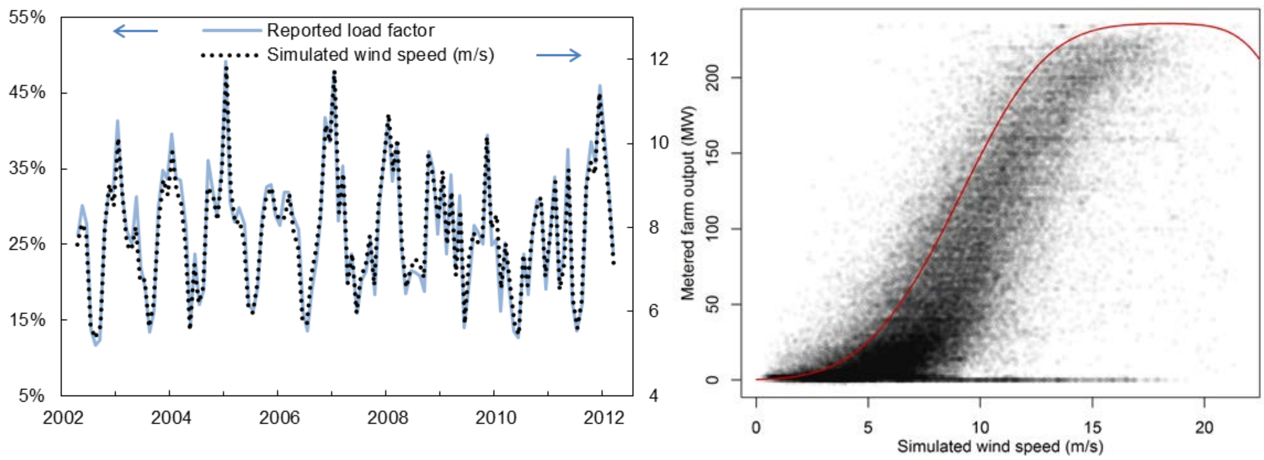

Fig. 1: Correlation between simulated wind speeds and actual turbine output: *(left)* monthly aggregates for the UK national fleet; *(right)* hourly values for Hadyard Hill in SW Scotland.

Fig 2 highlights two features of the UK wind fleet: sites are getting worse, and farms suffer from the effects of ageing. We find that if farms had used identical turbines over time, their starting load factor would have fallen by a fifth over the last two decades, falling from 32% for early 1990s sites to just below 26% for early 2010s sites. A farm's output also declines by a quarter over the first 20 years of life as a result of mechanical wear, blade soiling, and other forms of degradation. After initial teething troubles in the first year, new farms of an average design at an average site would achieve a 28% load factor when new, which would fall to 21% by their nineteenth birthday.

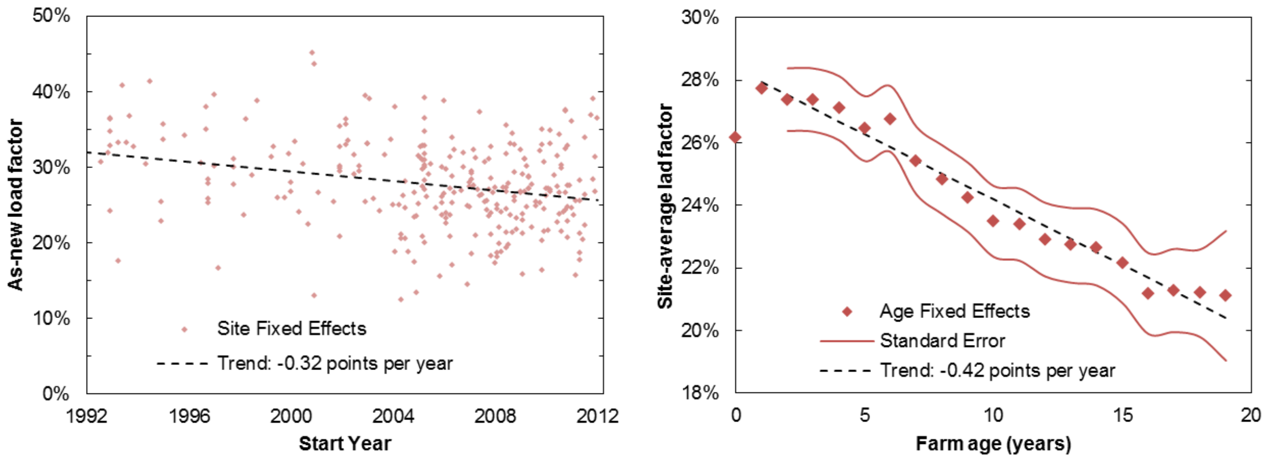

Fig. 2: Regression of observed vs. expected load factors: *(left)* standardised load factor of each farm when new; *(right)* the impact of aging on a farm's standardised annual average load factor.

Countering these effects is the fact that turbines are getting better. Comparing the potential yield from modern 80m turbines with those actually installed reveals that the rate of technology improvement has offset the decreasing suitability of sites, so that there is in fact no overall trend in load factors over the last 20 years. This improved performance is primarily driven by increasing hub heights.

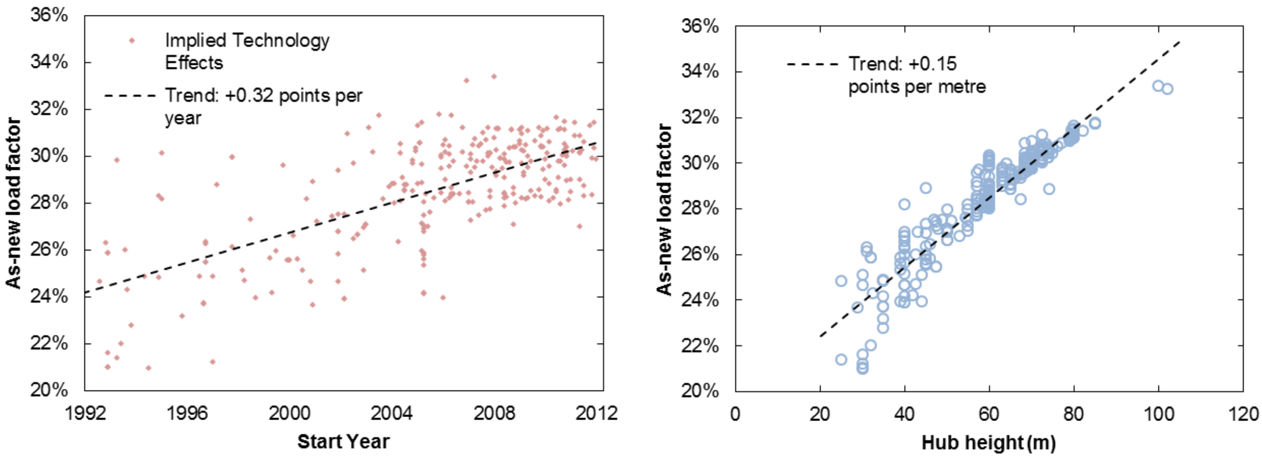

Fig. 3: Comparison of the site fixed effects from the two regressions: *(left)* giving the rate of technology progress over two decades; *(right)* which is strongly correlated to increasing turbine hub height.

(4) Conclusions

We have shown to what extent the lower quality of many more recent sites has affected the output of wind turbines, and that this has almost exactly offset the benefits of better, taller, turbines in the UK. Our initial calculations show that these gradual declines in site suitability and turbine performance are not sufficient to justify re-powering many wind farms before the end of their design lives, even though a new set of turbines would produce more power. Our results are likely to have implications for the future trajectory of subsidies.

References

Staffell, I and R Green (2013) "How Does Wind Farm Performance Deteriorate with Age?", *mimeo*.