Wind Power Investment

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Abstract

Due to increasing concern with climate change, producing energy from the wind has become an tool to substitute electric production away from fossil fuels. In the last decade, wind power capacity has grown tenfold, reaching 42% of newly installed electric capacity in 2008, yet accounts for less than 2% of electric generation. We study the determinants of investment choices in wind generated electricity. First we look at the permitting process for electric power by gathering information from the interconnection queues from ISOs across the country. We find large differences in the number of proposed versus completed projects in different ISOs, with high completion rates in ERCOT versus low completion rates in NYISO and NEISO. Second, we collect extensive data on the revenues of wind farms to evaluate the entire economic costs of these wind farms to the utilities that purchase power from them, and find large dispersion in the price of wind power. Finally we evaluate the role of technological change in wind power - principally due to larger windmills which enjoy increasing returns to scale - in driving further investment into wind power. The estimated cost of wind farms is used to investigate the effect of several policies, such as increasing the production tax credit, increasing investment tax credits and introducing a European style feed-in tariff, on the long-run supply curve of wind power.
1 Introduction

This paper tries to understand the decision to build renewable electric power generators, and how different policies could encourage the build out of wind turbines over the next 20 years. The importance of electric power generated without fossil fuels is quite relevant to the broader debate on global warming, and which measures could reduce greenhouse gas emissions. Indeed, coal, gas and oil fired electric power plants are responsible for more than 40% of carbon dioxide emissions in the United States.

Wind power is increasingly seen as an alternative to coal, oil and gas generators for producing electricity. For instance, Denmark now produces 26% of it’s electricity using wind power, while in the United States wind power accounts for 1.1% of total electric power generation and 3% of generating capacity. Figure 1 presents installations and total installed capacity of wind-power. The bottom panel shows that total installed capacity has increased from almost zero to more than 30 000 MW from 2000 to 2009. Likewise, the top panel shows that installations of wind-power peaked in 2008 with 10 000 MW of new capacity. Table 2 presents windfarm installations broken down by state, with Texas having about 40% of installed wind power in the United States.

Wind powered installations receive approximately 2/3 of their revenues from government programs, primarily the Production Tax Credit (henceforth PTC) which gives wind a 21\$ tax credit per megawatt hour of production for their first ten years of operation, and from state level Renewable Portfolio Standard (henceforth RPS) which raise the contracted prices for wind-power above wholesale prices for other sources of power. Thus there cannot be a discussion of wind-power buildout without a discussion of the evolution of government programs which support this buildout.

The main policies that we consider are how change in the PTC and state RPS mandates would affect the growth of wind powered electricity production over the next decade. Some of these policies, such as the PTC, are uncertain, and we want to quantify the effect of this uncertainty on investment choices. Moreover, the are other techniques for subsidizing wind powered electricity such as the Feed-In-Tariff, a guaranteed price for renewable produced electric power, which has been used in much of Europe to foster wind energy. We also analyze how a Feed-In-Tariff would affect the location and intensity of wind investment. Finally, a recent policy development is also examined, the use of Renewable Energy Certificates (henceforth REC). These REC’s allow a utility in say Massachusetts, to purchase the renewable attributes of electricity produced by a wind turbine in Texas. To the extent that there is stronger wind in North Texas than in New England, this will induce the buildout of wind turbines in areas which have high wind speed, rather than in areas with strong...

Figure 1: Installed Capacity and Yearly Installations of Wind Power
support for renewable power.

Finally, we also seek to quantify the effect of policies that may impede the buildout of wind-farms. The two most important ones are the issue of grid interconnection costs and delays and local land use regulations which may make it disproportionately difficult to get permits to build a wind-farm in say Massachusetts versus say Texas. Rather trying to measures these obstacles directly, we will quantify the size of the obstacles needed.

Note that our paper will have

2 Data

The data on windfarms are collected from an assortment of sources which are summarized in Table 1.

1. Interconnection queues
   Entry in the queue date ($\chi_{it}^A = 1$), capacity $k_i$, location, withdrawal decision ($\chi_{it}^W = 1$), interconnection agreement date ($\chi_{it}^{IA} = 1$).

2. AWEA projects database:
   Build date $\chi_{it}^b = 1$, Turbines Type, Developer, Power Purchasser.

3. EIA Form 860 and 923
   Windfarm location $l_i$, capacity $k_i$, generation $q_{it}$, interconnection costs.

4. EIA Form 923-Schedule 7 and FERC EQR
   Data on power contracts, prices $p_{it}^{C,EIA}$, $p_{it}^{C,EQR}$ and quantity $q_{it}$ for resales.

5. Platts:
   Wholesale price data $p_{it}^{S,Peak}$ and $p_{it}^{S,Off-Peak}$.

6. NREL EWITS Study:
   Potential Windfarm location and capacity $k_i$, windspeed $w_i$.

Table 1: Data Sources

3 Model

Our model proceeds in three major steps. First a windfarm decides if they want to apply for interconnection at a location $l_i$, which we call the application
decision $\chi^A$. Second, conditional on getting approval, the windfarm decides to build $\chi^B$. Finally, a built windfarm enjoys profits from its operation over a 20 year period. Figure 2 illustrates the timing of the model.

- Location $l_i$ picked with $\omega_i$ wind speed and capacity $k_i$.
- Apply for interconnection $\chi^A_{it}$.
- Get Interconnection Agreement $IA_{it}$.
- Sign Long-Term Power Purchase Agreement at price $p^C_{it}$.
- Build Wind Farm $\chi_{it}$ at cost $C_i$.
- Receive Profits $V^b(p^C, w_i, k_i)$

Figure 2: Model Outline

### 3.1 Value of a built Windfarm

Value of Building $V^b$ is:

$$
V^b(q_i, p^C, k_i) = \sum_{\tau=1}^{10} \beta^\tau \left( (p^C_{i\tau} + \tau PTC)q_i - OM(k_i) \right) + \sum_{\tau=11}^{20} \beta^\tau \left( p^C_{i\tau}q_i - OM(k_i) \right)
$$

(1)

Figure 3 presents the NPV computed for the windfarms in the data.
Figure 3: Net Present Value Per Unit of Capacity from a Built Windfarm
4 Appendix

Wind Resource in the United States

Figure 4: Wind Speed and Wind Farm Locations

Source EWITS Study and EIA Form 860
<table>
<thead>
<tr>
<th>State</th>
<th>MW Capacity Installed</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX</td>
<td>9373</td>
<td>81</td>
</tr>
<tr>
<td>IA</td>
<td>3435</td>
<td>35</td>
</tr>
<tr>
<td>CA</td>
<td>2510</td>
<td>61</td>
</tr>
<tr>
<td>WA</td>
<td>1999</td>
<td>14</td>
</tr>
<tr>
<td>OR</td>
<td>1610</td>
<td>20</td>
</tr>
<tr>
<td>IL</td>
<td>1582</td>
<td>15</td>
</tr>
<tr>
<td>MN</td>
<td>1457</td>
<td>26</td>
</tr>
<tr>
<td>ND</td>
<td>1321</td>
<td>18</td>
</tr>
<tr>
<td>CO</td>
<td>1218</td>
<td>10</td>
</tr>
<tr>
<td>OK</td>
<td>1129</td>
<td>13</td>
</tr>
<tr>
<td>Remaning States</td>
<td>8509</td>
<td>120</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>34143</td>
<td>413</td>
</tr>
</tbody>
</table>

Capacity is production if the wind blows all the time. Production is on average 1/3 of capacity called the capacity factor.

**Table 2: Installed Wind Capacity by State**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windturbines†</td>
<td>514</td>
<td>58</td>
<td>146</td>
<td>1</td>
<td>3046</td>
</tr>
<tr>
<td>Capacity in MW†</td>
<td>514</td>
<td>67</td>
<td>84</td>
<td>1</td>
<td>736</td>
</tr>
<tr>
<td>Generation in MWH†</td>
<td>508</td>
<td>144777</td>
<td>184588</td>
<td>0</td>
<td>1269348</td>
</tr>
<tr>
<td>Generation MWH per MW of Capacity†</td>
<td>507</td>
<td>2199</td>
<td>931</td>
<td>0</td>
<td>5622</td>
</tr>
<tr>
<td>Price per MWH†*</td>
<td>419</td>
<td>47</td>
<td>21</td>
<td>14</td>
<td>212</td>
</tr>
<tr>
<td>Year Built</td>
<td>508</td>
<td>2003</td>
<td>6.8</td>
<td>1981</td>
<td>2009</td>
</tr>
</tbody>
</table>

Source: † EIA Form 860, 923, 923 Schedule 7. * FERC EQR.