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Carbon price and wind power support in Denmark

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HIGHLIGHTS

- I analyze wind power development in Denmark between 2000 and 2010.
- I use probit and tobit techniques to assess the determinants of this deployment.
- The level and policy type of wind power support are the main drivers.
- I deduct the critical level of premium needed to trigger wind power.
- I convert this into an equivalent carbon price and I find that it is below 50€/ton.

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ABSTRACT

This paper aims at characterizing the conditions of wind power deployment in order to infer a carbon price level that would provide wind power with comparable advantage over fossil fuel technologies as effective wind support policies. The analysis is conducted on Denmark after the electricity market liberalization. Probit and tobit techniques are employed to take account of a potential threshold effect. I find that the level and type of the support policy are the dominant drivers of deployment. A feed-in tariff significantly brings more wind power in than a premium policy. The additional capacity installed monthly increases by more than 1 MW for each additional €/MWh of support. This is compared to the effect of the electricity price, investment cost, interest rate and general economic activity. If the policy is a premium, I find that 23€/MWh of support in addition to electricity price is needed to observe the connection of new turbines to the grid with a 0.5 probability. I convert this support level into a carbon price of 27€/ton if wind power competes with coal, and 48€/t if it competes with gas.

1. Introduction

In Europe, the 2030 climate and energy framework, like the 2020 package, includes three objectives: one on greenhouse gases emissions reductions, one on renewable energy, and one on energy efficiency. National renewable energy (RE) support policies (EU, 2009) have coexisted with a common carbon market. While the European Union Emission Trading Scheme (EU ETS) is designed to curb carbon emissions, renewable energy support policies aim at increasing the share of renewable energy sources in total energy consumption, in particular to improve energy independence. However, renewable energy resources are not necessarily the most efficient way to decrease carbon emissions, as underlined for example by Palmer and Burtraw (2004) or Fischer and Newell (2008). Energy consumption reduction as well as efficiency improvement might be other ways to reduce emissions. The coexistence of these instruments raises several questions. What is the actual abatement cost of renewable energy support policies? What is their impact on the European carbon price? What is the impact of the latter on renewable energy deployment? Do the instruments mutually reinforce or weaken one another?

Some studies already enlighten these questions. For example, Marcantonini and Ellerman (2015) calculate the annual CO_2 abatement cost of renewable energy incentive in Germany in the time period 2006–2010. They find that the CO_2 abatement cost of wind power is relatively low (the average for 2006–2010 is 43€/tCO_2) while CO_2 abatement cost for solar energy is very high (the average for 2006–2010 is 537€/tCO_2). Fischer and Preonas (2010) develop a theoretical framework to explain interactions between overlapping energy and climate policies. Morris (2009) shows that, in the U.S., a renewable energy portfolio standard (RPS) in addition to an emission trading scheme would increase welfare cost compared to a trading scheme alone. The reason is that the RPS reduces the flexibility for power producers to choose the cheapest abatement solutions. Other studies on the United States case question the usefulness to have renewable energy policies in parallel of a national cap-and-trade system (Paltsev et al., 2009; McGuinness and Ellerman, 2008). On the European case, Weigt et al. (2013) model the German power sector to analyze the carbon abatement due to renewable energy in Germany and the

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Table 1
On-shore wind support policies in Denmark between 2000 and 2010 (Source: Jaureguy-Naudin, 2010).

Date of connection to the grid	Support scheme
From 1976 to 1989	Financial support from the Danish state.
From 1984 to 2001	Electricity price paid to producers: 85% of the local retail price, excluding taxes
From 1991 to 2001	Fixed premium of 36€/MWh in addition to the previous scheme
Existing turbines bought before the end of 1999	Feed-in tariff of 80€/MWh for a number of full load hours Then feed-in tariff of 58€/MWh until the turbine is 10 years old Then premium of 13€/MWh or less until the turbine is 20 years old
From 2000 to 2002	Feed-in tariff of 58€/MWh for 22,000 full load hours Then premium of 13€/MWh or less until the turbine is 20 years old with a limit of 48€/MWh on the sum of market price and premium Additional premium of 3€/MWh
From 2003 to 2004	Premium of 13€/MWh or less until the turbine is 20 years old, with a limit of 48€/MWh on the sum of market price and premium. Additional premium of 3€/MWh
From 2005 to February 20th 2008	Fixed premium of 13€/MWh until the turbine is 20 years old Additional premium of 3€/MWh
After February 21st 2008	Premium of 34€/MWh for the first 25,000 full load hours Additional premium of 3€/MWh

impact of carbon price on this, for the time period 2006–2010. They estimate that CO_2 emissions from the electricity sector are reduced by 10–16% of what estimated emissions would have been without any RE policy. They also find that the abatement attributable to RE injection is 4–10% greater in the presence of a carbon price than otherwise. In conclusion, Weigt et al. actually find that both instruments reinforce one another.

In the context of a dual objective of energy independence and emissions reductions, and under the constraint of tight public budgets, the question is raised whether a carbon price alone could achieve comparable renewable energy deployment as effective renewable energy support policies. On this question of comparable carbon price level, Blanco and Rodrigues (2008) compute a carbon credit level equivalent to each national wind support policy in effect in Europe in 2006. Their analysis includes the 27 member states of the European Union. They use assumptions on the amount of greenhouse gases avoided by wind energy but they do not take account of the actual impact of each policy on wind power deployment. On the other hand, many studies compare the impact of various types of renewable support policies, without necessarily taking into account the stringency level of each of them. It is the case of Menz and Vachon (2006) on the United States experience.

The purpose of the work presented here is to analyze the conditions that lead to wind power deployment, to infer the carbon price level that would provide wind power with a comparable price advantage over fossil technologies, and to compare this level with the European carbon price. The analysis focuses on Denmark because of the frequency of changes in the type and level of its wind support policies and the large amount of data available for wind energy. We examine the time period after electricity market liberalization. The existing debate on the coexistence of renewable energy support policies and an emission trading scheme is indeed conducted in the context of a liberalized electricity market. This work provides some insights on the issue in this context. The wind power profit function is used to identify the parameters that might impact wind power deployment. A discrete choice econometric model (probit) is employed to test the effect of these parameters on new on-shore wind turbine connections to the grid on a monthly basis for the time period 2000–2010.[1] Tobit technique is used to estimate the effect of the same parameters on the additional wind power capacity installed each month. The probit estimates allow calculating the probability of new connections to the grid as a function of the support policy type and level. The support level needed to attain wind power deployment with a probability of 0.5 is converted into a carbon price that would provide wind power producers with a comparable price advantage compared to coal or gas power plant owners. This carbon price is computed from the difference in profitability between renewable and fossil fuel technologies.

In Section 2, the history of wind power in Denmark is presented as the context of the work. Section 3 explains the theoretical background on which the econometric analysis and carbon price inference are based. It introduces the econometric models employed. Section 4 shows how the database is prepared. In Section 5, results are presented and discussed.

2. Wind energy in Denmark

On shore wind support policies began in Denmark in 1976 (Energistyrelsen; Jaureguy-Naudin, 2010). They are summarized in Table 1. Between 1976 and 2000, several policies juxtaposed each other and sometimes overlapped. From 1976 to 1989, the Danish state reimbursed part of the investment for building wind turbines. The support was originally 40% of the investment cost and was then reduced gradually until the scheme was cancelled in 1989. From 1984 to 2001, the electricity price paid to producers of wind power was 85% of the local retail price of electricity excluding taxes. In 1991, a fixed price premium of 36€/MWh was introduced in addition to the previous scheme. It was in place until 2001.

In 1999, the Danish electricity market was liberalized. Existing turbines were then covered by a special feed-in tariff (FIT)[2] which

[1] The choice is made to focus on on-shore wind power only as off-shore wind power is significantly different, for example in terms of cost and grid infrastructure development. On-shore wind capacity and generation were respectively 2.82 GW and 5.072 TWh in Denmark in 2009, compared to 0.662 GW and 1.644 TWh for off-shore wind. Total power capacity was approaching 13 GW in 2009 and total power generation was 34 TWh.

[2] A feed-in tariff is a guaranteed price that power producers receive for every kWh they produce, instead of receiving the market electricity price. It provides more revenue certainty than a premium policy under which the electricity price