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The market value and impact of offshore wind on the electricity spot market: Evidence from Germany

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HIGHLIGHTS

- Market value of offshore wind based on feed-in and weather data is assessed.
- Merit order effect caused by wind energy is simulated for 2006–2014.
- Results indicate same impact of on- and offshore wind on market price and value.
- Steadier wind resource offshore imposes less variability on market price.
- Characteristic of variable wind feed-in cannot be blamed for price deterioration.

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ABSTRACT

Although the expansion of offshore wind has recently increased in Germany, as in other countries, it is still forced to defend its role in long-term energy policy plans, particularly against its onshore counterpart, to secure future expansion targets and financial support. The objective of this article is to investigate the economic effects of offshore wind on the electricity spot market and thus open up another perspective that has not been part of the debate about offshore vs. onshore wind thus far. A comprehensive assessment based on a large amount of market, feed-in and weather data in Germany revealed that the market value of offshore wind is generally higher than that of onshore wind. Simulating the merit order effect on the German day-ahead electricity market for the short term and long term in the years 2006–2014 aimed to identify the reason for this observation and show whether it is also an indication of a lower impact on the electricity spot market due to a steadier wind resource prevailing offshore. Although the results suggest no difference regarding the impact on market price and value, they indeed reveal that offshore wind imposes less variability on the spot market price than onshore wind. In addition, the long-term simulation proved that the ongoing price deterioration cannot be blamed on the characteristic of variable wind production.

1. Introduction

Even prior to the disaster at the nuclear power plant in Fukushima, Germany's long-term energy strategy was dedicated to sustainable development of its energy supply and a reduction of its economic costs that also took into consideration long-term external effects and a conservation of fossil resources [1]. However, the energy turnaround ("Energiewende") that was enacted as a consequence, which designates a change of the energy mix towards a domination of renewable energy sources [2], and the nuclear phase-out in 2011 generated more emphasis and determination for this intention [3]. Wind energy is one of the key technologies that should ensure the success of the energy turnaround and is thus endowed with a benevolent subsidy scheme. Fig. 1 shows the expansion of wind energy in Germany during the past several years and a medium-term prognosis until 2019. According to the current German Renewable Energies Act (Erneuerbare-Energien-Gesetz (EEG)) [7], the expansion target for onshore wind is defined to be a net (difference between addition and decommissioning) annual increase in installed capacity of 2.5 GW and a total offshore wind capacity of 6.5 GW in 2020 and 15 GW in 2030. This would lead to an electricity generation market share of at least 18% in 2020, which reflects the increasing importance of wind energy in the German electricity industry [4].

Abbreviations: German Renewable Energies Act (Erneuerbare-Energien-Gesetz), EEG; transmission system operators, TSOs; average, AV; coefficient of variation, CV.

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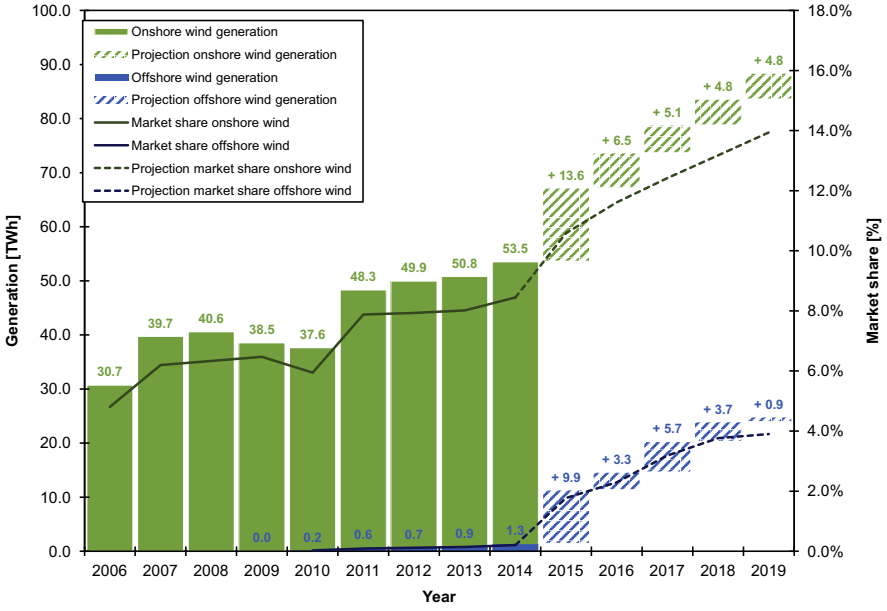

Fig. 1. Increasing importance of wind energy in the German electricity market [4–6].

Onshore wind in particular seems to have demonstrated that it is a key pillar of the German energy turnaround. By contrast, offshore wind is still in its nascent stage. There might be several reasons for this, such as the great distance to shore and water depth at the planning sites, which imply considerable effort. Another possible reason could be that the German state may have underestimated the burden that is coupled with the responsibility of ensuring grid connection for all wind farms far away from shore. These circumstances consistently promote discussion on the future role of offshore wind in the German energy turnaround, especially compared with its onshore counterpart in the battle for subsidies. The reviews [8,9] show that many pros and cons should be considered in this discussion. However, the economic effects occurring when onshore and offshore wind production is traded on the electricity spot market have not been part of these comparisons so far although they might be of significant importance in changing the energy mix. This article thus analyses the marketing of wind energy and its impact on the electricity spot market in detail with the objective of quantifying the difference between onshore and offshore wind and investigating whether offshore wind offers a benefit due to the steadier wind resource prevailing offshore.

The marketing and realised market value of wind energy is significantly affected by its property of being non-dispatchable because the operator is forced to feed-in and sell the electricity when there is wind, which is in contrast to dispatchable generators that can adjust their production in relation to the electricity market. This leads to a market value below the average market price because electricity is increasingly sold when the market price is rather low. This reduction in value is also referred to as profile costs and is the topic of several recent publications, of which [10] provides a comprehensive review. However, to the author's knowledge, the market value has so far only been analysed for onshore wind. Thus, the first aim of this article is to assess the market value of offshore wind. As investigated in [11] for onshore wind in Germany, the spatial position has an effect on wind power revenues and therefore this assessment should show whether the argument of a higher and steadier wind resource prevailing offshore has a positive effect on the marketing of its electricity in addition to the increased energy yield [12]. The reason that this article might be the first analysis could be due to the lack of data availability, which was overcome by using weather data from measurement stations located in the German North and Baltic Sea in addition to feed-in data.

The variability of wind does not only have an impact on its own economics, however. In combination with the property of near zero marginal costs and supported by a benevolent subsidy scheme wind energy has a significant impact on the electricity spot market. The so-called merit order effect causes a price deterioration with increasing feed-in capacity [13]. A considerable amount of research has been performed on this topic, whereof [14] provides an comprehensive review until the year 2013 including the assessment region and period, reported price change and a short description of the used approach. Recent publications analysing the relationship between variable wind electricity generation and electricity price behaviour in Germany confirm the decreasing effect on the spot price [14–18]. In addition to that [14], suggests that the impact of wind varies depending on the region and assessment method chosen [16], reports that wind feed-in also increases spot price volatility and [17,18] indicate the load dependence of the merit order effect. Again, none of these analyses distinguishes between onshore and offshore wind. Thus, the second objective of this article is to investigate and quantify the impact of offshore wind energy on the electricity spot market compared with its onshore counterpart, which is a novelty in this field of research. The fact that its generation is less variable might be a reason for less deterioration and less variability in the spot market price, which would again be an argument in favour of offshore wind.

Modelling this impact is challenging, especially with the aim of generating reliable and significant results. In the literature this problem is generally solved by employing empirical analyses, simulation-based approaches or a combination of both. Most common when aiming for quantifying the merit order effect applying empirical analyses is the design of a regression model and applying it to historical data as, for example, done in [19] for the Spanish, in [20] for the Italian and in the before mentioned [14–17] for the German electricity market. Furthermore [21], investigated the impact of weather conditions in the Netherlands and Germany on the Dutch electricity market and [22] the effect of wind feed-in on the level of spot prices and spot-price variance in Texas using also regression analysis. In contrast to that, simulation-based approaches require the design of an electricity market model that enables to simulate the impact of increasing variable generation